PapaCambridge

Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021

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Appendix A

Answers

1. 9702_w21_MS_41 Q: 1

	Answer	Marks
(a)	constant speed **or** constant magnitude of velocity	B1
	acceleration (always) perpendicular to velocity	B1
(b)(i)	$F = mv^2 / r$ **or** $v = r\omega$ **and** $F = mr\omega^2$	C1
	$F = 790 \times 94^2 / 318$ $= 22\,000$ N	A1
(b)(ii)	centripetal acceleration: same	B1
	maximum speed: greater	B1
	time taken for one lap of the track: greater	B1

2. 9702_w21_MS_42 Q: 1

	Answer	Marks
(a)	acceleration perpendicular to velocity	B1
(b)(i)	decreases	B1
(b)(ii)	(acceleration of) 9.8 m s^{-2} is caused by weight of car **or** centripetal force must be greater than weight of car	B1
	(acceleration > 9.8 m s^{-2}) requires contact force from track **or** (centripetal force > weight) requires contact force from track	B1
(c)	$½mv_Y^2 = ½mv_X^2 – mgh$	C1
	$a = v^2 / r$	C1
	$v_Y^2 = 3.8^2 – 2 \times 9.81 \times 0.62$ so $v_Y = 1.5$ m s^{-1} $a = 1.5^2 / 0.31 = 7.3$ m s^{-2} (which is less than 9.8 m s^{-2}) so no	A1
	or	
	$v_Y = \sqrt{(9.81 \times 0.31)} = 1.74$ m s^{-1} so $v_X^2 = 1.74^2 + 2 \times 9.81 \times 0.62$ $v_X = 3.9$ m s^{-1} (which is greater than 3.8 m s^{-1}) so no	(A1)
(d)	acceleration is independent of mass so makes no difference **or** mass cancels in the equation so makes no difference	B1

3. 9702_w21_MS_43 Q: 1

	Answer	Marks
(a)	constant speed **or** constant magnitude of velocity	**B1**
	acceleration (always) perpendicular to velocity	**B1**
(b)(i)	$F = mv^2 / r$ **or** $v = r\omega$ **and** $F = mr\omega^2$	**C1**
	$F = 790 \times 94^2 / 318$ $= 22\,000$ N	**A1**
(b)(ii)	centripetal acceleration: same	**B1**
	maximum speed: greater	**B1**
	time taken for one lap of the track: greater	**B1**

4. 9702_s20_MS_41 Q: 1

	Answer	Marks
(a)	force acting between two masses **or** force on mass due to another mass **or** force on mass in a gravitational field	**B1**
(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12}$ m	**A1**
(c)(i)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$ $= 4.5 \times 10^{-9}$ rad s^{-1}	**A1**
(c)(ii)	gravitational forces are equal **or** centripetal force about P is the same	**C1**
	$M_1 x\omega^2 = M_2(d - x)\omega^2$ so $M_1 / M_2 = (d - x) / x$	**A1**
(c)(iii)	$x = 0.4d$	**C1**
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	**C1**
	$M_1 = 1.1 \times 10^{30}$ kg	**A1**

5. 9702_s20_MS_43 Q: 1

	Answer	Marks
(a)	force acting between two masses **or** force on mass due to another mass **or** force on mass in a gravitational field	B1
(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12}$ m	A1
(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$ $= 4.5 \times 10^{-9}$ rad s^{-1}	A1
(c)(ii)	gravitational forces are equal **or** centripetal force about P is the same	C1
	$M_1 x\omega^2 = M_2(d - x)\omega^2$ so $M_1 / M_2 = (d - x) / x$	A1
(c)(iii)	$x = 0.4d$	C1
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	C1
	$M_1 = 1.1 \times 10^{30}$ kg	A1

6. 9702_w19_MS_41 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)(i)	above the equator	B1
	from west to east	B1
(b)(ii)	gravitational force provides/is the centripetal force	B1
	$GM / r^2 = r(2\pi / T)^2$	C1
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	C1
	$M = 6.0 \times 10^{24}$ kg	A1

7. 9702_w19_MS_42 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)	gravitational force provides/is the centripetal force	B1
	$GM / R^2 = R\omega^2$ **or** $GM / R^2 = v^2 / R$	M1
	$\omega = 2\pi / T$ **or** $v = 2\pi R / T$	M1
	algebra leading to $R^3/T^2 = GM / 4\pi^2$	A1
(c)	$(6.67 \times 10^{-11} \times M) / 4\pi^2 = (4.38 \times 10^6)^3 / (2.44 \times 3600)^2$	C1
	$M = 6.45 \times 10^{23}$ kg	A1

8. 9702_w19_MS_43 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)(i)	above the equator	B1
	from west to east	B1
(b)(ii)	gravitational force provides/is the centripetal force	B1
	$GM / r^2 = r(2\pi / T)^2$	C1
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	C1
	$M = 6.0 \times 10^{24}$ kg	A1

9. 9702_s18_MS_41 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
(b)(ii)1.	gravitational force equals/is centripetal force	C1
	$GMm / R^2 = mR\omega^2$ **and** $\omega = 2\pi / T$ **or** $Gm / R^2 = mv^2 / R$ **and** $v = 2\pi r / T$ **or** $GMm / R^2 = mR\,(2\pi / T)^2$	M1
	convincing algebra leading to $k = GM / 4\pi^2$	A1
1(b)(ii)2.	correct use of R^3 / T^2 for one planet (c gives 3.54×10^{21}; e and g both give 3.56×10^{21})	C1
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33}$ kg	A1
	two or three values of R^3 / T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	B1

10. 9702_s18_MS_43 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
(b)(ii)1.	gravitational force equals/is centripetal force	C1
	$GMm/R^2 = mR\omega^2$ **and** $\omega = 2\pi/T$ **or** $Gm/R^2 = mv^2/R$ **and** $v = 2\pi r/T$ **or** $GMm/R^2 = mR(2\pi/T)^2$	M1
	convincing algebra leading to $k = GM/4\pi^2$	A1
(b)(ii)2.	correct use of R^3/T^2 for one planet (c gives 3.54×10^{21}; e and g both give 3.56×10^{21})	C1
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M)/4\pi^2$ $M = 2.1 \times 10^{33}$ kg	A1
	two or three values of R^3/T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	B1

11. 9702_s17_MS_43 Q: 1

	Answer	Marks
(a)	gravitational force (of attraction between satellite and planet)	B1
	provides / is centripetal force (on satellite about the planet)	B1
(b)	$M = (4/3) \times \pi R^3 \rho$	B1
	$\omega = 2\pi/T$ or $v = 2\pi nR/T$	B1
	$GM/(nR)^2 = nR\omega^2$ or v^2/nR	M1
	substitution clear to give $\rho = 3\pi n^3/GT^2$	A1
(c)	$n = (3.84 \times 10^5)/(6.38 \times 10^3) = 60.19$ or 60.2	C1
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	C1
	$\rho = 5.54 \times 10^3$ kg m^{-3}	A1

12. 9702_w17_MS_42 Q: 1

	Answer	Marks
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
(b)	mass of Jupiter (M) = $(4/3)\pi R^3\rho$	B1
	$\omega = 2\pi / T$ **or** $v = 2\pi nR / T$	B1
	$(m)\omega^2 x = GM(m)/x^2$ **or** $(m)v^2/x = GM(m)/x^2$	M1
	substitution and correct algebra leading to $\rho T^2 = 3\pi n^3 / G$	A1
(c)(i)	$n = (4.32 \times 10^5) / (7.15 \times 10^4)$ **or** $n = 6.04$	C1
	$\rho \times (42.5 \times 3600)^2 = (3\pi \times 6.04^3)/(6.67 \times 10^{-11})$	C1
	$\rho = 1.33 \times 10^3\,\mathrm{kg\,m^{-3}}$	A1
(c)(ii)	Jupiter likely to be a gas/liquid (at high pressure) [allow other sensible suggestions]	B1

13. 9702_w16_MS_41 Q: 1

(a)	gravitational force provides/is the centripetal force	B1	
	$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$ **and** $v = 2\pi r/T$ *or* $\omega = 2\pi/T$	M1	
	with algebra to $T^2 = 4\pi^2 r^3/GM$	A1	[3]
	or		
	acceleration due to gravity is the centripetal acceleration	(B1)	
	$GM/r^2 = v^2/r$ *or* $GM/r^2 = r\omega^2$ **and** $v = 2\pi r/T$ *or* $\omega = 2\pi/T$	(M1)	
	with algebra to $T^2 = 4\pi^2 r^3/GM$	(A1)	
(b) (i)	equatorial orbit/orbits (directly) above the equator	B1	
	from west to east	B1	[2]
(ii)	$(24 \times 3600)^2 = 4\pi^2 r^3/(6.67 \times 10^{-11} \times 6.0 \times 10^{24})$	C1	
	$r^3 = 7.57 \times 10^{22}$		
	$r = 4.2 \times 10^7$ m	A1	[2]
(c)	$(T/24)^2 = \{(2.64 \times 10^7)/(4.23 \times 10^7)\}^3 = 0.243$	B1	
	$T = 12$ hours	A1	[2]
	or		
	$k\ (= T^2/r^3) = 24^2/(4.23 \times 10^7)^3 = 7.61 \times 10^{-21}$	(B1)	
	$T^2\ (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3 = 140$		
	$T = 12$ hours	(A1)	

14. 9702_w16_MS_43 Q: 1

(a) gravitational force provides/is the centripetal force B1

$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$
and $v = 2\pi r/T$ *or* $\omega = 2\pi/T$ M1

with algebra to $T^2 = 4\pi^2 r^3/GM$ A1 [3]

or

acceleration due to gravity is the centripetal acceleration (B1)

$GM/r^2 = v^2/r$ *or* $GM/r^2 = r\omega^2$
and $v = 2\pi r/T$ *or* $\omega = 2\pi/T$ (M1)

with algebra to $T^2 = 4\pi^2 r^3/GM$ (A1)

(b) **(i)** equatorial orbit/orbits (directly) above the equator B1

from west to east B1 [2]

(ii) $(24 \times 3600)^2 = 4\pi^2 r^3/(6.67 \times 10^{-11} \times 6.0 \times 10^{24})$ C1

$r^3 = 7.57 \times 10^{22}$

$r = 4.2 \times 10^7$ m A1 [2]

(c) $(T/24)^2 = \{(2.64 \times 10^7)/(4.23 \times 10^7)\}^3$
$= 0.243$ B1

$T = 12$ hours A1 [2]

or

$k\ (= T^2/r^3) = 24^2/(4.23 \times 10^7)^3$
$= 7.61 \times 10^{-21}$ (B1)

$T^2\ (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3$
$= 140$

$T = 12$ hours (A1)

15. 9702_s21_MS_42 Q: 1

	Answer	Marks
(a)	(gravitational) force per unit mass	B1
(b)(i)	$g = GM / r^2$	C1
	$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$ $= 3.73\ \text{N kg}^{-1}$	A1
(b)(ii)	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$	C1
	$a = 3.39 \times 10^6 \times (2\pi / (24.6 \times 3600))^2$ $= 0.0171\ \text{m s}^{-2}$	A1
(b)(iii)	force per unit mass $= 3.73 - 0.0171$ $= 3.71\ \text{N kg}^{-1}$	A1

16. 9702_s19_MS_42 Q: 1

	Answer	Marks
(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	B1
(b)(i)	angle $= (1.2 \times 10^{-3}) / (8.0 \times 10^{-2}) = 1.5 \times 10^{-2}$ (rad)	B1
(b)(ii)	torque $= 1.5 \times 10^{-2} \times 9.3 \times 10^{-10}$ $= 1.4 \times 10^{-11}\ \text{N m}$	A1
(c)(i)	force $\times 8.0 \times 10^{-2} = 1.4 \times 10^{-11}$	C1
	$(G \times 1.3 \times 7.5 \times 10^{-3} \times 8.0 \times 10^{-2}) / (6.0 \times 10^{-2})^2 = 1.4 \times 10^{-11}$	C1
	$G = 6.4 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	A1
(c)(ii)	Any one from: • law applies only to point masses/spheres are not point masses • radii of spheres not small compared with separation • spheres may not be uniform • the masses are not isolated • force between L and rod • spheres may be charged/may be electrostatic force (between spheres)	B1

17. 9702_m18_MS_42 Q: 1

	Answer	Marks
(a)(i)	*either* direction of force on a (small test) mass *or* direction of acceleration of a (small test) mass	B1
(a)(ii)	Any three from: • the lines are radial • near the surface the lines are (approximately) parallel • parallel lines so constant field strength • constant field strength hence constant acceleration of free fall	B3
(b)(i)	$g = GM / R^2$ $g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^3 \times 10^3)^2$	C1
	$g =$ **1.62 N kg^{-1}**	A1
(b)(ii)	*either* $x\omega^2 = GM / x^2$ <u>and</u> $\omega = 2\pi / T$ *or* $v^2 / x = GM / x^2$ <u>and</u> $v = 2\pi r / T$	C1
	$(1.74 \times 10^6 + 320 \times 10^3)^3 \times 4\pi^2 / T^2 = (6.67 \times 10^{-11} \times 7.35 \times 10^{22})$	C1
	$T^2 = 7.04 \times 10^7$ $T =$ **8400 s** (8390)	A1

18. 9702_s18_MS_42 Q: 1

	Answer	Marks
(a)(i)	direction of force on a (small test) <u>mass</u> **or** path in which a (small test) <u>mass</u> will move	B1
(a)(ii)	(at surface,) lines (of force) are radial	B1
	Earth has large radius/height above surface is small so lines are (approximately) parallel	B1
	parallel lines → constant field strength	B1
(b)	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm / R$	C1
	$(m)v^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (1.7 \times 10^3 \times 10^3)$	C1
	$v = 2.4 \times 10^3 \text{ m s}^{-1}$	A1
	correct conclusion based on <u>comparison</u> of v with 2.8 km s^{-1}	B1
	or	
	(change in) KE of rock = (change in) PE	(C1)
	(at infinity) $E_P = (6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times m) / (1.7 \times 10^3 \times 10^3)$ $= 2.9 \times 10^6\, m$	(C1)
	E_K of rock $= \frac{1}{2} \times m \times (2.8 \times 10^3)^2 = 3.9 \times 10^6\, m$	(A1)
	correct conclusion based on <u>comparison</u> of E_K and E_P values	(B1)
	or	

	Answer	Marks
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\ (2800)^2 = (m)\ (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / R$	**(C1)**
	$R = 1.3 \times 10^3$ km	**(A1)**
	correct conclusion based on <u>comparison</u> of R with 1.7×10^3 km	**(B1)**
	or	
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\ (2800)^2 = (m)\ (2 \times 6.67 \times 10^{-11} \times M) / (1.7 \times 10^6)$	**(C1)**
	$M = 1.0 \times 10^{23}$ kg	**(A1)**
	correct conclusion based on <u>comparison</u> of M with 7.4×10^{22} kg	**(B1)**

19. 9702_w18_MS_42 Q: 1

	Answer	Marks
(a)(i)	force per unit mass	**B1**
(a)(ii)	acceleration = F/m, field strength = F/m, so equal	**B1**
(b)	smooth curve between R and $4R$ with negative gradient of decreasing magnitude	**B1**
	line passing through (R, 1.00g) and (2R, 0.25g)	**B1**
	line ending at (4R, 0.0625g)	**B1**
(c)	$M = (4/3 \times \pi R^3)\rho$	**C1**
	$g = GM/(2R)^2$	**C1**
	$g = \frac{1}{3} \times 6.67 \times 10^{-11} \times \pi \times 3.4 \times 10^6 \times 4.0 \times 10^3$ $= 0.95$ m s^{-2}	**A1**

20. 9702_s17_MS_41 Q: 1

	Answer	Marks
(a)	gravitational force (of attraction between satellite and planet)	**B1**
	<u>provides / is</u> centripetal force (on satellite about the planet)	**B1**
(b)	$M = (4/3) \times \pi R^3 \rho$	**B1**
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$	**B1**
	$GM / (nR)^2 = nR\omega^2$ or v^2 / nR	**M1**
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	**A1**
(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	**C1**
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	**C1**
	$\rho = 5.54 \times 10^3$ kg m^{-3}	**A1**

21. 9702_s17_MS_42 Q: 1

	Answer	Marks
(a)	force per unit mass	B1
(b)(i)	$g = GM / r^2$ $= (6.67 \times 10^{-11} \times 1.0 \times 10^{13}) / (3.6 \times 10^3)^2$	C1
	$= 5.1 \times 10^{-5}$ N kg^{-1}	A1
(b)(ii)	mass = (960 / 9.81) kg weight on comet = $(960 / 9.81) \times 5.1 \times 10^{-5}$	C1
	$= 5.0 \times 10^{-3}$ N	A1
(c)	similarity: e.g. both attractive/pointed towards the comet e.g. same order of magnitude	B1
	difference: e.g. radial/non-radial e.g. same (over surface)/varies (over surface)	B1

22. 9702_w17_MS_41 Q: 3

	Answer	Marks
(a)	force per unit mass	B1
(b)	changes in height <u>much</u> less than radius of Earth	M1
	so (radial) field lines are almost parallel **or** $g = GM / R^2 \approx GM / (R + h)^2$	A1

	Answer	Marks
(c)	gravitational force provides/is centripetal force	B1
	$GMm / r^2 = mv^2 / r$	C1
	$v = (2\pi \times 1.5 \times 10^{11}) / (3600 \times 24 \times 365) = 2.99 \times 10^4$ (m s^{-1})	C1
	$6.67 \times 10^{-11} M = 1.5 \times 10^{11} \times (2.99 \times 10^4)^2$	C1
	$M = 2.0 \times 10^{30}$ kg	A1
	or	
	$GMm / r^2 = mr\omega^2$	(C1)
	$\omega = 2\pi / (3600 \times 24 \times 365) = 1.99 \times 10^{-7}$ (rad s^{-1})	(C1)
	$6.67 \times 10^{-11} M = (1.5 \times 10^{11})^3 \times (1.99 \times 10^{-7})^2$	(C1)
	$M = 2.0 \times 10^{30}$ kg	(A1)
	or	
	$T^2 = 4\pi^2 r^3 / GM$	(C2)
	$M = 4\pi^2 \times (1.5 \times 10^{11})^3 / (\{3600 \times 24 \times 365\}^2 \times 6.67 \times 10^{-11})$	(C1)
	$= 2.0 \times 10^{30}$ kg	(A1)

23. 9702_w17_MS_43 Q: 3

	Answer	Marks
(a)	force per unit mass	B1
(b)	changes in height <u>much</u> less than radius of Earth	M1
	so (radial) field lines are almost parallel **or** $g = GM / R^2 \approx GM / (R + h)^2$	A1

	Answer	Marks
(c)	gravitational force provides/is centripetal force	B1
	$GMm/r^2 = mv^2/r$	C1
	$v = (2\pi \times 1.5 \times 10^{11})/(3600 \times 24 \times 365) = 2.99 \times 10^4$ (m s^{-1})	C1
	$6.67 \times 10^{-11}M = 1.5 \times 10^{11} \times (2.99 \times 10^4)^2$	C1
	$M = 2.0 \times 10^{30}$ kg	A1
	or	
	$GMm/r^2 = mr\omega^2$	(C1)
	$\omega = 2\pi/(3600 \times 24 \times 365) = 1.99 \times 10^{-7}$ (rad s^{-1})	(C1)
	$6.67 \times 10^{-11}M = (1.5 \times 10^{11})^3 \times (1.99 \times 10^{-7})^2$	(C1)
	$M = 2.0 \times 10^{30}$ kg	(A1)
	or	
	$T^2 = 4\pi^2r^3/GM$	(C2)
	$M = 4\pi^2 \times (1.5 \times 10^{11})^3 / (\{3600 \times 24 \times 365\}^2 \times 6.67 \times 10^{-11})$	(C1)
	$= 2.0 \times 10^{30}$ kg	(A1)

24. 9702_m16_MS_42 Q: 1

(a) force proportional to product of the (two) masses and inversely proportional to the square of their separation — M1
either reference to point masses *or* separation << 'size' of masses — A1 [2]

(b) gravitational force provides / is the centripetal force — B1

$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$ *and* $v = r\omega$
and algebra leading to $v = (GM/r)^{1/2}$ — B1 [2]

(c) (i) 1. $v_A/v_B = (r_B/r_A)^{1/2}$
$= (2.2 \times 10^{10}/1.3 \times 10^8)^{1/2}$ — C1
$= 13$ (13.0) — A1 [2]

2. $v = 2\pi r/T$ *or* $v \propto r/T$ *or* vT/r = constant — C1
$T_A/T_B = (r_A/r_B) \times (v_B/v_A)$
$= (1.3 \times 10^8/2.2 \times 10^{10}) \times (1/13)$ — C1
$= 4.5\ (4.54) \times 10^{-4}$ — A1

or

$T^2 = 4\pi^2r^3/GM$ *or* $T^2 \propto r^3$ *or* T^2/r^3 = constant — (C1)
$T_A/T_B = (r_A^3/r_B^3)^{1/2}$
$= [(1.3 \times 10^8)^3/(2.2 \times 10^{10})^3]^{1/2}$ — (C1)
$= 4.5\ (4.54) \times 10^{-4}$ — (A1) [3]

(ii) $T = 2\pi/1.7 \times 10^{-4}$
$= 3.70 \times 10^4$ s — C1
$T_B = 3.70 \times 10^4/4.54 \times 10^{-4}$
$= 8.1 \times 10^7$ s — A1 [2]
If identifies T_A as T_B then 0/2

25. 9702_w16_MS_42 Q: 1

(a) force per unit mass	B1	[1]
(b) (i) radius/diameter/size (of Proxima Centauri) ≪ /is <u>much</u> less than 4.0×10^{13} km/separation (of Sun and star) *or* (because) it is a <u>uniform</u> sphere	B1	[1]
(ii) 1. field strength $= GM/x^2$		
$= (6.67 \times 10^{-11} \times 2.5 \times 10^{29})/(4.0 \times 10^{13} \times 10^3)^2$	C1	
$= 1.0 \times 10^{-14}\ \text{N kg}^{-1}$	A1	[2]
2. force = field strength × mass		
$= 1.0 \times 10^{-14} \times 2.0 \times 10^{30}$	C1	
or		
force $= GMm/x^2$		
$= (6.67 \times 10^{-11} \times 2.5 \times 10^{29} \times 2.0 \times 10^{30})/(4.0 \times 10^{13} \times 10^3)^2$	(C1)	
$= 2.0 \times 10^{16}$ N	A1	[2]
(c) force (of 2×10^{16} N) would have little effect on (large) <u>mass</u> of Sun	B1	
would cause an acceleration of Sun of $1.0 \times 10^{-14}\ \text{m s}^{-2}$/very small/negligible acceleration	B1	[2]
or		
many stars all around the Sun	(B1)	
net effect of forces/fields is zero	(B1)	

26. 9702_m21_MS_42 Q: 1

	Answer	Marks
(a)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
(b)	correct read offs from the graph with correct power of ten for R^3	C1
	$M = \dfrac{4\times\pi^2\times1.2\times10^{34}}{6.67\times10^{-11}\times2.4\times(365\times24\times3600)^2}$	C1
	$=3.0\times10^{30}$ kg	A1
(c)(i)	potential energy is zero at infinity	B1
	(gravitational) forces are attractive	B1
	work must be done on the rock to move it to infinity	B1
(c)(ii)	$\dfrac{GMm}{r^2}=\dfrac{mv^2}{r}$ OR $v^2=\dfrac{GM}{r}$ OR $v=\sqrt{\dfrac{GM}{r}}$	M1
	use of ½ mv^2 (e.g. multiplication by ½ m) leading to $\dfrac{GMm}{2r}$	A1
(c)(iii)	$Ep = \phi m$ and $\phi = \dfrac{-GM}{r}$ or $E_p = \dfrac{-GMm}{r}$ Total energy = $E_k + E_p$	C1
	Total energy $=\dfrac{GMm}{2r}+\dfrac{-GMm}{r} = \dfrac{-GMm}{2r}$	A1

27. 9702_s21_MS_41 Q: 1

	Answer	Marks
(a)	force per unit mass	B1
(b)	$GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$ **or** $GMm / r^2 = mv^2 / r$ **and** $v = 2\pi r / T$	C1
	$6.67\times10^{-11}\times6.0\times10^{24} = r^3\times[2\pi / (94\times60)]^2$	C1
	$r = 6.9\times10^6$ m	A1
(c)(i)	$r^3\omega^2$ = constant **or** r^3 / T^2 = constant	C1
	$r^3 / (6.9\times10^6)^3 = (150 / 94)^2$ so $r = 9.4\times10^6$ m	A1
	or	
	$GMT^2/4\pi^2 = r^3$ **and** clear that M is 6.0×10^{24}	(C1)
	$6.67\times10^{-11}\times6.0\times10^{24} = r^3\times[2\pi / (150\times60)]^2$ so $r = 9.4\times10^6$ m	(A1)
(c)(ii)	separation increases so (potential energy) increases **or** movement is against gravitational force so (potential energy) increases	B1
(c)(iii)	potential energy = (–)GMm / r	C1
	$\Delta E_P = 6.67\times10^{-11}\times6.0\times10^{24}\times1200\times[(6.9\times10^6)^{-1} - (9.4\times10^6)^{-1}]$	C1
	$= 1.9\times10^{10}$ J	A1

28. 9702_s21_MS_43 Q: 1

	Answer	Marks
(a)	force per unit mass	B1
(b)	$GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$ **or** $GMm / r^2 = mv^2 / r$ **and** $v = 2\pi r / T$	C1
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (94 \times 60)]^2$	C1
	$r = 6.9 \times 10^6$ m	A1
(c)(i)	$r^3\omega^2$ = constant **or** r^3 / T^2 = constant	C1
	$r^3 / (6.9 \times 10^6)^3 = (150 / 94)^2$ so $r = 9.4 \times 10^6$ m	A1
	or	
	$GMT^2/4\pi^2 = r^3$ **and** clear that M is 6.0×10^{24}	(C1)
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$ so $r = 9.4 \times 10^6$ m	(A1)
(c)(ii)	separation increases so (potential energy) increases **or** movement is against gravitational force so (potential energy) increases	B1
(c)(iii)	potential energy = (–)GMm / r	C1
	$\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1200 \times [(6.9 \times 10^6)^{-1} - (9.4 \times 10^6)^{-1}]$	C1
	$= 1.9 \times 10^{10}$ J	A1

29. 9702_w21_MS_41 Q: 2

	Answer	Marks
(a)	work done per unit mass	B1
	(work done in) moving mass from infinity	B1
(b)(i)	(gravitational) fields from the Earth and Moon are in opposite directions	B1
	(resultant is zero where gravitational) fields are equal (in magnitude)	B1
(b)(ii)	$g \propto M / r^2$	C1
	$5.98 \times 10^{24} / x^2 = 7.35 \times 10^{22} / (3.84 \times 10^8 - x)^2$ leading to $x = 3.5 \times 10^8$ (m)	A1
(b)(iii)	ϕ (Earth) = (–)$6.67 \times 10^{-11} \times (5.98 \times 10^{24} / 3.5 \times 10^8)$ **and** ϕ (Moon) = (–)$6.67 \times 10^{-11} \times (7.35 \times 10^{22} / 0.38 \times 10^8)$	C1
	ϕ = (–)$6.67 \times 10^{-11} \times [(5.98 \times 10^{24} / 3.5 \times 10^8) + (7.35 \times 10^{22} / 0.38 \times 10^8)]$	C1
	$= -1.3 \times 10^6$ J kg^{-1}	A1

30. 9702_w21_MS_42 Q: 2

	Answer	Marks
(a)	(gravitational) field strength equals (gravitational) potential gradient	**M1**
	reference to minus sign	**A1**
(b)(i)	potential is zero at infinity	**B1**
	(gravitational) force is attractive	**B1**
	(test) mass getting closer (from infinity) loses potential energy	**B1**
(b)(ii)	• potential at (surface of) planet is smaller than at (surface of) moon • potential gradient at (surface of) planet is smaller than at (surface of) moon • magnitude of potential varies inversely with distance from centre near the spheres • (point of) maximum potential is nearer to moon than planet *Any two points, 1 mark each*	**B2**
(b)(iii)	sketch: one curve, starting with gradient of decreasing magnitude at 2*R* and finishing with gradient of increasing magnitude at *D* – *R*	**B1**
	field strength shown as zero (only) near the point of maximum potential	**B1**
	negative field strength near one sphere and positive field strength near the other	**B1**

31. 9702_w21_MS_43 Q: 2

	Answer	Marks
(a)	work done per unit mass	**B1**
	(work done in) moving mass from infinity	**B1**
(b)(i)	(gravitational) fields from the Earth and Moon are in opposite directions	**B1**
	(resultant is zero where gravitational) fields are equal (in magnitude)	**B1**
(b)(ii)	$g \propto M / r^2$	**C1**
	$5.98 \times 10^{24} / x^2 = 7.35 \times 10^{22} / (3.84 \times 10^8 - x)^2$ leading to $x = 3.5 \times 10^8$ (m)	**A1**
(b)(iii)	ϕ (Earth) = $(-)6.67 \times 10^{-11} \times (5.98 \times 10^{24} / 3.5 \times 10^8)$ **and** ϕ (Moon) = $(-)6.67 \times 10^{-11} \times (7.35 \times 10^{22} / 0.38 \times 10^8)$	**C1**
	$\phi = (-)6.67 \times 10^{-11} \times [(5.98 \times 10^{24} / 3.5 \times 10^8) + (7.35 \times 10^{22} / 0.38 \times 10^8)]$	**C1**
	$= -1.3 \times 10^6$ J kg^{-1}	**A1**

32. 9702_m20_MS_42 Q: 1

	Answer	Marks
(a)	work done per unit mass	B1
	work done moving mass from infinity (to the point)	B1
(b)(i)	gravitational force provides centripetal force	C1
	$mv^2 / r = GMm / r^2$ and $v = 2\pi r / T$ OR $mr\omega^2 = GMm / r^2$ and $\omega = 2\pi / T$ OR $r^3 = GMT^2 / 4\pi^2$	C1
	$r^3 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (13.7 \times 24 \times 3600)^2 / 4\pi^2$ so $r = 2.4 \times 10^8$ m	A1
(b)(ii)	$(E_P = -)\ GMm / r$ work done = $GMm / r_1 - GMm / r_2$	C1
	$= 6.67 \times 10^{-11} \times 360 \times 6.0 \times 10^{24}\ (1/6.4 \times 10^6 - 1 / 2.4 \times 10^8)$	C1
	= **2.2×10^{10}** J	A1
(b)(iii)	$g = GM / r^2$	C1
	ratio $= r_{TESS}^2 / r_{earth}^2$ $= (2.4 \times 10^8 / 6.4 \times 10^6)^2$ = **1400**	A1

33. 9702_s20_MS_42 Q: 1

	Answer	Marks
(a)	work done per unit mass	B1
	(work done to) move mass from infinity (to the point)	B1
(b)	curve from r to $4r$, with gradient of decreasing magnitude and starting at $(r, \pm\phi)$	B1
	line passing through $(2r, \pm0.5\phi)$ and $(4r, \pm0.25\phi)$	B1
	line showing potential is negative throughout	B1
(c)(i)	gravitational potential energy = (–) GMm / R	C1
	change $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 3.4 \times 10^3) / (6.4 \times 10^6) \times [1/3 - 1/4]$	C1
	$= 1.8 \times 10^{10}$ J	A1
(c)(ii)	rock loses potential energy	B1
	(so) kinetic energy increases so speed increases	B1
	or	
	force is attractive	(B1)
	moves towards planet so speeds up	(B1)

34. 9702_m19_MS_42 Q: 1

	Answer	Marks
(a)(i)	work done per unit mass	B1
	idea of work done moving mass from infinity (to the point)	B1
(a)(ii)	(gravitational) force is attractive	B1
	(gravitational) potential at infinity is zero	B1
	decrease in potential energy as masses approach *or* displacement and force in opposite directions	B1
(b)(i)	*Either* $mv^2 / R = GMm / R^2$ *Or* $v = \sqrt{(GM / R)}$ $v^2 = (6.67 \times 10^{-11} \times 6.00 \times 10^{24}) / (7.30 \times 10^6)$	C1
	giving $v = 7.4 \times 10^3$ m s^{-1}	A1
(b)(ii)	$V_P = -GMm / R$	C1
	$= -(6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times 340) / (7.30 \times 10^6)$	C1
	$V_P = -1.9 \times 10^{10}$ J	A1
(c)	$v^2 \propto 1 / r$, (r smaller) so v greater	M1
	and E_K greater	A1

35. 9702_s19_MS_41 Q: 1

	Answer	Marks
(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	B1
(b)(i)	$GMm / x^2 = mv^2 / x$ **or** $v^2 = GM / x$	C1
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$ so $v = 3.7 \times 10^3$ m s^{-1}	A1
(b)(ii)	potential energy = (–)GMm / x	C1
	$E_A = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$ **or** $E_B = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	M1
	correct substitution and subtraction $E_B - E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9$ J	A1
	or	
	$\phi = (-)GM / x$ **and** potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) - (1 / (5.00 \times 10^7))]$ $(= 1.27 \times 10^7$ J kg$^{-1})$	(M1)
	$\Delta E_p = 1.27 \times 10^7 \times 650$ $= 8.3 \times 10^9$ J	(A1)
(c)	kinetic energy <u>or</u> potential energy decreases	B1
	kinetic energy <u>and</u> potential energy decrease so total energy decreases	B1

36. 9702_s19_MS_43 Q: 1

	Answer	Marks
(a)	(F =) GMm / x^2, where G is the (universal) gravitational constant	B1
(b)(i)	$GMm / x^2 = mv^2 / x$ **or** $v^2 = GM / x$	C1
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$ so $v = 3.7 \times 10^3$ m s^{-1}	A1
(b)(ii)	potential energy = (–)GMm / x	C1
	$E_A = (–)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$ **or** $E_B = (–)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	M1
	correct substitution and subtraction $E_B – E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9$ J	A1
	or	
	ϕ = (–)GM / x **and** potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^6)) – (1 / (5.00 \times 10^7))]$ (= 1.27×10^7 J kg^{-1})	(M1)
	$\Delta E_p = 1.27 \times 10^7 \times 650$ $= 8.3 \times 10^9$ J	(A1)
(c)	kinetic energy or potential energy decreases	B1
	kinetic energy and potential energy decrease so total energy decreases	B1

37. 9702_w18_MS_41 Q: 1

	Answer	Marks
(a)(i)	work done per unit mass	B1
	work done moving mass from infinity (to the point)	B1
(a)(ii)	(near Earth's surface change in) height ≪ radius **or** height much less than radius	B1
	potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	B1
(b)	initial kinetic energy = (–) potential energy (at surface) **or** $½mv^2 = GMm / r$	B1
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (0.5 \times 3.5 \times 10^6)$	C1
	$v = 2.4 \times 10^3$ m s^{-1}	A1

38. 9702_w18_MS_43 Q: 1

	Answer	Marks
(a)(i)	work done per unit mass	B1
	work done moving mass from infinity (to the point)	B1
(a)(ii)	(near Earth's surface change in) height ≪ radius **or** height much less than radius	B1
	potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	B1
(b)	initial kinetic energy = (–) potential energy (at surface) **or** $½mv^2 = GMm / r$	B1
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (0.5 \times 3.5 \times 10^6)$	C1
	$v = 2.4 \times 10^3$ m s^{-1}	A1

39. 9702_m17_MS_42 Q: 1

	Answer	Marks
(a)	work done per unit mass	**M1**
	bringing (small test) mass from infinity (to the point)	**A1**
(b)(i)	$\Delta\phi = (GM/2R) - (GM/5R) = 3GM/10R$	**A1**
(b)(ii)	change in GPE = $(3 \times 4.0 \times 10^{14} / 10R) \times 4.7 \times 10^4$	**C1**
	$(3 \times 4.0 \times 10^{14} / 10R) \times 4.7 \times 10^4 = (1.70 - 0.88) \times 10^{12}$ $R = 6.88 \times 10^6$	**C1**
	distance $= 3 \times 6.88 \times 10^6$ $= 2.1 \times 10^7$ m	**A1**

40. 9702_w19_MS_41 Q: 2

	Answer	Marks
(a)	(total volume of molecules is) negligible	**M1**
	compared with volume occupied by the gas	**A1**
(b)(i)	$pV = NkT$	**C1**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	**C1**
	or	
	$pV = nRT$	**(C1)**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49$ (mol) $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.7 \times 10^{24}$	**A1**

	Answer	Marks
(b)(ii)	volume of one atom = d^3 (= 2.7×10^{-29} m^3)	C1
	volume of all atoms = $2.7 \times 10^{-29} \times 2.7 \times 10^{24}$	C1
	= 7×10^{-5} m^3	A1
	or	
	volume of one atom = $(4/3)\pi r^3$ (= 1.41×10^{-29} m^3)	(C1)
	volume of all atoms = $2.7 \times 10^{24} \times 1.41 \times 10^{-29}$	(C1)
	= 4×10^{-5} m^3	(A1)
(c)	numerical comparison between answer to **(b)(ii)** and 2.4×10^{-2} (m^3) showing **(b)(ii)** is much less than 2.4×10^{-2} (m^3)	B1

41. 9702_w16_MS_42 Q: 2

(a) **(i)** number of moles/amount of substance B1 [1]

(ii) kelvin temperature/absolute temperature/thermodynamic temperature B1 [1]

(b) $pV = nRT$

$4.9 \times 10^5 \times 2.4 \times 10^3 \times 10^{-6} = n \times 8.31 \times 373$ B1

$n = 0.38$ (mol) C1

number of molecules or $N = 0.38 \times 6.02 \times 10^{23} = 2.3 \times 10^{23}$ A1 [3] *or*

$pV = NkT$ (C1)

$4.9 \times 10^5 \times 2.4 \times 10^3 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 373$ (M1)

number of molecules or $N = 2.3 \times 10^{23}$ (A1)

volume occupied by one molecule $= (2.4 \times 10^3) / (2.3 \times 10^{23})$ C1

$= 1.04 \times 10^{-20}$ cm^3

mean spacing $= (1.04 \times 10^{-20})^{1/3}$ C1

$= 2.2 \times 10^{-7}$ cm (*allow 1 s.f.*) A1 [3]

(*allow other dimensionally correct methods e.g.* $V = (4/3)\pi r^3$)

42. 9702_m21_MS_42 Q: 2

	Answer	Marks
(a)(i)	$pV = NkT$ or $pV = nRT$ and $N = nN_A$ $N = \frac{2.3 \times 10^5 \times 3.5 \times 10^{-3}}{1.38 \times 10^{-23} \times 294}$	C1
	= **2.0** × **10**^{23}	A1
(a)(ii)	$pV = \frac{1}{3}Nmc^2$ $c^2 = \frac{3 \times 2.3 \times 10^5 \times 3.5 \times 10^{-3}}{2.0 \times 10^{23} \times 40 \times 1.66 \times 10^{-27}}$ = 182 000 r.m.s. speed = **430** m s^{-1}	C1
	or $\frac{1}{2}mc^2 = \frac{3}{2}kT$	A1
	$c^2 = \frac{3 \times 1.38 \times 10^{-23} \times 294}{40 \times 1.66 \times 10^{-27}}$ = 183 000	(C1)
	r.m.s.speed = 430 m s^{-1}	(A1)

	Answer	Marks
(b)	$c^2 = \dfrac{3\times2.0\times10^{23}\times1.38\times10^{-23}\times(294+84)}{2.0\times10^{23}\times40\times1.66\times10^{-27}}$ $c^2 = 236000$ $c = 485$	C1
	$ratio\left(=\dfrac{485}{430}\right)=1.1$	A1
	OR $v\propto\sqrt{T}$ or $v^2\propto T$	(C1)
	$ratio=\sqrt{\dfrac{273+21+84}{273+21}}$ or $\sqrt{\dfrac{378}{294}}$ ratio = **1.1**	(A1)

43. 9702_s20_MS_42 Q: 2

	Answer	Marks
(a)	ρ: Nm/V	B1
	⅓: molecules move in three dimensions (not one) so ⅓ in any (one) direction	B1
	$<c^2>$: molecules have different speeds so take average	M1
	of $(\text{speed})^2$	A1
(b)	$pV = NkT$	C1
	$N = (3.0\times10^5\times6.0\times10^{-3})/(1.38\times10^{-23}\times290)$	C1
	$= 4.5\times10^{23}$	C1
	mass $= 20.7/(4.5\times10^{23})$ $= 4.6\times10^{-23}$ g	A1

44. 9702_m19_MS_42 Q: 2

	Answer	Marks
(a)(i)	gas obeys formula pV/T = constant	M1
	symbols V and T explained	A1
(a)(ii)	mean-square-speed (of atoms / molecules)	B1
(b)(i)	use of $T = 393$	C1
	$pV = nRT$	C1
	$2.4\times10^5\times6.8\times10^{-3} = n\times8.31\times393$ and $N = n\times6.02\times10^{23} = 3.0\times10^{23}$	A1
	or $pV = NkT$	(C1)
	$2.4\times10^5\times6.8\times10^{-3} = N\times1.38\times10^{-23}\times393$ hence $N = 3.0\times10^{23}$	(A1)
(b)(ii)	volume of one atom $= 4/3\pi r^3$	C1
	volume occupied $= 3.0\times10^{23}\times4/3\times\pi\times(3.2\times10^{-11})^3$ $= 4\times10^{-8}$ m^3	A1
(b)(iii)	assumption: volume of atoms negligible compared to volume of container / cylinder	B1
	4×10^{-8} (m^3) << 6.8×10^{-3} (m^3) so yes	B1

45. 9702_w19_MS_43 Q: 2

	Answer	Marks
(a)	(total volume of molecules is) negligible	M1
	compared with volume occupied by the gas	A1
(b)(i)	$pV = NkT$	C1
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	C1
	or	
	$pV = nRT$	(C1)
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49$ (mol) $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.7 \times 10^{24}$	A1

	Answer	Marks
(b)(ii)	volume of one atom $= d^3$ $(= 2.7 \times 10^{-29}\ m^3)$	C1
	volume of all atoms $= 2.7 \times 10^{-29} \times 2.7 \times 10^{24}$	C1
	$= 7 \times 10^{-5}\ m^3$	A1
	or	
	volume of one atom $= (4/3)\pi r^3$ $(= 1.41 \times 10^{-29}\ m^3)$	(C1)
	volume of all atoms $= 2.7 \times 10^{24} \times 1.41 \times 10^{-29}$	(C1)
	$= 4 \times 10^{-5}\ m^3$	(A1)
(c)	numerical comparison between answer to **(b)(ii)** and 2.4×10^{-2} (m^3) showing **(b)(ii)** is <u>much</u> less than 2.4×10^{-2} (m^3)	B1

46. 9702_w18_MS_42 Q: 2

	Answer	Marks
(a)	gas that obeys equation pV = constant × T	M1
	symbols p, V and T explained	A1
(b)(i)	$pV = \frac{1}{3} Nm\langle c^2 \rangle$ **and** $M = Nm$ (and so) $p = \frac{1}{3}\rho\langle c^2 \rangle$	C1
	$2.12 \times 10^7 = \frac{1}{3} \times [3.20/(1.84 \times 10^{-2})] \times \langle c^2 \rangle$	C1
	$c_{r.m.s.} = 605\ m\ s^{-1}$	A1
(b)(ii)	**1.** $pV = nRT$ **and** $T = (22 + 273)$ K	C1
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-2}) / (8.31 \times 295)$ $= 159$ mol	A1
	2. mass $= 3.20/(159 \times 6.02 \times 10^{23})$ **or** mass $= [2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	C1
	mass $= 3.34 \times 10^{-26}$ kg	A1
(c)	$A = (3.34 \times 10^{-26}) / (1.66 \times 10^{-27})$ $= 20$	A1

47. 9702_s17_MS_43 Q: 4

	Answer	Marks
(a)	random/haphazard	B1
	constant velocity **or** speed in a straight line between collisions **or** distribution of speeds/different directions	B1
(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	M1
	moving haphazardly/randomly/jerky/in a zigzag fashion	A1
(c)(i)	$pV = ⅓ Nm\langle c^2\rangle$ $1.05 \times 10^5 \times 0.0240 = ⅓ \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	C1
	$\langle c^2\rangle = 1.89 \times 10^6$	C1
	or	
	$½ m\langle c^2\rangle = (3/2)kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2\rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^6$	(C1)
	or	
	$nRT = ⅓ Nm\langle c^2\rangle$ $1.00 \times 8.31 \times 300 = ⅓ \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^6$	(C1)
	$c_{r.m.s.} = 1.37 \times 10^3\ m\,s^{-1}$	A1

	Answer	Marks
(c)(ii)	$\langle c^2\rangle \propto T$	C1
	$\langle c^2\rangle$ at 177 °C = $1.89 \times 10^6 \times (450/300)$	C1
	$c_{r.m.s.}$ at 177 °C = $1.68 \times 10^3\ m\,s^{-1}$	A1

48. 9702_w21_MS_42 Q: 3

	Answer	Marks
(a)(i)	no loss of kinetic energy	B1
(a)(ii)	• molecules have negligible volume (compared with gas/container) • no forces between molecules (except during collisions) • molecules are in random motion • collisions are instantaneous *Any two points, 1 mark each*	B2
(b)(i)	$2mu$	A1
(b)(ii)	$2L / u$	A1
(b)(iii)	force = change in momentum / time = $2mu / (2L / u)$ $= mu^2 / L$	A1
(b)(iv)	pressure = force / area = $(mu^2 / L) / L^2$ $= mu^2 / L^3$	A1
(c)	$pV = NkT$	C1
	$NkT = ⅓Nm<c^2>$ leading to $½m<c^2> = (3/2)kT$ and $½m<c^2> = E_K$	A1
(d)	$½ \times 3.34 \times 10^{-27} \times <c^2> = (3/2) \times 1.38 \times 10^{-23} \times (25 + 273)$	C1
	r.m.s. speed = $1.9 \times 10^3\ m\,s^{-1}$	A1

49. 9702_s18_MS_42 Q: 2

	Answer	Marks
(a)	no intermolecular forces (so no potential energy)	B1
(b)(i)	mean square speed (of molecule(s))	B1
(b)(ii)	kelvin/thermodynamic/absolute temperature	B1
(c)(i)1.	$pV = NkT$	C1
	$4.7 \times 10^{-2} \times 2.6 \times 10^{5} = N \times 1.38 \times 10^{-23} \times 446$	C1
	or	
	$pV = nRT$ **and** $N = nN_A$ $4.7 \times 10^{-2} \times 2.6 \times 10^{5} = n \times 8.31 \times 446$ $n = 3.3$ (mol)	(C1)
	$N = 3.3 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.0 \times 10^{24}$	A1
(c)(i)2.	average increase $= 2900 / (2.0 \times 10^{24})$ $= 1.5 \times 10^{-21}$ J	A1
(c)(ii)	$\Delta E_K = (3/2)k(\Delta)T$ $1.5 \times 10^{-21} = (3/2) \times 1.38 \times 10^{-23} \times (\Delta)T$	C1
	$(\Delta)T$ in range 70–72 K	C1
	$T = 173 + 273 + 70$ $= 520$ K	A1

50. 9702_s17_MS_41 Q: 4

	Answer	Marks
(a)	random/haphazard	B1
	constant velocity **or** speed in a straight line between collisions **or** distribution of speeds/different directions	B1
(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	M1
	moving haphazardly/randomly/jerky/in a zigzag fashion	A1
(c)(i)	$pV = ⅓Nm\langle c^2\rangle$ $1.05 \times 10^{5} \times 0.0240 = ⅓ \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	C1
	$\langle c^2\rangle = 1.89 \times 10^{6}$	C1
	or	
	$½m\langle c^2\rangle = (3/2)kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2\rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^{6}$	(C1)
	or	
	$nRT = ⅓Nm\langle c^2\rangle$ $1.00 \times 8.31 \times 300 = ⅓ \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	(C1)
	$\langle c^2\rangle = 1.87 \times 10^{6}$	(C1)
	$c_{r.m.s.} = 1.37 \times 10^{3}$ m s^{-1}	A1

	Answer	Marks
(c)(ii)	$\langle c^2 \rangle \propto T$	C1
	$\langle c^2 \rangle$ at 177 °C = 1.89 × 10^6 × (450 / 300)	C1
	$c_{r.m.s.}$ at 177 °C = 1.68 × 10^3 m s^{-1}	A1

51. 9702_m21_MS_42 Q: 3

	Answer	Marks
(a)	Any 2 from: • particles / atoms / molecules / ions (very) close together / touching • regular, repeating pattern • vibrate about a fixed point	B2
(b)	(much) greater <u>increase</u> in spacing of molecules (for vaporisation compared with fusion)	B1
(c)(i)	–100 °C	B1

	Answer	Marks
(c)(ii)	time = 8.5 – 3.0 = 5.5 min	C1
	$Pt = mL$ energy = power × time = 150 × 5.5 × 60 = 49 500 J $L = \frac{E}{m}$ $= \frac{49500}{0.045}$	C1
	$= 1100\,kJ\,kg^{-1}$	A1
(c)(iii)	gas has a higher specific heat capacity (than liquid)	B1

52. 9702_m20_MS_42 Q: 2

	Answer	Marks
(a)	n = 110 / 0.032 or 110000 / 32 or 3440	C1
	$pV = nRT$	C1
	T = (1.0 × 10^5 × 85) / (8.31 × (110 / 0.032)) = 300 K	A1
(b)	$E = mc\Delta\theta$ = 110 × 0.66 × 50	C1
	= **3600** J	A1
(c)	Any 3 from: • molecule collides with wall • momentum of molecule changes during collision (with wall) • force on molecule so force on wall • many forces act over surface area of container exerting a pressure	B3
(d)	$KE \propto T$ $v \propto \sqrt{T}$	C1
	ratio = √(350 / 300) = **1.1**	A1

53. 9702_w19_MS_41 Q: 3

	Answer	Marks
(a)	(thermal) energy per (unit) mass (to change state)	**B1**
	(heat transfer during) change of state at constant temperature	**B1**
(b)(i)	32 g	**A1**
(b)(ii)	temperature difference (between liquid and surroundings) does not change	**B1**
(b)(iii)	$VIt = mL$	**C1**
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	**C1**
	$86 \times 600 = (56 - 32) \times L$	**C1**
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	**(C1)**
	$276 - 190 = (24 \times L) / 600$	**(C1)**
	$L = 2200\ \text{J g}^{-1}$	**A1**

	Answer	Marks
(b)(iv)	230 × 1.2 × 600 = (56 × 2150) + *H* **or** 190 × 1.0 × 600 = (32 × 2150) + *H*	**C1**
	H = 45 200 rate = 45 200 / 600 = 75 W	**A1**
	or	
	230 × 1.2 = (56 × 2150) / (60 × 10) + *P* **or** 190 × 1.0 = (32 × 2150) / (60 × 10) + *P*	**(C1)**
	rate (= *P*) = 75 W	**(A1)**

54. 9702_w19_MS_42 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to change state)	**B1**
	change of state without any change of temperature	**B1**
(b)(i)	140 g	**A1**
(b)(ii)	temperature difference (between apparatus and surroundings) does not change	**B1**
(b)(iii)	*VIt* = *mL*	**C1**
	({15.1 × 3.6} + *R*) × 600 = 140 × *L* **or** ({7.3 × 1.8} + *R*) × 600 = 65 × *L*	**C1**
	41.22 × 600 = 75 × *L*	**C1**
	L = 330 J g^{-1}	**A1**
(b)(iv)	15.1 × 3.6 × 600 = (140 × 330) – *H* **or** 7.3 × 1.8 × 600 = (65 × 330) – *H*	**C1**
	H = 13 600 rate of gain = 13 600 / 600 = 23 W	**A1**

55. 9702_w19_MS_43 Q: 3

	Answer	Marks
(a)	(thermal) energy per (unit) mass (to change state)	B1
	(heat transfer during) change of state at constant temperature	B1
(b)(i)	32 g	A1
(b)(ii)	temperature difference (between liquid and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	C1
	$86 \times 600 = (56 - 32) \times L$	C1
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	(C1)
	$276 - 190 = (24 \times L) / 600$	(C1)
	$L = 2200\ \text{J g}^{-1}$	A1

	Answer	Marks
(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ **or** $190 \times 1.0 \times 600 = (32 \times 2150) + H$	C1
	$H = 45\,200$ rate $= 45\,200 / 600$ $= 75$ W	A1
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	(C1)
	rate (= P) = 75 W	(A1)

56. 9702_s18_MS_42 Q: 3

	Answer	Marks
(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
(b)(i)	$(\Delta Q =)\ mc\Delta\theta$	C1
	loss = $(160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ $= 2.3 \times 10^4$ J	A1
(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$ $L = 350\ \text{J g}^{-1}$	A1

57. 9702_w18_MS_42 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause change of state)	B1
	(energy transfer during) change of state between solid and liquid at constant temperature	B1
(b)(i)	Any one from: • rate of increase in mass (of beaker and water) is constant • level of water rises at a constant rate • volume of water (in beaker) increases at a constant rate • constant time between drops • constant rate of dripping	B1
(b)(ii)	(electrical power supplied =) 12.8×4.60 (= 58.9 W)	C1
	(rate of transfer to ice =) $[(185.0 - 121.5) \times 332] / [5.00 \times 60]$ (= 70.3 W)	C1
	1. rate = 70.3 W	A1
	2. rate = 70.3 – 58.9 = 11.4 W	A1

58. 9702_s17_MS_42 Q: 2

	Answer	Marks
(a)(i)	mean/average square speed/velocity	B1
(a)(ii)	$pV = NkT$ **or** $pV = nRT$	B1
	$\rho = Nm / V$ **or** $\rho = nN_A m / V$ **and** $k = nR / N$	B1
	$E_K = ½ m\langle c^2 \rangle$ with algebra to $(3/2)kT$	B1
(b)(i)	no (external) work done **or** $\Delta U = q$ **or** $w = 0$	B1
	$q = N_A \times (3/2)k \times 1.0$	M1
	$N_A k = R$ so $q = (3/2)R$	A1
(b)(ii)	specific heat capacity $= \{(3/2) \times R\} / 0.028$	C1
	$= 450\ J\ kg^{-1}\ K^{-1}$	A1

59. 9702_w17_MS_41 Q: 1

	Answer	Marks
(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	B1
(a)(ii)	uses a property (of a substance) that changes with temperature	B1
(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	B2
(c)(i)	$Pt = mc(\Delta)\theta$	C1
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	M1
	$\Delta\theta = 56\ °C$ so final temperature = 56 + 24 = 80 °C	A1
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	(M1)
	so final temperature or $\theta = 80\ °C$	(A1)

	Answer	Marks
(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J	**(A1)**
	loss = (95 × 6 × 60) – 24400 = 9800 J	

60. 9702_w17_MS_43 Q: 1

	Answer	Marks
(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	**B1**
(a)(ii)	uses a property (of a substance) that changes with temperature	**B1**
(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	**B2**
(c)(i)	$Pt = mc(\Delta)\theta$	**C1**
	95 × 6 × 60 = 0.670 × 910 × $\Delta\theta$	**M1**
	$\Delta\theta$ = 56 °C so final temperature = 56 + 24 = 80 °C	**A1**
	or	
	95 × 6 × 60 = 0.67 × 910 × (θ – 24)	**(M1)**
	so final temperature or θ = 80 °C	**(A1)**

	Answer	Marks
(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J loss = (95 × 6 × 60) – 24400 = 9800 J	**(A1)**

61. 9702_s21_MS_41 Q: 2

	Answer	Marks
(a)	$pV = NkT$	**C1**
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5) / (1.38 \times 10^{-23} \times 310) = 1.4 \times 10^{23}$	**A1**
	or	
	$pV = nRT$ **and** $nN_A = N$	**(C1)**
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5 \times 6.02 \times 10^{23}) / (8.31 \times 310) = 1.4 \times 10^{23}$	**(A1)**
(b)	speed of molecule decreases on impact with moving piston	**B1**
	mean square speed (directly) proportional to (thermodynamic) temperature **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature	**B1**
	kinetic energy (of molecules) decreases (so temperature decreases)	**B1**
(c)(i)	$\Delta U = 3/2 \times k \times \Delta T \times N$	**C1**
	$= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$	**C1**
	= – 64 J	**A1**
(c)(ii)	decrease in internal energy is less than work done by gas	**M1**
	(thermal energy is) transferred <u>to</u> the gas (during the expansion)	**A1**

62. 9702_s21_MS_42 Q: 2

	Answer	Marks
(a)	$pV = nRT$	C1
	$pV = nRT$ **and** $N = nN_A$ **or** $pV = NkT$	C1
	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = (N \times 290 \times 8.31) / (6.02 \times 10^{23})$ so $N = 6.6 \times 10^{23}$ **or** $3.1 \times 10^{-3} \times 8.5 \times 10^5 = N \times 1.38 \times 10^{-23} \times 290$ so $N = 6.6 \times 10^{23}$	A1
(b)(i)	$(3.1 \times 10^{-3} \times 8.5 \times 10^5) / 290 = (6.3 \times 10^{-3} \times 2.7 \times 10^5) / T$ so $T = 190$ K **or** $6.3 \times 10^{-3} \times 2.7 \times 10^5 = 6.6 \times 10^{23} \times 1.38 \times 10^{-23} \times T$ so $T = 190$ K	A1
(b)(ii)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (190 - 290) \times 6.6 \times 10^{23}$	C1
	$= -1400$ J	A1
(c)	$\Delta U = q + w$	M1
	$q = 0$ so $\Delta U = w$	A1

63. 9702_s21_MS_43 Q: 2

	Answer	Marks
(a)	$pV = NkT$	C1
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5) / (1.38 \times 10^{-23} \times 310) = 1.4 \times 10^{23}$	A1
	or	
	$pV = nRT$ **and** $nN_A = N$	(C1)
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5 \times 6.02 \times 10^{23}) / (8.31 \times 310) = 1.4 \times 10^{23}$	(A1)
(b)	speed of molecule decreases on impact with moving piston	B1
	mean square speed (directly) proportional to (thermodynamic) temperature **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature	B1
	kinetic energy (of molecules) decreases (so temperature decreases)	B1
(c)(i)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$	C1
	$= -64$ J	A1
(c)(ii)	decrease in internal energy is less than work done by gas	M1
	(thermal energy is) transferred <u>to</u> the gas (during the expansion)	A1

64. 9702_w21_MS_41 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	$(T =) pV / Nk$	B1
(b)(ii)	$(pV =) NkT = ⅓Nm<c^2>$ **or** $pV = NkT$ **and** $pV = ⅓Nm<c^2>$	M1
	leading to $½m<c^2> = (3/2)kT$ and $½m<c^2> = E_K$	A1
(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) **or** no forces between molecules	B1
	potential energy of molecules is zero	B1
(c)(i)	increase in internal energy = Q + work done	B1
	constant volume so no work done	B1
(c)(ii)	$c = Q / Nm\Delta T$	C1
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	A1
(d)	(as it expands) gas does work (against the atmosphere/external pressure)	B1
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	B1

65. 9702_w21_MS_43 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	$(T =) pV / Nk$	B1
(b)(ii)	$(pV =) NkT = ⅓Nm<c^2>$ **or** $pV = NkT$ **and** $pV = ⅓Nm<c^2>$	M1
	leading to $½m<c^2> = (3/2)kT$ and $½m<c^2> = E_K$	A1
(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) **or** no forces between molecules	B1
	potential energy of molecules is zero	B1
(c)(i)	increase in internal energy = Q + work done	B1
	constant volume so no work done	B1
(c)(ii)	$c = Q / Nm\Delta T$	C1
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	A1
(d)	(as it expands) gas does work (against the atmosphere/external pressure)	B1
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	B1

66. 9702_s20_MS_41 Q: 2

	Answer	Marks
(a)	total potential energy and kinetic energy (of molecules/atoms)	**M1**
	reference to random motion of molecules/atoms	**A1**
(b)	(in ideal gas,) no intermolecular forces	**B1**
	no potential energy (so change in kinetic energy is change in internal energy)	**B1**
(c)	(random) potential energy of molecules does not change	**M1**
	(random) kinetic energy of molecules does not change	**M1**
	so internal energy does not change	**A1**
	or	
	decrease in total potential energy = gain in total kinetic energy	**(M1)**
	no external energy supplied	**(M1)**
	so internal energy does not change	**(A1)**
	or	
	no compression (of ball) so no work done on the ball	**(M1)**
	no resistive forces so no heating of the ball	**(M1)**
	so internal energy does not change	**(A1)**

	Answer	Marks
(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	**(M1)**
	no temperature rise so kinetic energy (of molecules) unchanged	**(M1)**
	so internal energy does not change	**(A1)**

67. 9702_s20_MS_42 Q: 3

	Answer	Marks
(a)	(little/no volume change so) little/no external work done	**B1**
	thermal energy supplied to provide latent heat	**M1**
	internal energy increases	**A1**
(b)	(rapid) increase in volume	**B1**
	gas does work against the atmosphere	**M1**
	internal energy decreases	**A1**

68. 9702_s20_MS_43 Q: 2

	Answer	Marks
(a)	total potential energy and kinetic energy (of molecules/atoms)	M1
	reference to random motion of molecules/atoms	A1
(b)	(in ideal gas,) no intermolecular forces	B1
	no potential energy (so change in kinetic energy is change in internal energy)	B1
(c)	(random) potential energy of molecules does not change	M1
	(random) kinetic energy of molecules does not change	M1
	so internal energy does not change	A1
	or	
	decrease in total potential energy = gain in total kinetic energy	(M1)
	no external energy supplied	(M1)
	so internal energy does not change	(A1)
	or	
	no compression (of ball) so no work done on the ball	(M1)
	no resistive forces so no heating of the ball	(M1)
	so internal energy does not change	(A1)
(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	(M1)
	no temperature rise so kinetic energy (of molecules) unchanged	(M1)
	so internal energy does not change	(A1)

69. 9702_s19_MS_41 Q: 2

	Answer	Marks
(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028$ mol	A1
(a)(ii)	$V \propto T$ **or** $T = pV / nR$ with value of n from **(i)**	C1
	$T = (140 / 210) \times 270$ **or** $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180$ K	A1
(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21$ J	A1

	Answer	Marks
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32$ J	A1

70. 9702_s19_MS_42 Q: 2

	Answer	Marks
(a)(i)	**1.** energy transfer <u>to</u> the system by heating	B1
	2. (external) work done <u>on</u> the system	B1
(a)(ii)	<u>decrease</u> in internal energy	B1
(b)(i)	no change (in internal energy)	B1
	(because) no change in temperature	B1
(b)(ii)	work done $= p\Delta V$ $= (-)1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3}$	C1
	$= (-)240$ J	A1
(b)(iii)	first row all correct (0, 480, 480)	A1
	second row all correct (–1100, 0, –1100)	A1
	final column of third row calculated correctly from the two values above it, so that the final column adds up to 0	A1
	second column in final row correct, with correct negative sign **and** first column in final row calculated correctly so that it adds to the second column to give the third column (fully correct table is: 0 | 480 | 480 –1100 | 0 | –1100 860 | –240 | 620)	A1

71. 9702_s19_MS_43 Q: 2

	Answer	Marks
(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028$ mol	A1
(a)(ii)	$V \propto T$ **or** $T = pV / nR$ with value of n from **(i)**	C1
	$T = (140 / 210) \times 270$ **or** $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180$ K	A1
(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21$ J	A1

	Answer	Marks
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32$ J	A1

72. 9702_w19_MS_42 Q: 2

	Answer	Marks
(a)(i)	specks of light moving haphazardly	B1
(a)(ii)	(gas) molecules collide with (smoke) particles **or** random motion of the (gas) molecules	M1
	<u>causes</u> the (haphazard) motion of the smoke particles **or** <u>causes</u> the smoke particles to change direction	A1
(b)(i)	$pV = nRT$	C1
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 310)$	C1
	or	
	$pV = NkT$	(C1)
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 310)$	(C1)
	$n = 0.350$ mol **or** 0.349 mol	A1
(b)(ii)	energy transfer = (0.349 **or** 0.35) × 12.5 × (310 – 290)	C1
	= 87.3 J **or** 87.5 J	A1
(c)(i)	zero	A1
(c)(ii)	87.3 J **or** 87.5 J	A1
	increase	B1

73. 9702_m18_MS_42 Q: 2

	Answer	Marks
(a)	$pV = nRT$ $T = (5.60 \times 10^5 \times 3.80 \times 10^{-2}) / (5.12 \times 8.31)$	C1
	T = **500 K**	A1
(b)(i)	V / T is constant $V = (3.80 \times 10^4) \times (500 + 125) / 500$	C1
	V = **4.75 × 10⁴** cm³	A1
(b)(ii)	(for ideal gas,) change in internal energy is change in (total) kinetic energy (of molecules)	B1
	$\Delta U = 3/2 \times 1.38 \times 10^{-23} \times 125 \times 5.12 \times 6.02 \times 10^{23}$	C1
	= **7980** J	A1
(c)(i)	$w = p\Delta V$ $= 5.60 \times 10^5 \times (4.75 - 3.80) \times 10^{-2}$	C1
	= **5320** J	A1
(c)(ii)	total = 7980 + 5320 = **13300** J	A1

74. 9702_s18_MS_41 Q: 3

	Answer	Marks
(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
(b)	$pV = NkT$	C1
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	C1
	or	
	$pV = nRT$ **and** $N = n \times N_A$	(C1)
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.8 \times 10^{25}$	A1

75. 9702_s18_MS_43 Q: 3

	Answer	Marks
(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
(b)	$pV = NkT$	C1
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	C1
	or	
	$pV = nRT$ **and** $N = n \times N_A$	(C1)
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.8 \times 10^{25}$	A1

76. 9702_w18_MS_43 Q: 2

	Answer	Marks
(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	**1.** work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): –42.5 J	A1
	3. increase in internal energy (R→P): –54.5 J	A1
	thermal energy supplied (R→P): –91.5 J	A1

77. 9702_m17_MS_42 Q: 2

	Answer	Marks
(a)	$+\Delta U$ increase in internal energy $+q$ heat (energy) transferred to the system / heating of system $+w$ work done on system	B2
(b)(i)	$W = p\Delta V$ $= 5.2 \times 10^5 \times (5.0 - 1.6) \times 10^{-4}$ (=177 J)	B1
	$\Delta U = q + w$ $= 442 - 177 = 265$ J	A1
(b)(ii)	no (molecular) potential energy	B1
	internal energy decreases so (total molecular) kinetic energy decreases	B1
	(mean molecular) kinetic energy decreases so temperature decreases	B1

	Answer	Marks
(b)(iii)	$\Delta U + 265 - 313 = 0$ $\Delta U = 48$ J	A1
(b)(iv)	$pV = NkT$ or $pV = nRT$ <u>and</u> $N = nN_A$	C1
	$5.2 \times 10^5 \times 1.6 \times 10^{-4} = N \times 1.38 \times 10^{-23} \times (273 + 227)$ *or* $5.2 \times 10^5 \times 1.6 \times 10^{-4} = n \times 8.31 \times (273 + 227)$ and $n = N / 6.02 \times 10^{23}$ $N = 1.2 \times 10^{22}$	A1

78. 9702_w17_MS_42 Q: 2

	Answer	Marks
(a)	(thermal) energy <u>per</u> (unit) mass (to cause change of state)	B1
	(energy required to cause/released in) change of state at constant temperature	B1
(b)(i)	**1.** (work done on/against) the <u>atmosphere</u>	B1
	2. <u>water</u> as it turns from liquid to vapour	M1
	as potential energy of <u>molecules</u> increases	A1
	or	
	<u>surroundings</u> as its temperature rises	(M1)
	as energy is lost/transferred to surroundings	(A1)
(b)(ii)	$VI - h = M / t \times L$ (where h = power loss) **or** $L = (VIt - Q) / M$ (where Q = energy loss)	C1
	$(14.2 \times 6.4) - (11.5 \times 5.2) = (9.1 - 5.0) \times L/300$ **or** $L = [(14.2 \times 6.4) - (11.5 \times 5.2)] \times 300 / (9.1 - 5.0)$	C1
	$L = 2300\,\text{J g}^{-1}$	A1

79. 9702_m16_MS_42 Q: 2

(a) (i) sum of kinetic and potential energy of atoms/molecules — M1
reference to random (distribution) — A1 [2]

(ii) no forces (of attraction or repulsion) between molecules — B1 [1]

(b) $pV = NkT$ *or* $pV = nRT$ *and* $R = kN_A$, $n = N / N_A$ — B1
$^1/_3\, Nm\langle c^2\rangle = NkT$ *or* $^1/_3\, m\langle c^2\rangle = kT$ — B1
$\langle E_K\rangle = {}^1/_2\, m\langle c^2\rangle$ <u>so</u> $\langle E_K\rangle = {}^3/_2\, kT$ — B1 [3]

(c) (i) $\langle E_K\rangle = {}^3/_2 \times 1.38 \times 10^{-23} \times (273 + 12)$ — C1
$= 5.9\ (5.90) \times 10^{-21}$ J — A1 [2]

(*use of* T = 12 K *not* T = 285 K scores 0/2)

(ii) number $= (17/32) \times 6.02 \times 10^{23}$ — C1
$= 3.2\ (3.20) \times 10^{23}$ — A1 [2]

(iii)	internal energy $= 5.9 \times 10^{-21} \times 3.2 \times 10^{23}$ $= 1900\ (1890)$ J	A1	[1]

80. 9702_w16_MS_41 Q: 2

(a)	**(i)**	$p \propto T$ *or* pV/T = constant *or* $pV = nRT$	C1	
		T (= 5 × 300 =) 1500 K	A1	[2]
	(ii)	$pV = nRT$		
		$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$ *or* $5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$	C1	
		n = 0.016 mol	A1	[2]
(b)	**(i)**	**1.** heating/thermal energy supplied	B1	
		2. work done on/to system	B1	[2]
	(ii)	**1.** 240 J	A1	
		2. same value as given in **1.** (= 240 J) **and** zero given for **3.**	A1	
		3. zero	A1	[3]

81. 9702_w16_MS_42 Q: 3

(a)		(sum of/total) potential energy and kinetic energy of (all) molecules/particles reference to random (distribution)	M1 A1	 [2]
(b)	**(i)**	no heat enters (gas)/leaves (gas)/no heating (of gas)	B1	
		work done by gas (against atmosphere as it expands)	M1	
		internal energy decreases	A1	[3]
	(ii)	volume decreases so work done on ice/water (*allow work done negligible because* ΔV *small*)	B1	
		heating of ice (to break rigid forces/bonds)	M1	
		internal energy increases	A1	[3]

82. 9702_w16_MS_43 Q: 2

(a) **(i)**	$p \propto T$ *or* pV/T = constant *or* $pV = nRT$	C1	
	T (= 5 × 300 =) 1500 K	A1	[2]
(ii)	$pV = nRT$		
	$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$ *or* $5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$	C1	
	n = 0.016 mol	A1	[2]
(b) **(i)**	**1.** heating/thermal energy supplied	B1	
	2. work done on/to system	B1	[2]
(ii)	**1.** 240 J	A1	
	2. same value as given in **1.** (= 240 J) **and** zero given for **3.**	A1	
	3. zero	A1	[3]

83. 9702_m21_MS_42 Q: 4

	Answer	Marks
(a)	acceleration and displacement are in opposite directions	**B1**
(b)(i)	$F = kx$ $= 8.0 \times (0.060 - 0.048)$ *or* $8.0 \times (0.060 + 0.048)$ or 8.0×0.012 *or* 8.0×0.108	**M1**
	$\Sigma F = (8.0 \times 0.012) - (8.0 \times 0.108) = 0.77N$ or $\Sigma F = 0.864 - 0.096 = 0.77N$	**A1**

	Answer	Marks
(b)(ii)	$a = \frac{F}{m}$ $= \frac{0.77}{0.25}$ $= 3.1 m s^{-2}$	A1
(b)(iii)	$a = -\ \omega^2 x$ $\omega\ = \sqrt{\frac{3.1}{0.048}}$ $\omega = 8.04$	C1
	$T = 2\ \pi\ /\ \omega$	C1
	$T = 2\pi\ /\ 8.04$ $= 0.78$ s	A1
(b)(iv)	(resultant) force halved and distance halved	B1
	same T	B1

84. 9702_s21_MS_43 Q: 3

	Answer	Marks
(a)	acceleration (directly) proportional to displacement	B1
	acceleration is in opposite direction to displacement	B1
(b)	$\omega^2 = 2k\ /\ m$ **and** $\omega = 2\pi f$	C1
	$(2\pi f)^2 = (2 \times 130)\ /\ 0.84$	C1
	$f = 2.8$ Hz	A1
(c)(i)	resonance	B1
(c)(ii)	oscillator supplies energy (continuously)	B1
	energy of trolley constant so energy must be dissipated **or** without loss of energy the amplitude would continuously increase	B1

85. 9702_s20_MS_41 Q: 3

	Answer	Marks
(a)(i)	amplitude = 4.9 cm	A1
(a)(ii)	frequency = 2700 / 60 = 45 Hz	A1
(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	C1
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ $= 14$ m s^{-1}	A1
(a)(iv)	$v\ = \omega\,(x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	C1
	$= 12$ m s^{-1}	A1

	Answer	Marks
(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	C1
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	C1
	= 2500 N	A1

86. 9702_s20_MS_43 Q: 3

	Answer	Marks
(a)(i)	amplitude = 4.9 cm	A1
(a)(ii)	frequency = 2700 / 60 = 45 Hz	A1
(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	C1
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ = 14 m s^{-1}	A1
(a)(iv)	$v = \omega(x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	C1
	= 12 m s^{-1}	A1

	Answer	Marks
(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	C1
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	C1
	= 2500 N	A1

87. 9702_m19_MS_42 Q: 3

	Answer	Marks
(a)(i)	mention of upthrust and weight	B1
(a)(ii)	upthrust is greater than the weight	B1
	(resultant force is) upwards	B1
(b)	*A*, *ρ*, *g* and *M* are constant	B1
	either acceleration ∝ – displacement *or* acceleration ∝ displacement and (– sign indicates) *a* and *x* in opposite directions	B1
(c)(i)	*either* $\omega = 2\pi / T$ *or* $\omega = 2\pi f$ and $f = 1 / T$	C1
	$\omega = 2\pi / 1.3$ = 4.8 rad s^{-1}	A1
(c)(ii)	$\omega^2 = A\rho g / m$	C1
	$4.83^2 = (4.5 \times 10^{-4} \times \rho \times 9.81) / 0.17$	C1
	ρ = 900 kg m^{-3}	A1

88. 9702_w19_MS_41 Q: 4

	Answer	Marks
(a)(i)	distance from a (reference) point in a given direction	B1
(a)(ii)	line is not straight **or** gradient is not constant	B1
(b)(i)	0.85–0.90 cm	A1
(b)(ii)	$a = -(2\pi f)^2 x$	C1
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	C1
	$f = 1.8$ Hz	A1
(c)	complete circle/ellipse enclosing the origin	B1
	closed shape passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	B1

89. 9702_w19_MS_43 Q: 4

	Answer	Marks
(a)(i)	distance from a (reference) point in a given direction	B1
(a)(ii)	line is not straight **or** gradient is not constant	B1
(b)(i)	0.85–0.90 cm	A1
(b)(ii)	$a = -(2\pi f)^2 x$	C1
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	C1
	$f = 1.8$ Hz	A1
(c)	complete circle/ellipse enclosing the origin	B1
	closed shape passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	B1

90. 9702_s18_MS_41 Q: 2

	Answer	Marks
(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	C1
	$f = 3.8$ Hz	A1
(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
(b)(ii)	(just leaves plate when) acceleration = 9.81 m s^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

91. 9702_s18_MS_43 Q: 2

	Answer	Marks
(a)(i)	straight line through origin indicates acceleration ∝ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	C1
	$f = 3.8$ Hz	A1
(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
(b)(ii)	(just leaves plate when) acceleration = 9.81 m s^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

92. 9702_w18_MS_41 Q: 2

	Answer	Marks
(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	**1.** work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): –42.5 J	A1
	3. increase in internal energy (R→P): –54.5 J	A1
	thermal energy supplied (R→P): –91.5 J	A1

93. 9702_w17_MS_41 Q: 2

	Answer	Marks
(a)	(angular frequency =) 2π × frequency **or** 2π/period	B1
(b)(i)	**1.** displacement = 2.0 cm	A1
	2. amplitude = 1.5 cm	A1
(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	B1
	straight line indicates acceleration ∝ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1

	Answer	Marks
(b)(iii)	ω^2 = (–)1 / gradient **or** ω^2 = (–)$\Delta a / \Delta s$ **or** a = (–)$\omega^2 x$ <u>and</u> correct value of x	C1
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** 0.9 = $\omega^2 \times 0.015$ = 60	C1
	$f = \sqrt{60} / 2\pi$ = 1.2 Hz	A1

94. 9702_w17_MS_42 Q: 3

	Answer	Marks
(a)(i)	angle (subtended) where arc (length) is equal to radius	M1
	(angle subtended) at the centre of a circle	A1
(a)(ii)	angular frequency = $2\pi \times$ frequency **or** 2π / period	B1
(b)(i)	c / ML^3 is a constant so acceleration is proportional to displacement	B1
	minus sign shows that acceleration and displacement are in opposite <u>directions</u>	B1
(b)(ii)	$c / ML^3 = (2\pi f)^2$	C1
	$c = 4\pi^2 \times 3.2^2 \times 0.24 \times 0.65^3$	C1
	= 27 kg m^3 s^{-2}	A1

95. 9702_w17_MS_43 Q: 2

	Answer	Marks
(a)	(angular frequency =) $2\pi \times$ frequency **or** 2π/period	B1
(b)(i)	**1.** displacement = 2.0 cm	A1
	2. amplitude = 1.5 cm	A1
(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	B1
	straight line indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1

	Answer	Marks
(b)(iii)	ω^2 = (–)1 / gradient **or** ω^2 = (–)Δ*a* / Δ*s* **or** *a* = (–)$\omega^2 x$ and correct value of *x*	C1
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** 0.9 = $\omega^2 \times 0.015$ = 60	C1
	f = √60 / 2π = 1.2 Hz	A1

96. 9702_w16_MS_41 Q: 3

(a) $2k/m = \omega^2$ M1

$\omega = 2\pi f$ M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to f = 2.0 Hz A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$

$= 0.20\,\text{m s}^{-1}$ A1 [2]

(c) frequency: reduced/decreased B1
maximum speed: reduced/decreased B1 [2]

97. 9702_w16_MS_42 Q: 4

(a) (i) 0.225 s and 0.525 s A1 [1]

(ii) period or T = 0.30 s and $\omega = 2\pi / T$ C1

$\omega = 2\pi / 0.30$

$\omega = 21\,\text{rad s}^{-1}$ A1 [2]

(iii) speed = ωx_0 or $\omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$= 20.9 \times 2.0 \times 10^{-2} = 0.42\,\text{m s}^{-1}$ A1 [2] *or*

use of tangent method:
correct tangent shown on Fig. 4.2 (C1)
working e.g. $\Delta y / \Delta x$ leading to maximum speed in range (0.38–0.46) m s^{-1} (A1)

(b) sketch: reasonably shaped continuous oval/circle surrounding (0,0) B1
curve passes through (0, 0.42) and (0, –0.42) B1
curve passes through (2.0, 0) and (–2.0, 0) B1 [3]

98. 9702_w16_MS_43 Q: 3

(a) $2k/m = \omega^2$ M1

$\omega = 2\pi f$ M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to f = 2.0 Hz A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$

= 0.20 m s^{-1} A1 [2]

(c) frequency: reduced/decreased B1
maximum speed: reduced/decreased B1 [2]

99. 9702_w21_MS_42 Q: 4

	Answer	Marks
(a)	straight line through the origin	B1
	negative gradient	B1
(b)	$a = (–)\omega^2 x$ **and** $T = 2\pi / \omega$	C1
	e.g. $\omega = \sqrt{(0.80 / 0.12)}$ (*any correct pair of values of a and x*) (= 2.58 rad s^{-1})	C1
	$T = 2\pi / 2.58$ = 2.4 s	A1
(c)(i)	Point labelled P at one end of the line	B1
(c)(ii)	Point labelled Q at displacement with magnitude more than half but less than maximum	B1

100. 9702_s19_MS_42 Q: 3

	Answer	Marks
(a)(i)	0.10 s **or** 0.30 s **or** 0.50 s **or** 0.70 s **or** 0.90 s	**A1**
(a)(ii)	0 **or** 0.40 s **or** 0.80 s	**A1**
(b)(i)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 0.40$ $= 16 \text{ rad s}^{-1}$	**A1**
(b)(ii)	$v_0 = \omega x_0$	**C1**
	$= 15.7 \times 2.5 \times 10^{-2}$ $= 0.39 \text{ m s}^{-1}$	**A1**
	or	
	tangent drawn at steepest part and working to show attempted calculation of gradient	**(C1)**
	leading to $v_0 = 0.39 \text{ m s}^{-1}$ (*allow ± 0.15 m s*$^{-1}$)	**(A1)**
(b)(iii)	$a_0 = \omega^2 x_0$	**C1**
	$a_0 = (15.7^2 \times 2.5 \times 10^{-2})$ $= 6.2 \text{ m s}^{-2}$	**A1**
	or	
	$a_0 = \omega v_0$	**(C1)**
	$a_0 = 15.7 \times 0.39$ $= 6.2 \text{ m s}^{-2}$	**(A1)**

	Answer	Marks
(c)	period is shorter/lower	**B1**
	Any one from: • greater spring constant/stiffness • (restoring) force is greater (for any given extension) • acceleration is greater (for any given extension) • greater energy/maximum speed (for a given amplitude)	**B1**

101. 9702_m17_MS_42 Q: 3

	Answer	Marks
(a)	*m* is constant *or k* / *m* is constant <u>and</u> so acceleration / *a* proportional to displacement / *x*	**B1**
	negative sign shows that acceleration / *a* is in opposite direction to displacement / *x* *or* negative sign shows acceleration / *a* is towards fixed point	**B1**
(b)	evidence of comparison to expression to $a = -\omega^2 x$	**B1**
	$\omega^2 = k/m$ *or* $\omega^2 = 4.0/m$ hence $\omega = 2.0/\sqrt{m}$	**A1**
(c)	$E_K = ½ m \omega^2 x_0^2$ *or* $E_K = ½mv^2$ <u>and</u> $v = \omega x_0$	**C1**
	$= ½m\,(4.0/m)\,(3.0 \times 10^{-2})^2$	**C1**
	$= 1.8 \times 10^{-3}$ J	**A1**

	Answer	Marks
(d)	new $x_0 = \sqrt{[(1.8\times10^{-3}/2)\times(2/m\times(m/4.0))]}$ *or* ($E_K \propto x_0^2$ so) new $x_0 = \sqrt{[½\times(3.0\times10^{-2})^2]}$	C1
	$= 2.12 \times 10^{-2}$ m	A1
(e)	flux linked to block changes / flux is cut by block which induces an e.m.f. in block	B1
	(eddy) currents induced in block cause heating	B1
	thermal / heat energy comes from (kinetic / potential) energy of oscillations / block	B1

102. 9702_m16_MS_42 Q: 4

(a) amplitude = 1.8 cm *and* period = 0.30 s A1 [1]

(b) $E_K = ½m\,\omega^2 (x_0^2 - x^2)$ *or* $E_K = ½mv^2$ *and* $v = \pm\,\omega\sqrt{(x_0^2 - x^2)}$ C1
$= ½ \times 0.080 \times (2\pi/0.30)^2 \times [(1.8\times10^{-2})^2 - (1.2\times10^{-2})^2]$ C1
$= 3.2 \times 10^{-3}$ J A1 [3]

103. 9702_s21_MS_41 Q: 3

	Answer	Marks
(a)	acceleration (directly) proportional to displacement	B1
	acceleration is in opposite direction to displacement	B1
(b)	$\omega^2 = 2k/m$ **and** $\omega = 2\pi f$	C1
	$(2\pi f)^2 = (2 \times 130) / 0.84$	C1
	$f = 2.8$ Hz	A1
(c)(i)	resonance	B1
(c)(ii)	oscillator supplies energy (continuously)	B1
	energy of trolley constant so energy must be dissipated **or** without loss of energy the amplitude would continuously increase	B1

104. 9702_s21_MS_42 Q: 3

	Answer	Marks
(a)	acceleration in opposite direction to displacement shown by – sign	B1
	g/L is constant	M1
	(so) acceleration is (directly) proportional to displacement	A1
(b)	$\omega^2 = g/L$	C1
	$\omega = 2\pi/T$ **or** $\omega = 2\pi f$ **and** $f = 1/T$	C1
	$(2\pi/T)^2 = 9.81/0.18$ $T = 0.85$ s	A1
(c)	energy $\propto x_0^2$	C1
	(after 3 cycles,) amplitude $= (0.94)^3 x_0$ $= 0.83x_0$	C1
	ratio final energy / initial energy $= 0.83^2$ $= 0.69$	A1

105. 9702_w21_MS_41 Q: 4

	Answer	Marks
(a)(i)	5.0 cm	A1
(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	C1
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$ $= 7.9$ cm s^{-1}	A1
(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	B3
(c)	sketch: closed loop encircling (20, 0)	B1
	minimum *L* shown as 15 cm and maximum *L* shown as 25 cm	B1
	minimum *v* shown as –7.9 cm s^{-1} and maximum *v* shown as +7.9 cm s^{-1}	B1

106. 9702_w21_MS_43 Q: 4

	Answer	Marks
(a)(i)	5.0 cm	A1
(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	C1
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$ $= 7.9$ cm s^{-1}	A1
(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	B3
(c)	sketch: closed loop encircling (20, 0)	B1
	minimum *L* shown as 15 cm and maximum *L* shown as 25 cm	B1
	minimum *v* shown as –7.9 cm s^{-1} and maximum *v* shown as +7.9 cm s^{-1}	B1

107. 9702_s20_MS_42 Q: 4

	Answer	Marks
(a)	($\omega = 2\pi / T$ and T = 2.2 s so) $\omega = 2\pi / 2.2 = 2.9$ rad s^{-1}	A1
(b)(i)	$\omega^2 = g / R$	C1
	R = 9.81 / 2.86^2 = 1.2 m	A1
(b)(ii)	$v_0 = \omega x_0$	C1
	= 2.9 × 3.0 × 10^{-2} = 0.087 m s^{-1}	A1
(c)	smooth wave starting at 3.0 cm when t = 0	B1
	positions of peaks and troughs show same period (or slightly longer)	B1
	each peak and trough at lower amplitude than the previous one	B1

108. 9702_s19_MS_41 Q: 3

	Answer	Marks
(a)(i)	amplitude = 0.020 m	A1
(a)(ii)	T = 0.60 s	C1
	f = 1 / T = 1.7 Hz	A1
(a)(iii)	$a = (-)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi / T$]	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$ = 2.2 m s^{-2}	A1
(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3$ kg m^{-3}	A1
(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

109. 9702_s19_MS_43 Q: 3

	Answer	Marks
(a)(i)	amplitude = 0.020 m	A1
(a)(ii)	T = 0.60 s	C1
	f = 1 / T = 1.7 Hz	A1
(a)(iii)	$a = (-)\omega^2 x$ **and** $[\omega = 2\pi f$ **or** $\omega = 2\pi / T]$	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$ $= 2.2\ \text{m s}^{-2}$	A1
(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3\ \text{kg m}^{-3}$	A1
(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

110. 9702_w19_MS_42 Q: 4

	Answer	Marks
(a)(i)	loss of energy	B1
(a)(ii)	amplitude (of oscillations) decreases (with time)	B1
(b)(i)	$\omega = 2\pi / T$	C1
	T = 0.80 s, so $\omega = 2\pi / 0.80$ $\omega = 7.9\ \text{rad s}^{-1}$	A1
(b)(ii)	$\omega^2 = 2k / M$	C1
	$7.9^2 = 2k / 1.2$ $k = 37\ \text{N m}^{-1}$	A1
(c)(i)	(one) smooth curve, not touching the f-axis, with two concave sides meeting at a peak in between them	B1
	(one) peak at 1.0ω	B1
(c)(ii)	• lower peak/(whole) line is lower • flatter peak/peak is less sharp • peak at (slightly) lower angular frequency/peak moves to left *any two points, one mark each*	B2

111. 9702_m18_MS_42 Q: 4

	Answer	Marks
(a)	frequency at which body will vibrate when there is no (resultant external) resistive force acting on it OR frequency at which body will vibrate when there is no driving force / external force acting on it	B1
(b)(i)	resonance	B1
(b)(ii)	peak is not sharp / peak not infinite height	M1
	so damped	A1
(c)	e.g. (quartz crystal) to produce ultrasound (quartz crystal) in watch to keep timing NMR / MRI microwave ovens tuning circuits	B1

112. 9702_s18_MS_42 Q: 4

	Answer	Marks
(a)	acceleration proportional to displacement	B1
	acceleration directed towards fixed point **or** displacement and acceleration in opposite directions	B1
(b)(i)	**1.** amplitude decreases gradually so light damping **or** oscillations continue so light damping	B1
	2. loss of energy	B1
	due to friction in wheels **or** due to friction between wheels and surface (during slipping) **or** due to air resistance (on trolley)	B1
(b)(ii)1.	$\omega^2 = 2k/m$	C1
	$= (2 \times 230)/0.950$	C1
	$\omega = 22$ rad s^{-1}	A1
(b)(ii)2.	$T = 2\pi/\omega$	C1
	$T = (2\pi/22) = 0.286$ s time $= 1.5T$ $= 0.43$ s	A1

113. 9702_w18_MS_41 Q: 3

	Answer	Marks
(a)	$\omega^2 = 2g/L$	C1
	$T = 2\pi/\omega$	C1
	$\omega^2 = (2 \times 9.81)/0.19$ $\omega = 10.2$ (rad s^{-1}) $T = 2\pi/10.2$ $= 0.62$ s	A1
(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	B1
(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	change $= \frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	C1
	$= 2.9 \times 10^{-4}$ J	A1

114. 9702_w18_MS_42 Q: 4

	Answer	Marks
4(a)	(defining equation of s.h.m. is) $a = -kx$ where k is a constant **or** $a \propto -x$	**B1**
	g and L are constant (so $a \propto -x$ and hence s.h.m.)	**B1**
(b)	$T = 0.50\,\text{s}$ **and** $T = 2\pi / \omega$	**C1**
	$\omega^2 = 2g / L$	**C1**
	$L = (2 \times 9.81 \times 0.50^2) / 4\pi^2$ $= 0.12\,\text{m}$	**A1**
(c)(i)	Any one from: • viscosity of liquid • friction within the liquid • viscous drag • friction/resistance between walls of tube and liquid	**B1**
(c)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	**C1**
	ratio = $(1.3/2.0)^2$ $= 0.42$	**A1**

115. 9702_w18_MS_43 Q: 3

	Answer	Marks
(a)	$\omega^2 = 2g / L$	**C1**
	$T = 2\pi / \omega$	**C1**
	$\omega^2 = (2 \times 9.81) / 0.19$ $\omega = 10.2\ (\text{rad s}^{-1})$ $T = 2\pi / 10.2$ $= 0.62\,\text{s}$	**A1**
(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	**B1**
(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	**C1**
	change $= \frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	**C1**
	$= 2.9 \times 10^{-4}\,\text{J}$	**A1**

116. 9702_s17_MS_41 Q: 2

	Answer	Marks
(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
(b)	light (damping)	B1
(c)	at 2.7 s, A_0 = 1.5 (cm)	B1
	energy $= ½ m \times 4\pi^2 f^2 A_0^2$	B1
	$= ½ \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	C1
	at 7.5 s, A_0 = 0.75 (cm)	B1
	energy = $¼ \times 5.51 \times 10^{-4}$ **or** energy = $½ \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

117. 9702_s17_MS_43 Q: 2

	Answer	Marks
(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
(b)	light (damping)	B1
(c)	at 2.7 s, A_0 = 1.5 (cm)	B1
	energy $= ½ m \times 4\pi^2 f^2 A_0^2$	B1
	$= ½ \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	C1
	at 7.5 s, A_0 = 0.75 (cm)	B1
	energy = $¼ \times 5.51 \times 10^{-4}$ **or** energy = $½ \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

118. 9702_s21_MS_41 Q: 4

	Answer	Marks
	(ultrasound) pulse	B1
	reflected at boundaries	B1
	gel is used to minimise reflection at skin **or** generated <u>and</u> detected by quartz crystal	B1
	time delay between generation and detection gives information about depth	B1
	intensity (of reflected wave) gives information about nature of boundary	B1

119. 9702_s21_MS_43 Q: 4

	Answer	Marks
	(ultrasound) pulse	B1
	reflected at boundaries	B1
	gel is used to minimise reflection at skin **or** generated and detected by quartz crystal	B1
	time delay between generation and detection gives information about depth	B1
	intensity (of reflected wave) gives information about nature of boundary	B1

120. 9702_w21_MS_42 Q: 11

	Answer	Marks
(a)	generates ultrasound	B1
	detects reflected ultrasound	B1
	applied p.d. causes crystal to vibrate **or** vibrations cause crystal to generate an e.m.f.	B1
(b)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(b)(ii)	difference between (the specific acoustic impedances)	C1
	• if similar/same then reflection coefficient is zero/very low • if very different then reflection coefficient is (nearly) 1 • the lower the difference means lower the reflection coefficient (*any one point*)	A1

121. 9702_m20_MS_42 Q: 4

	Answer	Marks
(a)(i)	Any 2 from: • allows the reflected signal to be distinguished from the emitted signal • detection occurs in the time between emitted pulses • (reflection of ultrasound) detected by same probe / transducer / crystal • cannot emit and detect at same time (hence pulses)	B2
(a)(ii)	piezo-electric crystal	B1
	ultrasound makes crystal vibrate / resonate	B1
	vibration produces (alternating) e.m.f. / p.d. across crystal	B1
(b)(i)	$= (1.6 \times 10^6 - 4.3 \times 10^2)^2 / (1.6 \times 10^6 + 4.3 \times 10^2)^2$ = **0.999**	B1
(b)(ii)	without the gel most of the ultrasound is reflected	B1
	Z values more similar / α reduces so less (ultrasound) is reflected / more (ultrasound) is transmitted	B1

122. 9702_s20_MS_41 Q: 4

	Answer	Marks
(a)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(a)(ii)	the greater the difference between Z_1 and Z_2, the closer the ratio is to 1 **or** if difference between Z_1 and Z_2 large, ratio is close to 1	B1
	the closer together Z_1 and Z_2, the closer the ratio is to 0 **or** if difference between Z_1 and Z_2 small, ratio close to 0	B1
(b)(i)	loss of intensity/amplitude/power (of the wave)	B1
(b)(ii)	$I = I_0 e^{-\mu x}$	C1
	$0.35 = e^{-0.046\mu}$ $\mu = 23 m^{-1}$	A1

123. 9702_s20_MS_42 Q: 5

	Answer	Marks
(a)	pulses of ultrasound	B1
	ultrasound incident on quartz crystal	B1
	waves make crystal oscillate	B1
	oscillations (of crystal) generates an e.m.f. (across the crystal)	B1
(b)	specific acoustic impedances of air and skin are very different	B1
	intensity reflection coefficient depends on difference between acoustic impedance	B1
	most ultrasound reflected so little transmission	B1

124. 9702_s20_MS_43 Q: 4

	Answer	Marks
(a)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(a)(ii)	the greater the difference between Z_1 and Z_2, the closer the ratio is to 1 **or** if difference between Z_1 and Z_2 large, ratio is close to 1	B1
	the closer together Z_1 and Z_2, the closer the ratio is to 0 **or** if difference between Z_1 and Z_2 small, ratio close to 0	B1
(b)(i)	loss of intensity/amplitude/power (of the wave)	B1
(b)(ii)	$I = I_0 e^{-\mu x}$	C1
	$0.35 = e^{-0.046\mu}$ $\mu = 23 m^{-1}$	A1

125. 9702_s19_MS_42 Q: 4

	Answer	Marks
(a)	product of density and speed	**M1**
	speed of sound in medium	**A1**
(b)	Any two from: • if $Z_A \gg Z_B$ then ratio is (nearly) zero **or** if $Z_B \gg Z_A$ then ratio is (nearly) zero **or** if Z_B and Z_A are very different then ratio is (nearly) zero **or** the greater the difference the lower the ratio • if $Z_A \approx Z_B$ then ratio is (nearly) 1 **or** if $Z_A = Z_B$ then ratio is 1 **or** the smaller the difference the closer the ratio to 1 (**not** 'large') • $I_T / I_0 = 1 - [(Z_A - Z_B)^2 / (Z_A + Z_B)^2]$	**B2**
(c)	$I = I_0 e^{-\mu x}$	**C1**
	$0.34 = \exp(-23 \times x)$	**C1**
	$x = 0.047$ m	**A1**

126. 9702_w19_MS_42 Q: 5

	Answer	Marks
(a)(i)	product of density and speed	**M1**
	speed of sound in the medium	**A1**
(a)(ii)	$Z_B = 1.8 \times 10^3 \times 4.1 \times 10^3$ $= 7.4 \times 10^6$ kg m^2 s^{-1}	**A1**
(b)	$\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2 = 0.018$ fraction = 0.98	**A1**
(c)(i)	reduction in power/intensity (of wave)	**M1**
	as the wave passes through the medium	**A1**
(c)(ii)	**1.** ratio $= e^{-\mu x}$	**C1**
	$= 0.90$	**A1**
	2. ratio $= 0.62$	**A1**
(d)	fraction $= 0.898 \times 0.617 \times 0.98$ $= 0.54$	**A1**

127. 9702_m18_MS_42 Q: 5

	Answer	Marks
(a)	pulses of ultrasound	B1
	reflected at boundaries (between media)	B1
	reflected pulses detected by (ultrasound) generator	B1
	Any three from:	
	(reflected signal) processed and displayed	(B1)
	time delay (between transmission and receipt) gives information about depth (of boundary)	(B1)
	intensity of reflected pulse gives information about (nature of) boundary	(B1)
	gel used to minimise reflection at skin / maximise transmission into skin	(B1)
	degree of reflection depends upon impedances of two media (at boundary)	(B1)
		B3
(b)(i)	product of density and speed	M1
	of sound in the medium	A1
(b)(ii)	(Z_1 about equal to Z_2,) coefficient very small / nearly 0	B1
	(Z_1 very different to Z_2,) coefficient nearly 1	B1

128. 9702_s18_MS_41 Q: 4

	Answer	Marks
(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	B1
(b)	pulses (of ultrasound)	B1
	reflected at boundaries (between media)	B1
	(reflected pulses) detected by (ultrasound) generator	B1
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) boundary • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	B3

129. 9702_s18_MS_43 Q: 4

	Answer	Marks
(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	B1
(b)	pulses (of ultrasound)	B1
	reflected at boundaries (between media)	B1
	(reflected pulses) detected by (ultrasound) generator	B1
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) boundary • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	B3

130. 9702_w18_MS_41 Q: 4

	Answer	Marks
(a)	pulses (of ultrasound from generator)	B1
	reflected at boundaries (between media)	B1
	time delay (between transmission and receipt) gives information about depth	B1
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	B1
	Any two from: • (reflected pulses) detected by the (ultrasound) generator • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	B2
(b)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	B1
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	B1

131. 9702_w18_MS_43 Q: 4

	Answer	Marks
(a)	pulses (of ultrasound from generator)	B1
	reflected at boundaries (between media)	B1
	time delay (between transmission and receipt) gives information about depth	B1
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	B1
	Any two from: • (reflected pulses) detected by the (ultrasound) generator • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	B2
(b)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	B1
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	B1

132. 9702_m17_MS_42 Q: 4

	Answer	Marks
	piezo-electric / quartz crystal / transducer	B1
	alternating p.d. applied across crystal / transducer	B1
	causes crystal to vibrate / resonate	B1
	crystal resonates at ultrasound frequencies / crystal's natural frequency is in the ultrasound range / alternating p.d. is in ultrasound frequency range	B1

133. 9702_s17_MS_42 Q: 4

	Answer	Marks
(a)	pulse (of ultrasound)	B1
	* produced by quartz crystal/piezo-electric crystal	
	* gel/coupling medium (on skin) used to reduce reflection at skin	
	reflected from boundaries (between media)	B1
	reflected pulse/wave detected by (ultrasound) transmitter	B1
	reflected wave processed and displayed	B1
	* intensity of reflected pulse/wave gives information about boundary	
	* time delay gives information about depth of boundary	
	*max. 2 of additional detail points marked **	B2
(b)	$I_T = I_0 \exp(-\mu x)$	C1
	$2.9 = \exp(4.6\mu)$	C1
	$\mu = 0.23\,\text{cm}^{-1}$	A1

134. 9702_w17_MS_42 Q: 4

	Answer	Marks
(a)	quartz/piezo-electric **and** crystal/transducer	B1
	p.d. across crystal causes it to distort	B1
	applying alternating p.d. causes oscillations/vibrations	B1
	when applied frequency is natural frequency, crystal resonates	B1
	natural frequency of crystal is in ultrasound range	B1
(b)	small(er) structures can be resolved/observed/identified	B1

135. 9702_m16_MS_42 Q: 6

(a) speed $= Z/\rho$
$= 1.4 \times 10^6 / 940\ (=1490)$ C1
time $= (1.1 \times 10^{-2} \times 2) / 1490$ C1
$= 1.5 \times 10^{-5}\,\text{s}$ A1 [3]
(time of $7.4 \times 10^{-6}\,\text{s}$ is one way only and scores 2/3 marks)
(use of speed of light is wrong physics and scores 0/3 marks)

(b) $I = I_0 \exp(-\mu x)$ *or* $I_2 = I_1 \exp(-\mu x)$ C1
ratio = exp (– 48 × 1.1 × 10^{-2})
= 0.59 A1 [2]

(c) 0.33 / 100 = 0.59 × (I_3 / I_2) × 0.59 C1
ratio = 9.5 × 10^{-3} A1
or
0.33 / 100 = exp (– 48 × 2.2 × 10^{-2}) × (I_3 / I_2) (C1)
ratio = 9.5 × 10^{-3} (A1) [2]

(d) ratio I_3 / I_2 increases B1 [1]
(accept: "there is an increase in the proportion of the intensity that is reflected")

136. 9702_w16_MS_42 Q: 5

(a) transducer/transmitter can be also be used as the receiver
or
transducer both transmits and receives

receives reflected pulses between the emitted pulses

(needs to be pulsed) in order to measure/determine depth(s)

(needs to be pulsed) to determine nature of boundaries

Any three of the above marking points, 1 mark each B2 [2]

(b) **(i)** product of speed of (ultra)sound and density (of medium) M1

reference to speed of sound in medium A1 [2]

(ii) if Z_1 and Z_2 are (nearly) equal, I_T / I_0 (nearly) equal to 1/unity/(very) little reflection/mostly transmission B1

if $Z_1 \gg Z_2$ or $Z_1 \ll Z_2$ or the difference between Z_1 and Z_2 is (very) large, then I_T / I_0 is small/zero/mostly reflection/little transmission B1 [2]

137. 9702_m21_MS_42 Q: 5

	Answer	Marks
(a)(i)	amplitude of the carrier wave varies	M1
	in synchrony with the displacement of the (information) signal	A1
(a)(ii)	Any 2 from: • fewer transmitters needed / each transmitter can cover a greater distance • more stations can share waveband • transmitters and receivers are cheaper	B2

	Answer	Marks
(b)(i)	$\lambda = \frac{v}{f}$ $= \frac{3.0 \times 10^8}{1.5 \times 10^6} = 200\,m$	A1
(b)(ii)	**10** kHz	B1
(c)	**1520** kHz	B1

138. 9702_s21_MS_42 Q: 4

	Answer	Marks
(a)(i)	frequency (modulation)	B1
(a)(ii)	**1.** zero	B1
	2. frequency (of 1.2 MHz) varies by ±50 kHz	B1
	frequency varies (by ±50 kHz) at a rate of 8000 times per second	B1
(b)(i)	wavelength = $(3.00 \times 10^8) / (240 \times 10^3)$	C1
	(= 1250 m) = 1.25 km	A1
(b)(ii)	bandwidth = 30 kHz	A1
(b)(iii)	frequency = 15 kHz	A1

139. 9702_w21_MS_42 Q: 5

	Answer	Marks
(a)(i)	unmodulated (radio) waves would interfere with each other **or** not modulating would require aerials too long (to be practical)	B1
(a)(ii)	advantage: • can transmit higher frequencies • higher quality reproduction • less prone to interference • same frequency can be used in different areas (*any one point*)	B1
	disadvantage: • takes up greater bandwidth • shorter range of transmission • requires a greater number of transmitting aerials (*any one point*)	B1
(b)	AM amplitude: min. 8 mV **and** max. 12 mV	B1
	AM frequency: min. 100 kHz **and** max. 100 kHz	B1
	FM amplitude: min. 10 mV **and** max. 10 mV	B1
	FM frequency: min. 90 kHz **and** max. 110 kHz	B1
(c)	8.4 kHz	A1

140. 9702_w19_MS_42 Q: 6

	Answer	Marks
(a)	period = 5.0 μs, so frequency = 2.0×10^5 Hz	A1
(b)	sketch: three equally spaced vertical lines sitting on *f*-axis	B1
	two outer vertical lines of equal length and central line longer	B1
	three vertical lines (and no others) shown at frequencies 190 kHz, 200 kHz and 210 kHz	B1

141. 9702_s18_MS_42 Q: 5

	Answer	Marks
(a)(i)	range of frequencies (of signal)	B1
(a)(ii)	advantage: e.g. better quality (of reproduction) greater rate of transfer of data less distortion	B1
	disadvantage: e.g. fewer stations (in any frequency range)	B1
(b)(i)	5.0 V	A1
(b)(ii)	maximum: 674 kHz	A1
	minimum: 626 kHz	A1
(b)(iii)	$T = 1 / (10 \times 10^3) = 1.0 \times 10^{-4}$ s minimum time = $T / 2$ $= 5.0 \times 10^{-5}$ s	A1

142. 9702_w18_MS_42 Q: 5

	Answer	Marks
(a)	amplitude of carrier (wave) varies	B1
	variation in synchrony with displacement of information signal	B1
5(b)(i)	wavelength = $(3.0 \times 10^8) / (900 \times 10^3)$ $= 3.3 \times 10^2$ m	A1
(b)(ii)	amplitude varies (continuously) between a maximum and a minimum	B1
	variations repeat 5000 times each second **or** variations repeat every 0.2 ms **or** variations above and below 4.0 V	B1
(b)(iii)	10000 Hz	A1
(c)(i)	Any two from: • (orbit is) above the Equator • (orbit is) from west to east/same direction as Earth's rotation • orbit is circular/orbit has a particular radius	B2
(c)(ii)	**1.** minimal reflection/absorption/attenuation by <u>atmosphere</u> **or** maximum penetration of/transmission through <u>atmosphere</u>	B1
	2. uplink signal is greatly attenuated/must be greatly amplified	B1
	prevents downlink signal swamping the uplink signal	B1

143. 9702_w21_MS_41 Q: 5

	Answer	Marks
(a)	• noise can be removed/signal can be regenerated • extra bits can be added for error-checking • signal can be encrypted (for increased security) • data compression/multiplexing is possible *Any two points, 1 mark each*	B2
(b)(i)	4 ms: 0101 **and** 8 ms: 0100	B1
(b)(ii)	sketch: horizontal line continues to 8 ms, then new horizontal line from 8 ms to 12 ms	B1
	level of line after 8 ms is 4 mV	B1
(c)	sketch: series of steps of width 2 ms	B1
	step heights at 0, 2, 4, 6, 4, 6 mV *2 marks if all correct, 1 mark if only one incorrect*	B2

144. 9702_w21_MS_43 Q: 5

	Answer	Marks
(a)	• noise can be removed/signal can be regenerated • extra bits can be added for error-checking • signal can be encrypted (for increased security) • data compression/multiplexing is possible *Any two points, 1 mark each*	B2
(b)(i)	4 ms: 0101 **and** 8 ms: 0100	B1
(b)(ii)	sketch: horizontal line continues to 8 ms, then new horizontal line from 8 ms to 12 ms	B1
	level of line after 8 ms is 4 mV	B1
(c)	sketch: series of steps of width 2 ms	B1
	step heights at 0, 2, 4, 6, 4, 6 mV *2 marks if all correct, 1 mark if only one incorrect*	B2

145. 9702_m18_MS_42 Q: 6

	Answer	Marks
(a)(i)	0101	A1
(a)(ii)	1000	A1
(b)	sketch: series of steps	B1
	changes every 0.25 ms	B1
	correct heights 0, 5, 10, 12, 15, 8 at correct times Two marks for all levels correct One mark if one mistake	B2

146. 9702_w18_MS_41 Q: 5

	Answer	Marks
(a)	Any two reasonable suggestions e.g.: • noise can be eliminated/(signal/data) can be regenerated • bits can be added to correct for errors • data compression/multiplexing (is possible) • signal can be encrypted/better security	B2
(b)	sketch: series of seven steps	B1
	each step width 2 ms	B1
	correct levels in correct order (2, 5, 14, 4, 9, 11, 7) *(1 mark for 6 levels correct, 2 marks for 7 levels correct)*	A2
(c)(i)	step width reduced **or** higher frequencies can be reproduced	B1
(c)(ii)	step height reduced **or** smaller changes in signal (intensity) can be reproduced	B1

147. 9702_w18_MS_43 Q: 5

	Answer	Marks
(a)	Any two reasonable suggestions e.g.: • noise can be eliminated/(signal/data) can be regenerated • bits can be added to correct for errors • data compression/multiplexing (is possible) • signal can be encrypted/better security	**B2**
(b)	sketch: series of seven steps	**B1**
	each step width 2 ms	**B1**
	correct levels in correct order (2, 5, 14, 4, 9, 11, 7) (*1 mark for 6 levels correct, 2 marks for 7 levels correct*)	**A2**
(c)(i)	step width reduced **or** higher frequencies can be reproduced	**B1**
(c)(ii)	step height reduced **or** smaller <u>changes</u> in signal (intensity) can be reproduced	**B1**

148. 9702_s17_MS_42 Q: 5

	Answer	Marks
(a)	any two reasonable suggestions e.g. • signal can be regenerated/noise removed (not "no noise") • circuits more reliable • circuits cheaper to produce • multiplexing (is possible) • error correction/checking • easier encryption/better security	**B2**
(b)(i)	samples the analogue signal	**M1**
	at regular intervals and converts it (to a digital number)	**A1**
(b)(ii)	**1.** smaller step depth	**B1**
	2. smaller step height	**B1**

149. 9702_w17_MS_42 Q: 5

	Answer	Marks
(a)	(0.2 ms) | 8.0 (mV) | 1000	**B1**
	(0.8 ms) | 5.8 (mV) | 0101	**B1**
(b)	series of steps	**B1**
	all (step) changes are at 0.2 ms intervals	**B1**
	steps with correct levels at correct times (*1 mark if five levels correct; 2 marks if all levels correct*)	**B2**
(c)	smaller step heights (possible)	**B1**
	smaller changes (in input signal) can be seen/reproduced/represented **or** (allows) more accurate <u>reproduction</u> (of the input signal)	**B1**

level	0	8	10	15	5	8
time / ms	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2

150. 9702_m16_MS_42 Q: 5

(a) **(i)** (series of) ‘highs’ and ‘lows’ / ‘on’ and ‘off’ / 1’s and 0’s / two values — M1
with no intermediate values / the values are discrete — A1 [2]

(ii) *either* use higher sampling frequency / rate
or use more bits in each sample / each digital number
or use more levels in each sample — B1 [1]

(b) voltage = 30 mV — A1 [1]

151. 9702_s19_MS_41 Q: 4

	Answer	Marks
(a)(i)	loss of (signal) power/amplitude/intensity	**B1**
(a)(ii)	unwanted/random signal	**B1**
	superposed on (transmitted) signal	**B1**
(b)	noise can be eliminated (from digital signals) **or** signal can be regenerated (from digital signals)	**B1**
(c)(i)	010<u>1</u>	**A1**
(c)(ii)	1000 at t = 4.0 ms	**B1**
	0110 at t = 5.0 ms **and** 0100 at t = 6.0 ms	**B1**
(d)	series of equally-spaced steps of width 1 ms	**B1**
	each step in correct time interval (0–1 ms, 1–2 ms, 2–3 ms, 3–4 ms)	**B1**
	correct step heights (2, 6, 4 and 5)	**B1**

152. 9702_s21_MS_41 Q: 5

	Answer	Marks
(a)	amplitude of the carrier wave varies	**M1**
	in synchrony with the displacement of the (information) signal	**A1**
(b)(i)	wavelength $= (3.0 \times 10^8) / (300 \times 10^3)$ $= 1000$ m	**A1**
(b)(ii)	bandwidth = 16 kHz	**A1**
(b)(iii)	frequency = 8 kHz	**A1**
(c)	attenuation = 10 lg (P_1 / P_2)	**C1**
	73 = 10 lg (P_T / P_R) 73 = 10 lg ($P_T x^2$ / 0.082 P_T) **or** x^2 / 0.082 = $10^{7.3}$	**C1**
	x = 1300 m	**A1**

153. 9702_s21_MS_43 Q: 5

	Answer	Marks
(a)	amplitude of the carrier wave varies	M1
	in synchrony with the displacement of the (information) signal	A1
(b)(i)	wavelength $= (3.0 \times 10^8) / (300 \times 10^3)$ $= 1000$ m	A1
(b)(ii)	bandwidth = 16 kHz	A1
(b)(iii)	frequency = 8 kHz	A1
(c)	attenuation = 10 lg (P_1 / P_2)	C1
	$73 = 10 \lg (P_T / P_R)$ $73 = 10 \lg (P_T x^2 / 0.082 P_T)$ **or** $x^2 / 0.082 = 10^{7.3}$	C1
	$x = 1300$ m	A1

154. 9702_m20_MS_42 Q: 5

	Answer	Marks
(a)	Any 2 from: • noise can be filtered out / noise can be removed / signal can be regenerated • can carry more information per unit time / greater rate of transmission of data • can have extra bits of data to check for errors • can be encrypted	B2
(b)(i)	$v \propto \lambda$	C1
	ratio $= v_{air} / v_{fibre}$ $= 3.00 \times 10^8 / 2.07 \times 10^8$ = **1.45**	A1
(b)(ii)	attenuation = 10 log (P_2/P_1)	C1
	$0.40 \times L = 10 \log (1.5 / 0.06)$ $0.40 \times L = 13.979$	C1
	L = **35** km	A1

155. 9702_s20_MS_41 Q: 6

	Answer	Marks
(a)(i)	greater information carrying capacity	B1
(a)(ii)	power/energy is radiated	B1
	signal picked up by adjacent fibre/wire	B1
(b)	ratio / dB = 10 lg(P_2 / P_1)	C1
	$13 = 10 \lg [P / (1.0 \times 10^{-3})]$ and so $P = 20$ mW	A1
(c)	$45 \times 0.18 = 10 \lg (20 / P)$	C1
	$P = 3.1$ mW	A1

156. 9702_s20_MS_42 Q: 6

	Answer	Marks
(a)	• greater bandwidth • less noise • less attenuation **or** fewer repeaters • less crosslinking **or** greater security *Any three points, 1 mark each*	**B3**
(b)(i)	ratio / dB = 10 lg(P_1 / P_2)	**C1**
	21 = 10 lg [(6.3 × 10^{-17}) / P] P = 5.0 × 10^{-19} W	**A1**
(b)(ii)	attenuation per unit length = (1 / 4.5 × 10^3) × 10 lg [(9.8 × 10^{-3}) / (6.3 × 10^{-17})]	**C1**
	= 0.032 dB km^{-1}	**A1**

157. 9702_s20_MS_43 Q: 6

	Answer	Marks
(a)(i)	greater information carrying capacity	**B1**
(a)(ii)	power/energy is radiated	**B1**
	signal picked up by adjacent fibre/wire	**B1**
(b)	ratio / dB = 10 lg(P_2 / P_1)	**C1**
	13 = 10 lg [P / (1.0 × 10^{-3})] and so P = 20 mW	**A1**
(c)	45 × 0.18 = 10 lg (20 / P)	**C1**
	P = 3.1 mW	**A1**

158. 9702_m19_MS_42 Q: 4

	Answer	Marks
(a)	Any three from: above the Equator period 24 hours orbits west to east one particular orbital radius	**B3**
(b)	attenuation = 10 lg(P_1 / P_2) 194 = 10 lg (3.2 × 10^3 / P_2)	**C1**
	P_2 = 1.3 × 10^{-16} W	**A1**
(c)	advantage: e.g. no tracking required	**B1**
	disadvantage: e.g. longer time delay	**B1**

159. 9702_s19_MS_42 Q: 5

	Answer	Marks
(a)(i)	loss of (signal) power/amplitude/intensity	B1
(a)(ii)	unwanted/random signal	B1
	superposed on (transmitted) signal	B1
(b)(i)	attenuation = 10 lg(P_2 / P_1)	C1
	attenuation per unit length = (1 / L) × 10 lg(P_2 / P_1) = (1 / 52) × 10 lg [(2.5 × 10^{-3}) / (7.8 × 10^{-16})]	C1
	= 2.4 dB km^{-1}	A1
(b)(ii)	gain / dB = 10 lg(P_2 / P_1) 115 = 10 lg [P / (7.8 × 10^{-16})]	C1
	P = 2.5 × 10^{-4} W	A1

160. 9702_s19_MS_43 Q: 4

	Answer	Marks
(a)(i)	loss of (signal) power/amplitude/intensity	B1
(a)(ii)	unwanted/random signal	B1
	superposed on (transmitted) signal	B1
(b)	noise can be eliminated (from digital signals) **or** signal can be regenerated (from digital signals)	B1
(c)(i)	010<u>1</u>	A1
(c)(ii)	1000 at t = 4.0 ms	B1
	0110 at t = 5.0 ms **and** 0100 at t = 6.0 ms	B1
(d)	series of equally-spaced steps of width 1 ms	B1
	each step in correct time interval (0–1 ms, 1–2 ms, 2–3 ms, 3–4 ms)	B1
	correct step heights (2, 6, 4 and 5)	B1

161. 9702_w19_MS_41 Q: 5

	Answer	Marks
(a)(i)	provides return for the signal	B1
	shields signal from noise	B1
(a)(ii)	e.g. connection between aerial and TV set	B1
(b)(i)	gain / dB = 10 lg (P_1 / P_2)	C1
	32 = 10 lg {P_{MIN} / (7.6 × 10^{-6})} P_{MIN} = 0.012 W	A1
(b)(ii)	attenuation per unit length = (1 / L) × 10 lg (P_1 / P_2) 6.3 = (1 / L) × 10 lg (2.6 / 0.012)	C1
	L = 3.7 km	A1

162. 9702_w19_MS_43 Q: 5

	Answer	Marks
(a)(i)	provides return for the signal	B1
	shields signal from noise	B1
(a)(ii)	e.g. connection between aerial and TV set	B1
(b)(i)	gain / dB = 10 lg (P_1 / P_2)	C1
	32 = 10 lg {P_{MIN} / (7.6 × 10^{-6})} P_{MIN} = 0.012 W	A1
(b)(ii)	attenuation per unit length = (1 / L) × 10 lg (P_1 / P_2) 6.3 = (1 / L) × 10 lg (2.6 / 0.012)	C1
	L = 3.7 km	A1

163. 9702_s18_MS_41 Q: 5

	Answer	Marks
(a)(i)	west to east	B1
(a)(ii)	above the Equator	B1
(a)(iii)	value in range (1–300) × 10^9 Hz	A1
(b)(i)	gain / dB = 10 lg (P_2 / P_1)	C1
	–195 = 10 lg (P / 3000) **or** 195 = 10 lg (3000 / P)	C1
	power = 9.5 × 10^{-17} W	A1
(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) **or** down-link signal must be (greatly) amplified (before transmission back to Earth) **or** up-link has (much) smaller intensity/power than down-link	B1
	(different frequency) prevents down-link (signal) swamping up-link (signal)	B1

164. 9702_s18_MS_43 Q: 5

	Answer	Marks
(a)(i)	west to east	B1
(a)(ii)	above the Equator	B1
(a)(iii)	value in range (1–300) × 10^9 Hz	A1
(b)(i)	gain / dB = 10 lg (P_2 / P_1)	C1
	–195 = 10 lg (P / 3000) **or** 195 = 10 lg (3000 / P)	C1
	power = 9.5 × 10^{-17} W	A1
(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) **or** down-link signal must be (greatly) amplified (before transmission back to Earth) **or** up-link has (much) smaller intensity/power than down-link	B1
	(different frequency) prevents down-link (signal) swamping up-link (signal)	B1

165. 9702_m17_MS_42 Q: 5

	Answer	Marks
(a)	any **three** from: • greater bandwidth • does not suffer from (e.m.) interference / can be used in (e.m.) 'noisy' environments • no / less power / energy radiated / better security / less cross-talk • less attenuation / fewer repeaters / amplifiers needed • less weight / easier to handle / cheaper / occupy less space	**B3**
(b)(i)	attenuation / gain = 10 log P_1 / P_2	**C1**
	0.50 × 57 = 10 log (15 × 10^{-3}/*P*) so *P* = 2.1 × 10^{-5} W *or* – (0.50 × 57) = 10 log (*P*/15 × 10^{-3}) so *P* = 2.1 × 10^{-5} W	**A1**
(b)(ii)	*either*	
	(calculation of S / N ratio at receiver) S / N ratio = 10 log (2.1 × 10^{-5} / 9.0 × 10^{-7}) or S/N ratio = 14	**M1**
	14 < 24 or S/N ratio < minimum S/N ratio	**A1**
	so not able to distinguish signal from noise	**A1**
	or	
	(calculation of minimum acceptable power at receiver) 24 = 10 log (*P* / 9.0 × 10^{-7}) or *P* = 2.3 × 10^{-4}	**(M1)**
	2.1 × 10^{-5} < 2.3 × 10^{-4} or power < minimum power	**(A1)**
	so not able to distinguish signal from noise	**(A1)**

166. 9702_s17_MS_41 Q: 3

	Answer	Marks
(a)(i)	signal consists of (a series of) 1s and 0s **or** offs and ons **or** highs and lows	**B1**
(a)(ii)	component X: parallel-to-serial converter	**B1**
	component Y: DAC/digital-to-analogue converter	**B1**
(a)(iii)	sample the (analogue) signal	**M1**
	at regular intervals and converts the analogue number to a digital number	**A1**
(b)(i)	attenuation in fibre = 84 × 0.19 (= 16 dB)	**C1**
	ratio = 16 + 28 = 44 dB	**A1**
(b)(ii)	ratio / dB = 10 lg (P_2 / P_1)	**C1**
	44 = 10 lg ({9.7 × 10^{-3}} / *P*) **or** –44 = 10 lg (*P* / {9.7 × 10^{-3}})	**C1**
	power = 3.9 × 10^{-7} W	**A1**

167. 9702_s17_MS_43 Q: 3

	Answer	Marks
(a)(i)	signal consists of (a series of) 1s and 0s **or** offs and ons **or** highs and lows	**B1**
(a)(ii)	component X: parallel-to-serial converter	**B1**
	component Y: DAC/digital-to-analogue converter	**B1**
(a)(iii)	sample the (analogue) signal	**M1**
	at regular intervals and converts the analogue number to a digital number	**A1**
(b)(i)	attenuation in fibre = 84 × 0.19 (= 16 dB)	**C1**
	ratio = 16 + 28 = 44 dB	**A1**
(b)(ii)	ratio / dB = 10 lg (P_2 / P_1)	**C1**
	44 = 10 lg ({9.7×10^{-3}} / P) **or** –44 = 10 lg (P / {9.7×10^{-3}})	**C1**
	power = 3.9×10^{-7} W	**A1**

168. 9702_w17_MS_41 Q: 4

	Answer	Marks
(a)	• acts as 'return' (conductor) for signal • shielding from noise/crosstalk/interference *Two sensible suggestions, 1 mark each.*	**B2**
(b)	• small bandwidth • (there is) noise/interference/crosstalk • large attenuation/energy loss • reflections due to poor impedance matching *Two sensible suggestions, 1 mark each.*	**B2**
(c)	attenuation = 190 × 14 × 10^{-3} (= 2.66 dB)	**C1**
	ratio/dB = (–)10 lg(P_2/P_1)	**C1**
	2.66 = –10 lg (P_{OUT} / P_{IN}) P_{OUT} / P_{IN} = 0.54	**C1**
	fractional loss = 1 – (P_{OUT} / P_{IN}) = 1 – 0.54 = 0.46	**A1**
	or	
	2.66 = 10 lg (P_{IN} / P_{OUT}) P_{IN} / P_{OUT} = 1.85	**(C1)**
	fractional loss = (P_{IN} – P_{OUT}) / P_{IN} = (1.85 – 1) / 1.85 = 0.46	**(A1)**

169. 9702_w17_MS_43 Q: 4

	Answer	Marks
(a)	• acts as 'return' (conductor) for signal • shielding from noise/crosstalk/interference *Two sensible suggestions, 1 mark each.*	B2
(b)	• small bandwidth • (there is) noise/interference/crosstalk • large attenuation/energy loss • reflections due to poor impedance matching *Two sensible suggestions, 1 mark each.*	B2
(c)	attenuation = 190 × 14 × 10^{-3} (= 2.66 dB)	C1
	ratio / dB = (–)10 lg(P_2 / P_1)	C1
	2.66 = –10 lg (P_{OUT} / P_{IN}) P_{OUT} / P_{IN} = 0.54	C1
	fractional loss = 1 – (P_{OUT} / P_{IN}) = 1 – 0.54 = 0.46	A1
	or	
	2.66 = 10 lg (P_{IN} / P_{OUT}) P_{IN} / P_{OUT} = 1.85	(C1)
	fractional loss = (P_{IN} – P_{OUT}) / P_{IN} = (1.85 – 1) / 1.85 = 0.46	(A1)

170. 9702_w16_MS_41 Q: 4

(a) **(i)** noise/distortion is removed (from the signal) B1
the (original) signal is reformed/reproduced/recovered/restored B1 [2]

or

signal detected above/below a threshold creates new signal (B1)
of 1s and 0s (B1)

(ii) noise is superposed on the (displacement of the) signal/cannot be distinguished
or
analogue/signal is continuous (so cannot be regenerated)
or
analogue/signal is not discrete (so cannot be regenerated) B1

noise is amplified with the signal B1 [2]

(b) (i) gain/dB = 10 lg (P_2 / P_1)

$32 = 10\lg[P_{MIN}/(0.38 \times 10^{-6})]$
or
$-32 = 10\lg(0.38 \times 10^{-6}/P_{MIN})$ C1

$P_{MIN} = 6.0 \times 10^{-4}$ W A1 [2]

(ii) attenuation $= 10\lg[(9.5 \times 10^{-3})/(6.02 \times 10^{-4})]$ C1

= 12 dB

attenuation per unit length (= 12/58) = 0.21 dB km^{-1} A1 [2]

171. 9702_w16_MS_43 Q: 4

(a) (i) noise/distortion is removed (from the signal) B1
the (original) signal is reformed/reproduced/recovered/restored B1 [2]

or

signal detected above/below a threshold creates new signal (B1)
of 1s and 0s (B1)

(ii) noise is superposed on the (displacement of the) signal/cannot be distinguished
or
analogue/signal is continuous (so cannot be regenerated)
or
analogue/signal is not discrete (so cannot be regenerated) B1

noise is amplified with the signal B1 [2]

(b) (i) gain/dB = 10 lg (P_2 / P_1)

32 = 10 lg [P_{MIN} / (0.38 × 10^{-6})]
or
–32 = 10 lg (0.38 × 10^{-6} / P_{MIN}) C1

P_{MIN} = 6.0 × 10^{-4} W A1 [2]

(ii) attenuation = 10 lg [(9.5 × 10^{-3}) / (6.02 × 10^{-4})] C1

= 12 dB

attenuation per unit length (= 12/58) = 0.21 dB km^{-1} A1 [2]

172. 9702_s17_MS_41 Q: 5

	Answer	Marks
(a)	(loss in) kinetic energy of α-particle = $Qq / 4\pi\varepsilon_0 r$ **or** 7.7 × 10^{-13} = $Qq / 4\pi\varepsilon_0 r$	**C1**
	7.7 × 10^{-13} = 8.99 × 10^9 × 79 × 2 × (1.60 × 10^{-19})^2 / r	**M1**
	r = 4.7 × 10^{-14} m r is closest distance of approach so radius less than this	**A1**
(b)	force = $Qq / 4\pi\varepsilon_0 r^2$ = 4u × a	**C1**
	8.99 × 10^9 × 79 × 2 × (1.60 × 10^{-19})^2 / (4.7 × 10^{-14})^2 = 4 × 1.66 × 10^{-27} × a	**C1**
	a = 2.5 × 10^{27} m s^{-2}	**A1**
(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	**B1**

173. 9702_s20_MS_41 Q: 5

	Answer	Marks
(a)	similarity: both are radial **or** both have inverse square (variations)	**B1**
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	**B1**
(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	**C1**
	$E = Q / 36\pi\varepsilon_0 R^2$	**A1**
(c)(i)	fields (due to each sphere) are in same direction	**B1**
(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	**B1**
	spheres are not point charges (at their centres)	**B1**

174. 9702_s20_MS_42 Q: 7

	Answer	Marks
(a)	force per unit charge	M1
	(force on) positive charge	A1
(b)(i)	no electric field inside a conductor	B1
	$R = 4.5$ cm	A1
(b)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	clear correct read-off of a pair of values of E and x	C1
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ $= 4.0 \times 10^{-7}$ C **or** 4.1×10^{-7} C	A1
(c)	At 8.0 cm, $E = 5.75 \times 10^5$ V m^{-1}	C1
	$F = Eq$ **and** $a = F / m$	C1
	$F = (5.75 \times 10^5 \times 2 \times 1.6 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ $= 2.8 \times 10^{13}$ m s^{-2}	A1

175. 9702_s20_MS_43 Q: 5

	Answer	Marks
(a)	similarity: both are radial **or** both have inverse square (variations)	B1
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	B1
(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	C1
	$E = Q / 36\pi\varepsilon_0 R^2$	A1
(c)(i)	fields (due to each sphere) are in same direction	B1
(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	B1
	spheres are not point charges (at their centres)	B1

176. 9702_m19_MS_42 Q: 5

	Answer	Marks
(a)	region where charge experiences an (electric) force	B1
(b)	graph: field strength zero from $x = 0$ to $x = R$	B1
	curve with negative gradient, decreasing from $x = R$ to $x = 3R$	B1
	line passes through field strength E at $x = R$,	B1
	line passes through field strength $0.25E$ at $x = 2R$ <u>and</u> field strength $0.11E$ at $x = 3R$	B1

	Answer	Marks
(c)	field strength = $q / 4\pi\epsilon_0 x^2$	C1
	$2.0 \times 10^6 = q / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.26^2)$	C1
	$q = 1.5 \times 10^{-5}$ C	A1

177. 9702_s19_MS_41 Q: 5

	Answer	Marks
(a)	force per unit charge	B1
	(force on) positive charge	B1
(b)(i)	field changes <u>direction</u> (between A and B)/field is zero at a point (between A and B)	M1
	so charges have same sign	A1
(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	B1
(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	at x = 10 cm, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	A1

178. 9702_s19_MS_43 Q: 5

	Answer	Marks
(a)	force per unit charge	B1
	(force on) positive charge	B1
(b)(i)	field changes <u>direction</u> (between A and B)/field is zero at a point (between A and B)	M1
	so charges have same sign	A1
(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	B1
(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	at x = 10 cm, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	A1

179. 9702_w19_MS_41 Q: 6

	Answer	Marks
(a)	(E =) $Q / 4\pi\varepsilon_0 r^2$	M1
	where ε_0 is permittivity (of free space)	A1
(b)(i)	field does not change direction/field does not become zero	M1
	so (charges have) opposite (sign)	A1
(b)(ii)	minimum is at the midpoint (between the charges)	M1
	so (magnitudes are the) same	A1
(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	B1
	(from x = 3.0 cm) to x = 5.0 cm: acceleration decreases	B1
	at x = 5.0 cm: acceleration is a minimum	B1
	from x = 5.0 cm (to x = 7.0 cm): acceleration increases	B1

180. 9702_w19_MS_43 Q: 6

	Answer	Marks
(a)	(E =) $Q / 4\pi\varepsilon_0 r^2$	M1
	where ε_0 is permittivity (of free space)	A1
(b)(i)	field does not change direction/field does not become zero	M1
	so (charges have) opposite (sign)	A1
(b)(ii)	minimum is at the midpoint (between the charges)	M1
	so (magnitudes are the) same	A1
(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	B1
	(from x = 3.0 cm) to x = 5.0 cm: acceleration decreases	B1
	at x = 5.0 cm: acceleration is a minimum	B1
	from x = 5.0 cm (to x = 7.0 cm): acceleration increases	B1

181. 9702_s18_MS_41 Q: 6

	Answer	Marks
(a)	force per unit charge	B1
(b)	$E = Q / (4\pi\varepsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	A1
(c)	charge (= $Q\,[52/26]^2$) = 4Q	C1
	additional charge = 3Q	A1

182. 9702_s18_MS_43 Q: 6

	Answer	Marks
(a)	force per unit charge	B1
(b)	$E = Q / (4\pi\varepsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge $= 1.5 \times 10^{-7}$ C	A1
(c)	charge ($= Q\,[52/26]^2$) $= 4Q$	C1
	additional charge = 3Q	A1

183. 9702_m17_MS_42 Q: 6

	Answer	Marks
(a)	similarity: lines are radial / greater separation of lines with increased distance from the sphere	B1
	difference: gravitational lines directed towards sphere and electric lines directed away from sphere	B1
(b)(i)	$E = Q / 4\pi\varepsilon_0 r^2$ or $E = kQ / r^2$ with k defined / substituted in	C1
	$4.1 \times 10^{-5} = [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.025^2)] - [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.075^2)]$	C1
	$Q = 3.2 \times 10^{-18}$ C	A1
(b)(ii)	smooth curve with gradient decreasing starting at $(0, 4.1 \times 10^{-5})$ to d-axis at (2.5, 0)	B1
	smooth curve with gradient increasing from (2.5, 0) ending at $(5, -4.1 \times 10^{-5})$	B1
(b)(iii)	acceleration decreases (to zero at mid-point)	B1
	then acceleration increases in the opposite direction / increasing negative acceleration	B1

184. 9702_s19_MS_42 Q: 6

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)	straight line with non-zero gradient from $x = 0$ to $x = d$	B1
	line with gradient of constant sign and end-points between which $\Delta V = V_0$ and $\Delta x = d$	B1
	line passes through (d, 0) and (0, $+V_0$) with negative gradient throughout	B1
(c)	V constant (and non-zero) from $0 \to R$ and from $(D - R) \to D$	B1
	equal (non-zero) values of (magnitude of) V at R and $(D - R)$.	B1
	curve (with a minimum) from R to $(D - R)$ with V always positive	B1
	minimum at mid-point of curve	B1

185. 9702_w19_MS_42 Q: 9

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)(i)	energy $= 4.8 \times 1.60 \times 10^{-13}$ $= 7.7 \times 10^{-13}$ J	A1
(b)(ii)	$E_P = Qq / 4\pi\varepsilon_0 d$	C1
	$Q = 79e$ **and** $q = 2e$	C1
	$7.68 \times 10^{-13} = (79 \times 2 \times \{1.60 \times 10^{-19}\}^2 / (4\pi \times 8.85 \times 10^{-12} \times d)$	C1
	$d = 4.7 \times 10^{-14}$ m	A1
(c)	(diameter must be) less than/equal to 10^{-13} or 10^{-14} m	B1

186. 9702_m18_MS_42 Q: 7

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity (to the point)	B1
(b)(i)	potential always same sign / potential is always positive so same sign of charge	B1

	Answer	Marks
(b)(ii)	1 *from x = 12 cm to x = 25 cm:* speed increases and *from x = 27 cm to x = 31 cm*: speed decreases	B1
	(*from x = 12 cm to x = 25 cm:* speed increases) at decreasing rate or (*from x = 27 cm to x = 31 cm*: speed decreases) at increasing rate	B1
	at x = 26 cm: speed maximum	B1
	at 32 cm: speed still decreasing	B1
	2 $q\,\Delta V = ½mv^2$ $3.2 \times 10^{-19} \times (2.14 - 1.43) \times 10^4 = ½ \times 6.6 \times 10^{-27} \times v^2$ $v^2 = 6.88 \times 10^{11}$	C1
	$v =$ **8.3** $\times$ **10**^{5} m s^{-1} (8.30)	A1

187. 9702_w18_MS_41 Q: 6

	Answer	Marks
(b)(ii)	(at x = 0.40 cm), potential $= (–)\ 75 \times 0.40 / 1.2$ (= (–) 25 V)	C1
	$½mv^2 = qV$ $½ \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	C1
	or	
	$a = Vq / dm$ **and** $v^2 = 2as$	(C1)
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	(C1)
	$v = 4.9 \times 10^4$ m s^{-1}	A1

188. 9702_w18_MS_42 Q: 6

	Answer	Marks
(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
(a)(ii)	field strength = potential gradient	**M1**
	negative sign included **or** directions discussed	**A1**
(b)	horizontal straight lines, at non-zero potential, within the spheres	**B1**
	magnitude of potential greater at surface of sphere A than at surface of sphere B	**B1**
	concave curve between A and B, with a minimum nearer to B	**B1**
	lines show *V* positive all the way from 0 to *D*	**B1**

189. 9702_w18_MS_43 Q: 6

	Answer	Marks
(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
(a)(ii)	field strength = potential gradient	**M1**
	'–' sign included **or** directions discussed	**A1**
(b)(i)	gain in kinetic energy (= loss in potential energy) = charge × p.d. **or** $qV = ½mv^2$	**M1**
	so *v* is independent of separation (because separation not in expressions)	**A1**

	Answer	Marks
(b)(ii)	(at $x = 0.40$ cm), potential $= (–)\ 75 \times 0.40 / 1.2$ $(= (–)\ 25\text{ V})$	C1
	$½mv^2 = qV$ $½ \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	C1
	or	
	$a = Vq / dm$ **and** $v^2 = 2as$	(C1)
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	(C1)
	$v = 4.9 \times 10^4\text{ m s}^{-1}$	A1

190. 9702_s17_MS_42 Q: 6

	Answer	Marks
(a)	force proportional to product of charges and inversely proportional to the square of the separation	M1
	reference to point charges	A1
(b)(i)	(near to each sphere,) fields are in opposite directions **or** point (between spheres) where fields are equal and opposite **or** point (between spheres) where field strength is zero	M1
	so same (sign of charge)	A1
(b)(ii)	(at $x = 5.0$ cm,) $E = 3.0 \times 10^3\text{ V m}^{-1}$ **and** $a = qE / m$	C1
	$E = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$	C1
	$= 2.9 \times 10^{11}\text{ m s}^{-2}$	A1
(c)	field strength or E is potential gradient **or** field strength is rate of change of (electric) potential	M1
	(field strength) maximum at $x = 6$ cm	A1

191. 9702_s17_MS_43 Q: 5

	Answer	Marks
(a)	(loss in) kinetic energy of α-particle $= Qq / 4\pi\varepsilon_0 r$ **or** $7.7 \times 10^{-13} = Qq / 4\pi\varepsilon_0 r$	C1
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	M1
	$r = 4.7 \times 10^{-14}$ m r is closest distance of approach so radius less than this	A1
(b)	force $= Qq / 4\pi\varepsilon_0 r^2 = 4\text{u} \times a$	C1
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	C1
	$a = 2.5 \times 10^{27}\text{ m s}^{-2}$	A1
(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	B1

192. 9702_w17_MS_42 Q: 6

	Answer	Marks
(a)	electric field lines are radial/normal to surface (of sphere)	B1
	electric field lines <u>appear</u> to originate from centre (of sphere)	B1
(b)(i)	tangent drawn at x = 6.0 cm and gradient calculation attempted	C1
	$E = 9.0 \times 10^4$ N C^{-1} (*1 mark if in range ±1.2; 2 marks if in range ±0.6*)	A2
	or	
	correct pair of values of V and x read from curved part of graph and substituted into $V = q / 4\pi\varepsilon_0 x$	(C1)
	to give $q = 3.6 \times 10^{-8}$ C	(C1)
	(then $E = q / 4\pi\varepsilon_0 x^2$ and x = 6 cm gives) $E = 9.0 \times 10^4$ N C^{-1}	(A1)
	or	
	($E = q / 4\pi\varepsilon_0 x^2$ and $V = q / 4\pi\varepsilon_0 x$ and so) $E = V / x$	(C1)
	giving $E = 5.4 \times 10^3 / 0.060$	(C1)
	$= 9.0 \times 10^4$ N C^{-1}	(A1)
(b)(ii)	(R =) 2.5 cm	B1
	potential inside a conductor is constant **or** field strength inside a conductor zero (so gradient is zero)	B1

193. 9702_w16_MS_41 Q: 5

(a)	in an electric field, charges (in a conductor) would move	B1	
	no movement of charge so zero field strength *or* charge moves until $F = 0$ / $E = 0$	B1	[2]
	or		
	charges in metal do not move no (resultant) force on charges so no (electric) field	(B1) (B1)	
(b)	at P, $E_A = (3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2]$ (= 10.79 N C^{-1})	M1	
	at P, $E_B = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$ (= 10.79 N C^{-1})	M1	
	or		
	$(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$ *or* $(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$	(M2)	
	fields due to charged spheres are (equal and) opposite in direction, so $E = 0$	A1	[3]
(c)	potential $= 8.99 \times 10^9 \{(3.0 \times 10^{-12}) / (5.0 \times 10^{-2}) + (12 \times 10^{-12}) / (10 \times 10^{-2})\}$	C1	
	$= 1.62$ V	A1	[2]
(d)	$\frac{1}{2}mv^2 = qV$		
	$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$	C1	
	$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$	C1	
	$v^2 = 1.37 \times 10^8$		
	$v = 1.2 \times 10^4$ m s^{-1}	A1	[3]

194. 9702_w16_MS_42 Q: 6

(a)	$E = 0$ *or* $E_A = (-)E_B$ (at $x = 11$ cm)	B1	
	$Q_A / x^2 = Q_B / (20 - x)^2 = 11^2 / 9^2$	C1	
	Q_A / Q_B or ratio = 1.5	A1	[3]
	or		
	$E \propto Q$ because r same *or* $E = Q / 4\pi\varepsilon_0 r^2$ and r same	(B1)	
	$Q_A / Q_B = 48 / 32$	(C1)	
	Q_A / Q_B or ratio = 1.5	(A1)	

(b) **(i)** for max. speed, $\Delta V = (0.76 - 0.18)$ V or $\Delta V = 0.58$ V — C1

$q\Delta V = ½mv^2$

$2 \times (1.60 \times 10^{-19}) \times 0.58 = ½ \times 4 \times 1.66 \times 10^{-27} \times v^2$ — C1

$v^2 = 5.59 \times 10^7$

$v = 7.5 \times 10^3\,\text{m s}^{-1}$ — A1 [3]

(ii) $\Delta V = 0.22$ V — C1

$2 \times (1.60 \times 10^{-19}) \times 0.22 = ½ \times 4 \times 1.66 \times 10^{-27} \times v^2$

$v^2 = 2.12 \times 10^7$

$v = 4.6 \times 10^3\,\text{m s}^{-1}$ — A1 [2]

195. 9702_w16_MS_43 Q: 5

(a) in an electric field, charges (in a conductor) would move — B1

no movement of charge so zero field strength
or
charge moves until $F = 0$ / $E = 0$ — B1 [2]

or

charges in metal do not move — (B1)
no (resultant) force on charges so no (electric) field — (B1)

(b) at P, $E_A = (3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2]$ ($= 10.79\,\text{N C}^{-1}$) — M1

at P, $E_B = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$ ($= 10.79\,\text{N C}^{-1}$) — M1

or

$(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$
or
$(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$ — (M2)

fields due to charged spheres are (equal and) opposite in direction, so $E = 0$ — A1 [3]

(c) potential $= 8.99 \times 10^9 \{(3.0 \times 10^{-12}) / (5.0 \times 10^{-2}) + (12 \times 10^{-12}) / (10 \times 10^{-2})\}$ — C1

$= 1.62$ V — A1 [2]

(d) $½mv^2 = qV$

$E_K = ½ \times 107 \times 1.66 \times 10^{-27} \times v^2$ — C1

$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ — C1

$v^2 = 1.37 \times 10^8$

$v = 1.2 \times 10^4\,\text{m s}^{-1}$ — A1 [3]

196. 9702_m21_MS_42 Q: 6

	Answer	Marks
(a)	(both have) radial field lines	B1
(b)(i)	**2.1** cm	B1
(b)(ii)	$E = \frac{Q}{4\pi\varepsilon_o r^2}$ e.g. r = 2.1 cm, E = 1.30 × 10^5 V m^{-1} $Q = 4\pi\varepsilon_o r^2 E$ $= 4 \times \pi \times 8.85 \times 10^{-12} \times 0.021^2 \times 1.30 \times 10^5$	C1
	$= 6.4 \times 10^{-9} C$	A1

	Answer	Marks
(c)	$C = \frac{Q}{V}$ *either* $V = \frac{Q}{4\pi\varepsilon_o r}$ leading to $C = 4\pi\varepsilon_o r$	C1
	$C = 4 \times \pi \times 8.85 \times 10^{-12} \times 0.021$	C1
	$(C =) 2.3 \times 10^{-12}$ F	A1
	or $V = \frac{Q}{4\pi\varepsilon_o r}$ $= \frac{6.4 \times 10^{-9}}{4 \times \pi \times 8.85 \times 10^{-12} \times 0.021}$ $= 2740 V$ $C = \frac{6.4 \times 10^{-9}}{2740}$	(C1)
	$= 2.3 \times 10^{-12}$F	(A1)

197. 9702_s21_MS_41 Q: 7

	Answer	Marks
(a)	charge / potential	M1
	charge is on one plate, potential is p.d. between the plates	A1
(b)(i)	$I = Q / t$	M1
	charge = CV <u>and</u> time = 1 / f leading to $I = fCV$	A1
(b)(ii)	4.8 × 10^{-6} = 150 × 60 × C	C1
	C = 530 pF	A1
(c)	(total) capacitance is halved	B1
	charge (for each cycle/discharge) is halved **or** since f and V are constant, current is proportional to capacitance	B1
	current = 2.4 μA	B1

198. 9702_s21_MS_42 Q: 6

	Answer	Marks
(a)	potential difference applied between the plates	M1
	causes charge separation (between the plates) **or** causes energy to be stored (between the plates)	A1
(b)(i)	$I = Q / t$	M1
	clear substitution of $Q = CV$ and $f = 1 / t$, leading to $I = fCV$	A1
(b)(ii)	$2.5 \times 10^{-6} = 50 \times C \times 180$	C1
	$C = 280$ pF	A1
(c)	(total) capacitance increases	B1
	greater charge (for each cycle/discharge) so greater (average) current **or** V and f are constant so (average) current increases **or** I is (directly) proportional to C so (average) current increases	B1

199. 9702_s21_MS_43 Q: 7

	Answer	Marks
(a)	charge / potential	M1
	charge is on one plate, potential is p.d. between the plates	A1
(b)(i)	$I = Q / t$	M1
	charge = CV <u>and</u> time = $1 / f$ leading to $I = fCV$	A1
(b)(ii)	$4.8 \times 10^{-6} = 150 \times 60 \times C$	C1
	$C = 530$ pF	A1
(c)	(total) capacitance is halved	B1
	charge (for each cycle/discharge) is halved **or** since f and V are constant, current is proportional to capacitance	B1
	current = 2.4 μA	B1

200. 9702_w21_MS_42 Q: 6

	Answer	Marks
(a)	work done per unit charge	B1
	(work done in) moving positive charge from infinity	B1
(b)	$C = Q / V$	C1
	$V = Q / (4\pi\varepsilon_0 r)$ and so $C = Q / [Q / (4\pi\varepsilon_0 r)] = 4\pi\varepsilon_0 r$	A1
(c)	$Q = 4\pi\varepsilon_0 rV \quad = 4\pi \times 8.85 \times 10^{-12} \times 0.13 \times 4500$ $(= 6.5 \times 10^{-8}$ C)	C1
	$(Q - q) / 13 = q / 5.2$	C1
	$5.2Q - 5.2q = 13q$, so $q = (5.2 / 18.2)Q$ $q \quad = (5.2 / 18.2) \times 6.5 \times 10^{-8}$ $= 1.9 \times 10^{-8}$ C	A1
	or	
	$V_T = Q_T / C_T$ $= 6.5 \times 10^{-8} / [4\pi \times 8.85 \times 10^{-12} \times (0.13 + 0.052)]$ (= 3210 V)	(C1)
	$q \quad = 4\pi \times 8.85 \times 10^{-12} \times 0.052 \times 3210$ $= 1.9 \times 10^{-8}$ C	(A1)

201. 9702_m20_MS_42 Q: 6

	Answer	Marks
(a)	**2.0** cm	B1
(b)	At 16 (cm) from A the electric fields are equal or $E_A = E_B$	B1
	$E = Q / 4\pi\varepsilon_o r^2$ $Q_A / (4\pi\varepsilon_o r_A^2) = Q_B / (4\pi\varepsilon_o r_B^2)$ $3.6 \times 10^{-9} / 0.16^2 = Q_B / 0.08^2$	C1
	Q_B = **9.0 × 10^{-10}** C	A1
(c)(i)	$V = Q / 4\pi\varepsilon_o r_A$ $V = 3.6 \times 10^{-9} / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.020)$	C1
	V = **1600** V	A1
(c)(ii)	$C = Q / V$ $= 3.6 \times 10^{-9} / 1600$	C1
	= **2.3 × 10^{-12}** F	A1

202. 9702_s19_MS_41 Q: 6

	Answer	Marks
(a)	Any valid two points e.g.: • to store (electrical) energy • smoothing/reduce ripple (on direct voltages/currents) • to block d.c. • timing/time delay (circuits) • in oscillator (circuits) • in tuning (circuits) • to prevent arcing/sparks	B2
(b)	clear indication of equal charge on each capacitor	B1
	$E = V_1 + V_2 + V_3$ **and** $V = Q / C$	M1
	completion of algebra leading to $1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3$	A1
(c)(i)	three capacitors connected in parallel	B1
(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	B1

203. 9702_s19_MS_43 Q: 6

	Answer	Marks
(a)	Any valid two points e.g.: • to store (electrical) energy • smoothing/reduce ripple (on direct voltages/currents) • to block d.c. • timing/time delay (circuits) • in oscillator (circuits) • in tuning (circuits) • to prevent arcing/sparks	B2
(b)	clear indication of equal charge on each capacitor	B1
	$E = V_1 + V_2 + V_3$ **and** $V = Q / C$	M1
	completion of algebra leading to $1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3$	A1
(c)(i)	three capacitors connected in parallel	B1
(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	B1

204. 9702_s18_MS_41 Q: 7

	Answer	Marks
(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
(b)(i)	4.5×10^{-6} C	A1
(b)(ii)	9.0×10^{-8} C	A1
(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	C1
	$= 7.5 \times 10^{-10}$ F	A1
(c)	total capacitance is halved	B1
	current is halved	B1

205. 9702_s18_MS_43 Q: 7

	Answer	Marks
(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
(b)(i)	4.5×10^{-6} C	A1
(b)(ii)	9.0×10^{-8} C	A1
(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	C1
	$= 7.5 \times 10^{-10}$ F	A1
(c)	total capacitance is halved	B1
	current is halved	B1

206. 9702_w17_MS_41 Q: 6

	Answer	Marks
(a)(i)	$1 / T = 1 / (2C) + 1 / C$	C1
	$T = ⅔C$ **or** $0.67C$	A1
(a)(ii)	same charge on Q as on combination	B1
	so p.d. is 6.0 V	B1
(b)	P: p.d. will decrease (from 3.0 V)	B1
	to zero	B1
	Q: p.d. will increase (from 6.0 V)	B1
	to 9.0 V	B1

207. 9702_w17_MS_43 Q: 6

	Answer	Marks
(a)(i)	$1 / T = 1 / (2C) + 1 / C$	C1
	$T = ⅔C$ **or** $0.67C$	A1
(a)(ii)	same charge on Q as on combination	B1
	so p.d. is 6.0 V	B1
(b)	P: p.d. will decrease (from 3.0 V)	B1
	to zero	B1
	Q: p.d. will increase (from 6.0 V)	B1
	to 9.0 V	B1

208. 9702_w16_MS_42 Q: 7

(a) (i) charge / potential (difference) or charge per (unit) potential (difference) B1 [1]

(ii) ($V = Q/4\pi\varepsilon_0 r$ and $C = Q/V$)

for sphere, C (= Q/V) = $4\pi\varepsilon_0 r$ C1

$C = 4\pi \times 8.85 \times 10^{-12} \times 12.5 \times 10^{-2} = 1.4 \times 10^{-11}$ F A1 [2]

(b) (i) $1/C_T = 1/3.0 + 1/6.0$

$C_T = 2.0\,\mu$F A1 [1]

(ii) total charge = charge on 3.0 μF capacitor = 2.0 (μ) × 9.0 = 18 (μC) C1

potential difference = Q/C = 18 (μ)C / 3.0 (μ)F = 6.0 V A1 [2]

or

argument based on equal charges:

$3.0 \times V = 6.0 \times (9.0 - V)$ (C1)

$V = 6.0$ V (A1)

(iii) potential difference (= 9.0 – 6.0) = 3.0 V C1

charge (= 3.0 × 2.0 (μ)) = 6.0 μC A1 [2]

209. 9702_w21_MS_41 Q: 6

	Answer	Marks
(a)	$Q = CV$ **and** $E = ½CV^2$	**B1**
(b)(i)	$C_N = CL/(L - D)$	**B1**
(b)(ii)	(charge is unchanged by moving the plates so) $Q_N = CV$	**B1**
(b)(iii)	$V_N = Q_N / C_N$ $= (CV) / [CL / (L - D)]$ $= V(L - D) / L$	**B1**
(c)	oppositely charged plates attract, so energy stored decreases	**B1**

210. 9702_w21_MS_43 Q: 6

	Answer	Marks
(a)	$Q = CV$ **and** $E = ½CV^2$	**B1**
(b)(i)	$C_N = CL/(L - D)$	**B1**
(b)(ii)	(charge is unchanged by moving the plates so) $Q_N = CV$	**B1**
(b)(iii)	$V_N = Q_N / C_N$ $= (CV) / [CL / (L - D)]$ $= V(L - D) / L$	**B1**
(c)	oppositely charged plates attract, so energy stored decreases	**B1**

211. 9702_m19_MS_42 Q: 6

	Answer	Marks
(a)	charge / potential (difference)	M1
	charge on one plate, p.d. between the plates	A1
(b)(i)	all three capacitors connected in series	B1
(b)(ii)	8 (μF) in parallel with the two 4 (μF) capacitors connected in series	B1
(c)	discharge from 7.0 V to 4.0 V	C1
	Either energy = $\frac{1}{2}CV^2$ *or* energy = ½ QV and $C = Q / V$	C1
	energy = ½ × 47 × 10^{-6} × ($7^2 - 4^2$) = 7.8 × 10^{-4} J	A1

212. 9702_s18_MS_42 Q: 6

	Answer	Marks
(a)	capacitance = charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
(b)(i)	two in series, in parallel with the other (correct symbols)	A1
(b)(ii)	two in parallel connected to one in series (correct symbols)	A1
(c)(i)	capacitance = 1.2 μF	A1
(c)(ii)	**1.** $Q = CV$	C1
	= 1.2 × 8.0 = 9.6 μC	A1
	2. $E = \frac{1}{2}QV$ **and** $V = Q/C$ **or** $E = \frac{1}{2}CV^2$ **and** $V = Q/C$ **or** $E = \frac{1}{2}Q^2/C$	C1
	E = ½ (9.6 × 10^{-6})^2 / (3.0 × 10^{-6}) = 1.5 × 10^{-5} J	A1

213. 9702_s17_MS_42 Q: 7

	Answer	Marks
(a)	equal and opposite charges on the plates so no resultant charge	B1
	+ve and –ve charges separated so energy stored	B1
(b)	charge / potential difference	M1
	reference to charge on one plate and p.d. between plates	A1
(c)	energy = ½ CV^2 **or** energy = ½ QV **and** $C = Q / V$	C1
	(1 / 16) × ½ CV_0^2 = ½ CV^2 V = ¼ V_0	A1

214. 9702_m16_MS_42 Q: 7

(a) (capacitance =) charge / potential (difference) B1 [1]

(b) $V = V_1 + V_2 + V_3$ B1
either $Q/C = Q/C_1 + Q/C_2 + Q/C_3$ *or* $V/Q = V_1/Q + V_2/Q + V_3/Q$
and so $1/C = 1/C_1 + 1/C_2 + 1/C_3$ B1 [2]

(c) (i) 1. $1/C_T = (1/200) + (1/600)$
$C_T = 150\ \mu F$ A1 [1]

2. $Q = CV$
$= 150 \times 10^{-6} \times 12$ *or* $600 \times 10^{-6} \times 3.0$ *or* $200 \times 10^{-6} \times 9.0$
$= 1.8 \times 10^{-3}$ C A1 [1]

3. $V = Q/C = 1.8 \times 10^{-3} / 600 \times 10^{-6}$ *or* $V = [200/(200 + 600)] \times 12$
$= 3(.0)$ V A1 [1]

(ii) energy = $\frac{1}{2}CV^2$ or energy = $\frac{1}{2}QV$ and $C = Q/V$ C1
$\frac{1}{2} \times C \times 3^2 = 2 \times \frac{1}{2} \times C \times V^2$ C1
$V = 2.1$ V A1 [3]

215. 9702_m20_MS_42 Q: 7

	Answer	Marks
(a)	axes labelled with resistance and temperature	**M0**
	concave curve not touching temperature axis	**A1**
	line with negative gradient throughout	**A1**
(b)	resistance of thermistor decreases	**B1**
	total circuit resistance decreases so voltmeter reading increases *or* current increases so voltmeter reading increases *or* greater proportion of resistance in fixed resistor so voltmeter reading increases *or* p.d. across thermistor decreases so voltmeter reading increases	**B1**
(c)	(0.020 strain means) $\Delta R / R = 0.090$	**C1**
	$\Delta R = 0.090 \times 120 = 10.8\ \Omega$	**C1**
	resistance = 120 + 10.8 = **130 Ω**	**A1**

216. 9702_s19_MS_42 Q: 7

	Answer	Marks
(a)	Any five from: • (as temperature rises) energy of electrons increases • electrons (have enough energy to) cross forbidden band • electrons enter conduction band • leaving holes in valence band • both holes and electrons act as charge carriers • more charge carriers results in lower resistance • increased lattice vibrations outweighed by increase in (number of) charge carriers	B5
(b)	(at 10 °C resistance is) 2.55 kΩ	C1
	new potential difference = 9.00 × 2.55 / (2.55 + 12.0) = 1.58 V	C1
	change in p.d. = 0.58 V	A1
(c)	change of resistance with temperature is not linear	B1
	change in potential with resistance is not linear **or** potential divider equation is non-linear	B1

217. 9702_m17_MS_42 Q: 7

	Answer	Marks
(a)	correct grid shape (of wire)	B1
	fine wire / foil strip	B1
	plastic / insulating envelope containing the wire	B1
(b)(i)	2.00 / 6.00 = 153.0 / (R + 153.0) *or* 4.00 / 6.00 = R / (R + 153.0) (so R = 306.0)	C1
	ΔR = 306.0 – 300.0 = 6.0 (Ω)	C1
	so ΔL = 8(.0) × 10^{-5} m	A1

	Answer	Marks
(b)(ii)	R or ΔR increases	B1
	$V^+ < V^-$ or $V_A < 2.00$ or V^+ / V_A decreases	M1
	output is negative / –5 V	A1
	diode X emits light / is 'on'	A1

218. 9702_s21_MS_42 Q: 7

	Answer	Marks
(a)(i)	no current enters/leaves the input	B1
(a)(ii)	gain is the same for all frequencies	B1
(b)(i)	V_{IN} = 1.5 × 400 / (400 + 1100) = 0.40 V **or** V_{IN} = 1.5 – (1.5 × 1100 / 1500) = 0.40 V **or** (1.5 – V_{IN}) / 1100 = V_{IN} / 400 so V_{IN} = 0.40 V	A1
(b)(ii)	gain = (–) R_f / R_i	C1
	V_{OUT} / 0.40 = (360 + 100) / 96	C1
	V_{OUT} = 1.9 V	A1
(b)(iii)	resistance <u>of thermistor</u> decreases	B1
	(magnitude of) gain decreases so reading decreases	B1
(b)(iv)	(at gain 12.5) V_{OUT} is 5.0 V, so (above gain 12.5) output becomes saturated	B1

219. 9702_w21_MS_42 Q: 7

	Answer	Marks
(a)	output voltage / input voltage	M1
	input (voltage) is difference between (inverting and non-inverting) inputs	A1
(b)	• reduces the gain • greater bandwidth • more stable *Any two points, 1 mark each*	B2
(c)(i)	inverting amplifier	B1
(c)(ii)	X marked anywhere between right-hand edge of 480 Ω resistor, left-hand edge of 1.2 kΩ resistor and the inverting input	B1
(c)(iii)	gain = (–)R_f / R_i	C1
	= (–)1200 / 480 = –2.5	A1
(c)(iv)	V_{IN} = 6.5 / (–2.5) = –2.6 V	A1
(c)(v)	(–2.5) × (–5.4) = +13.5 V, and so output saturates V_{OUT} = (+)8.0 V	A1

220. 9702_w21_MS_43 Q: 7

	Answer	Marks
(a)	• infinite (open-loop) gain • infinite slew rate • infinite input impedance • zero output impedance • infinite bandwidth *Any two points, 1 mark each*	B2
(b)	X: thermistor **and** Y: relay	B1
(c)(i)	(any) difference in voltage at the inputs causes output to saturate (because gain is very large)	B1
	saturates positively if $V^+ > V^-$ and saturates negatively if $V^+ < V^-$	B1
(c)(ii)	comparator	B1
(c)(iii)	temperature	M1
	above a particular value	A1
(c)(iv)	to adjust the temperature (at which the lamp illuminates/extinguishes)	B1

221. 9702_s20_MS_42 Q: 8

	Answer	Marks
(a)(i)	constant gain for all frequencies	B1
(a)(ii)	unchanged	B1
(b)(i)	(open loop) gain of op-amp is infinite	B1
	feedback loop ensures $V^+ \approx V^-$ **or** any difference between V^+ and V^- results in saturated output	B1
	non-inverting input is 0 V so inverting input also at 0 V	B1
(b)(ii)	input = (40 × 1.5) / (40 + 110)	C1
	= 0.40 V	A1
(b)(iii)	gain = (–) (100 + 230) / 150 **or** feedback current = 0.40 / (150 × 10^3) (A)	C1
	p.d. = [(100 + 230) / 150] × 0.40 = 0.88 V	A1
(c)	(magnitude of) gain decreases	M1
	voltmeter reading decreases	A1

222. 9702_s20_MS_43 Q: 7

	Answer	Marks
(a)	output signal proportional to input signal	B1
	output signal has same sign/polarity as input signal	B1
(b)(i)	gain = V_{OUT} / V_{IN} = 2.6 / 0.084 = 31	A1
(b)(ii)	31 = 1 + (15 × 10^3) / R	C1
	R = 500 Ω	A1
(c)(i)	e.g. cathode-ray oscilloscope/CRO	B1
(c)(ii)	gain is reduced	B1
	(so) V_{OUT} is smaller	B1

223. 9702_m19_MS_42 Q: 7

	Answer	Marks
(a)(i)	output voltage / input voltage	B1
(a)(ii)	no time delay between input and output	B1
	clear reference to change(s) in input and / or output	B1
(b)(i)	V_{IN} only connected to non-inverting input	B1
	midpoint between R_1 and R_2 only connected to inverting input	B1

	Answer	Marks
(b)(ii)	gain = 1 + (R_1 / R_2) 25 = 1 + (12 × 10^3) / R_2	C1
	R_2 = 500 Ω	A1
(b)(iii)	V_{MAX} = 9/25 = 0.36 V	C1
	range is –0.36 V to + 0.36 V	A1

224. 9702_s19_MS_42 Q: 9

	Answer	Marks
(a)(i)	relay coil shown connected between diode and earth	B1
	switch shown connected across lamp	B1
(a)(ii)	Any one from: • (for diode to conduct) current flow is into output of op-amp • when earth is at higher potential diode is forward biased • diode blocks current when output positive • diode must conduct	M1
	so V_{OUT} is negative	A1
(b)(i)	strain gauge	B1
(b)(ii)	light-dependent resistor	B1

225. 9702_w18_MS_41 Q: 7

	Answer	Marks
(a)(i)	gain is constant	M1
	for all frequencies	A1
(a)(ii)	no time delay between input (voltage) and output (voltage)	B1
	clear reference to change(s) in input and/or output (voltages)	B1
(b)	diagram: V_{IN} connected to V^+ only	B1
	midpoint between resistors R_1 and R_2 connected to V^- only	B1
(c)(i)	–3.6 V	A1
(c)(ii)	(+)5.0 V	A1

226. 9702_w18_MS_43 Q: 7

	Answer	Marks
(a)(i)	gain is constant	M1
	for all frequencies	A1
(a)(ii)	no time delay between input (voltage) and output (voltage)	B1
	clear reference to change(s) in input and/or output (voltages)	B1
(b)	diagram: V_{IN} connected to V^+ only	B1
	midpoint between resistors R_1 and R_2 connected to V^- only	B1
(c)(i)	–3.6 V	A1
(c)(ii)	(+)5.0 V	A1

227. 9702_s17_MS_41 Q: 6

	Answer	Marks
(a)(i)	lamp needs 'high' power/'large' current/'large' voltage	B1
	op-amp can deliver only a small current/small voltage	B1
(a)(ii)	correct symbol for relay coil connected between output and earth	B1
	switch between mains supply and lamp	B1
(b)(i)	vary light intensity at which lamp is switched on/off	B1
(b)(ii)	so that relay operates for only one current/voltage direction **or** so that relay/lamp operates for either dark or light conditions	B1
(c)	when light level increases, LDR resistance decreases	B1
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	M1
	or	
	when light level decreases, LDR resistance increases	(B1)
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	(M1)
	lamp comes on as light level decreases **or** lamp goes off as light level increases	A1

228. 9702_s17_MS_43 Q: 6

	Answer	Marks
(a)(i)	lamp needs 'high' power/'large' current/'large' voltage	B1
	op-amp can deliver only a small current/small voltage	B1
(a)(ii)	correct symbol for relay coil connected between output and earth	B1
	switch between mains supply and lamp	B1
(b)(i)	vary light intensity at which lamp is switched on/off	B1
(b)(ii)	so that relay operates for only one current/voltage direction **or** so that relay/lamp operates for either dark or light conditions	B1
(c)	when light level increases, LDR resistance decreases	B1
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	M1
	or	
	when light level decreases, LDR resistance increases	(B1)
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	(M1)
	lamp comes on as light level decreases **or** lamp goes off as light level increases	A1

229. 9702_w17_MS_41 Q: 7

	Answer	Marks
(a)(i)	gain of amplifier is very large	B1
	V^+ is at earth (potential)	B1
	for amplifier not to saturate	M1
	difference between V^- and V^+ must be very small **or** V^- must be equal to V^+	A1
	or	
	if $V^- \neq V^+$ then feedback voltage	(M1)
	acts to reduce gap until $V^- = V^+$ when stable	(A1)
(a)(ii)	input impedance is infinite	B1
	(so) current in R_1 = current in R_2	B1
	$(V_{IN} - 0) / R_1 = (0 - V_{OUT}) / R_2$	B1
	(gain =) $V_{OUT} / V_{IN} = - R_2 / R_1$	B1
(b)	graph: correct inverted shape (straight diagonal line from (0,0) to a negative potential, then a horizontal line, then a straight diagonal line back to the t-axis at the point where V_{IN} = 0)	B1
	horizontal line at correct potential of (–)9.0 V	B1
	both ends of horizontal line occur at correct times (coinciding with when V_{IN} = 2.0 V)	B1

230. 9702_w17_MS_42 Q: 7

	Answer	Marks
(a)(i)	(part of) the output is combined with the input	**M1**
	reference to potential/voltage/signal	**A1**
(a)(ii)	• increased (operating) stability • increased bandwidth/range of frequencies over which gain is constant • less distortion (of output) *Any 2 points.*	**B2**
(b)(i)	**1.** gain $= 3.6/(48 \times 10^{-3})$	**C1**
	$= 75$	**A1**
	2. gain $= 1 + R_F / R$ $75 = 1 + (92.5 \times 10^3)/R$	**C1**
	$R = 1300\,\Omega$	**A1**
(b)(ii)	for 68 mV, gain × V_{IN} = 5.1 (V) **or** output voltage would be greater than the supply voltage	**M1**
	amplifier would saturate (at 5.0 V) **or** output voltage = 5.0 (V)	**A1**

231. 9702_w17_MS_43 Q: 7

	Answer	Marks
(a)(i)	gain of amplifier is very large	**B1**
	V^+ is at earth (potential)	**B1**
	for amplifier not to saturate	**M1**
	difference between V^- and V^+ must be very small **or** V^- must be equal to V^+	**A1**
	or	
	if $V^- \neq V^+$ then feedback voltage	**(M1)**
	acts to reduce gap until $V^- = V^+$ when stable	**(A1)**
(a)(ii)	input impedance is infinite	**B1**
	(so) current in R_1 = current in R_2	**B1**
	$(V_{IN} - 0) / R_1 = (0 - V_{OUT}) / R_2$	**B1**
	(gain =) $V_{OUT} / V_{IN} = - R_2 / R_1$	**B1**
(b)	graph: correct inverted shape (straight diagonal line from (0,0) to a negative potential, then a horizontal line, then a straight diagonal line back to the *t*-axis at the point where $V_{IN} = 0$)	**B1**
	horizontal line at correct potential of (–)9.0 V	**B1**
	both ends of horizontal line occur at correct times (coinciding with when V_{IN} = 2.0 V)	**B1**

232. 9702_m16_MS_42 Q: 8

(a) decreases gain — B1
increases bandwidth / decreases distortion / increases (operating) stability — B1 [2]

(b) (i) additional resistor connected between 7.2 kΩ resistor and earth — B1
V^- joined to lower end of 7.2 kΩ resistor <u>and</u> V^+ joined to V_{IN} — B1 [2]

(ii) either 5 = 1 + (7.2 / *R*) or 5 = 1 + (7200 / *R*) — C1
R = 1.8 kΩ — A1 [2]

(iii) horizontal line from (0, 8.0) to (1.8, 8.0) — B1
straight line from (1.8, 8.0) to (5.0, 0) — B1 [2]

(*allow a tolerance of ± ½ small square when marking the graph*)

233. 9702_w16_MS_42 Q: 8

(a) P shown between earth symbol and voltmeter — B1 [1]

(b) (i) gain = (50 × 10^3) / 100 = 500 — C1

V_{IN} (= 5.0 / 500) = 0.010 V — A1 [2]

(ii) V_{IN} (= 5.0 / 5.0) = 1.0 V — A1 [1]

(c) e.g. multi-range (volt)meter
c.r.o. sensitivity control
amplifier channel selector — B1 [1]

234. 9702_m21_MS_42 Q: 7

	Answer	Marks
(a)(i)	non-inverting (amplifier)	B1
(a)(ii)	gain $= \frac{R_f}{R} + 1$ gain $= \frac{3.6}{0.72} + 1 = 6.0$	B1
(a)(iii)	straight line from (0,0) to (*T* / 2, 3)	B1
	line from origin to 3.0 V then horizontal line at 3.0 V to *T*	B1
(a)(iv)	ldr / light dependent resistor replaces one of the two resistors	B1
(b)(i)	relay coil	B1
(b)(ii)	relay coil between op-amp and earth	B1
	diode with correct polarity (pointing away from output) connected between output and device and no other connections or diode with correct polarity (pointing towards earth) between device and earth and no other connections	B1
	switch connected to high voltage circuit	B1

235. 9702_s21_MS_41 Q: 8

	Answer	Marks
(a)	V^+ = 3.0 × 3.0 / (2.5 + 3.0)	C1
	= 1.6 V	A1
(b)	V^- is +2.0 V **or** $V^- > V^+$	B1
	output is negative so (LED) does not emit light	B1
(c)	at 0 °C, V^- = 1.7 V **or** for all temperatures above 0 °C, resistance of thermistor < 4.2 kΩ	B1
	V^- always greater than V^+ (so no switching)	B1
(d)	(at 20 °C,) R_T = 1.8 kΩ	C1
	2.5 / 3.0 = 1.8 / *R* **or** [*R* / (*R* + 1.8)] × 3.0 = 1.6	C1
	R = 2.2 kΩ	A1

236. 9702_s21_MS_43 Q: 8

	Answer	Marks
(a)	V^+ = 3.0 × 3.0 / (2.5 + 3.0)	C1
	= 1.6 V	A1
(b)	V^- is +2.0 V **or** $V^- > V^+$	B1
	output is negative so (LED) does not emit light	B1
(c)	at 0 °C, V^- = 1.7 V **or** for all temperatures above 0 °C, resistance of thermistor < 4.2 kΩ	B1
	V^- always greater than V^+ (so no switching)	B1
(d)	(at 20 °C,) R_T = 1.8 kΩ	C1
	2.5 / 3.0 = 1.8 / *R* **or** [*R* / (*R* + 1.8)] × 3.0 = 1.6	C1
	R = 2.2 kΩ	A1

237. 9702_w21_MS_41 Q: 7

	Answer	Marks
(a)	• infinite (open-loop) gain • infinite slew rate • infinite input impedance • zero output impedance • infinite bandwidth *Any two points, 1 mark each*	B2
(b)	X: thermistor **and** Y: relay	B1
(c)(i)	(any) difference in voltage at the inputs causes output to saturate (because gain is very large)	B1
	saturates positively if $V^+ > V^-$ and saturates negatively if $V^+ < V^-$	B1
(c)(ii)	comparator	B1
(c)(iii)	temperature	M1
	above a particular value	A1
(c)(iv)	to adjust the temperature (at which the lamp illuminates/extinguishes)	B1

238. 9702_s20_MS_41 Q: 7

	Answer	Marks
(a)	output signal proportional to input signal	B1
	output signal has same sign/polarity as input signal	B1
(b)(i)	gain $= V_{OUT} / V_{IN}$ $= 2.6 / 0.084$ $= 31$	A1
(b)(ii)	$31 = 1 + (15 \times 10^3) / R$	C1
	$R = 500\ \Omega$	A1
(c)(i)	e.g. cathode-ray oscilloscope/CRO	B1
(c)(ii)	gain is reduced	B1
	(so) V_{OUT} is smaller	B1

239. 9702_s19_MS_41 Q: 7

	Answer	Marks
(a)(i)	(amplifier) gain is very large/infinite	B1
	for amplifier not to saturate, $V^+ = V^-$ **or** feedback (loop) ensures $V^+ = V^-$	B1
	V^+ is at earth/0 V so V^- is (almost) at earth/0 V	B1
(a)(ii)	gain = (–)5200 / 800 **or** (–)5.2 / 0.80	C1
	= –6.5	A1

	Answer	Marks
(b)	(at saturation,) V_{OUT} = 5 V	C1
	p.d. across R = 5 – 2.3 = 2.7 (V)	C1
	resistance = 2.7 / (30 × 10^{-3}) = 90 Ω	A1
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω R_{total} = 5.0 / 0.030 = 167 Ω	(C1)
	$R_{resistor}$ (= 167 – 77) = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω 77 / ($R_{resistor}$ + 77) × 5 = 2.3	(C1)
	$R_{resistor}$ = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω $R_{resistor}$ = 77 × (2.7 / 2.3)	(C1)
	$R_{resistor}$ = 90 Ω	(A1)

240. 9702_s19_MS_43 Q: 7

	Answer	Marks
(a)(i)	(amplifier) gain is very large/infinite	B1
	for amplifier not to saturate, $V^+ = V^-$ **or** feedback (loop) ensures $V^+ = V^-$	B1
	V^+ is at earth/0 V so V^- is (almost) at earth/0 V	B1
(a)(ii)	gain = (–)5200 / 800 **or** (–)5.2 / 0.80	C1
	= –6.5	A1

	Answer	Marks
(b)	(at saturation,) V_{OUT} = 5 V	C1
	p.d. across R = 5 – 2.3 = 2.7 (V)	C1
	resistance = 2.7 / (30 × 10^{-3}) = 90 Ω	A1
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω R_{total} = 5.0 / 0.030 = 167 Ω	(C1)
	$R_{resistor}$ (= 167 – 77) = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω 77 / ($R_{resistor}$ + 77) × 5 = 2.3	(C1)
	$R_{resistor}$ = 90 Ω	(A1)
	or	
	R_{diode} = 2.3 / 0.030 = 77 Ω $R_{resistor}$ = 77 × (2.7 / 2.3)	(C1)
	$R_{resistor}$ = 90 Ω	(A1)

241. 9702_w19_MS_41 Q: 7

	Answer	Marks
(a)(i)	all frequencies are amplified equally	B1
(a)(ii)	no drop in output voltage (when there is a current)	B1
(b)(i)	gain = 1 + R_F / R_{IN} = 1 + (4000 / 800)	C1
	= 6.0	A1
(b)(ii)	2.0 / V_{IN} = 6.0 V_{IN} = (+)0.33 V	A1
(b)(iii)	5.0 V	A1
(b)(iv)	V = 5.0 – 2.2 (= 2.8 V)	C1
	R = V / I = 2.8 / 0.020 = 140 Ω	A1

242. 9702_w19_MS_43 Q: 7

	Answer	Marks
(a)(i)	all frequencies are amplified equally	B1
(a)(ii)	no drop in output voltage (when there is a current)	B1
(b)(i)	gain = 1 + R_F / R_{IN} = 1 + (4000 / 800)	C1
	= 6.0	A1
(b)(ii)	2.0 / V_{IN} = 6.0 V_{IN} = (+)0.33 V	A1
(b)(iii)	5.0 V	A1
(b)(iv)	V = 5.0 – 2.2 (= 2.8 V)	C1
	R = V / I = 2.8 / 0.020 = 140 Ω	A1

243. 9702_m18_MS_42 Q: 8

	Answer	Marks
(a)(i)	all frequencies have the same gain	B1
(a)(ii)	output changes at the same time as input changes	B1
(b)(i)	R_T / 800 = 1.8 / 1.2 R_T = **1200** Ω	A1
(b)(ii)	stepped from –9 V to +9 V or v.v.	B1
	V_{out} negative < R_T and V_{out} positive > R_T	B1
(b)(iii)	correct LED symbol with connection between V_{OUT} and earth	B1
	diode pointing upwards	B1

244. 9702_s18_MS_41 Q: 8

	Answer	Marks
(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	B2
(b)(i)	gain = (–)9600 / 800	C1
	= –12	A1
(b)(ii)	**1.** 1.2 V	B1
	2. –6 V	B1
(b)(iii)	replace the 9600 Ω resistor with an LDR	B1

245. 9702_s18_MS_42 Q: 7

	Answer	Marks
(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
(a)(ii)	Any two valid points e.g. • greater bandwidth/gain constant over a larger range of frequencies • smaller gain	B2
(b)(i)	gain = 1 + (6400 / 800) = 9.0	A1
(b)(ii)	**1.** (+)5.4 V	A1
	2. –9.0 V	A1
(b)(iii)	replace the 6400 Ω resistor with a thermistor	B1

246. 9702_s18_MS_43 Q: 8

	Answer	Marks
(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	B2
(b)(i)	gain = (–)9600 / 800	C1
	= –12	A1
(b)(ii)	**1.** 1.2 V	B1
	2. –6 V	B1
(b)(iii)	replace the 9600 Ω resistor with an LDR	B1

247. 9702_w18_MS_42 Q: 7

	Answer	Marks
(a)	$R / R_T = 2.4 / 1.8$ **or** at 4.0 °C, R_T = 3.2 kΩ	C1
	hence $R / 3.2 = 2.4 / 1.8$ R = 4.3 kΩ	A1
(b)	R_T = 3.37 kΩ **or** R_T is greater (than 3.2 kΩ)	B1
	$V^+ > V^-$	M1
	hence output is +5.0 V	A1

	Answer	Marks
(c)	correct LED symbol	B1
	two diodes shown connected, in parallel and with opposite polarities, between V_{OUT} and earth	M1
	diodes labelled to show correct polarities consistent with **(b)** (G pointing from V_{OUT} to earth and B pointing from earth to V_{OUT} if **(b)** correct)	A1

248. 9702_s17_MS_42 Q: 8

	Answer	Marks
(a)(i)	circle around both diodes	B1
(a)(ii)	indicates (whether) temperature	M1
	(is) above or below a set value	A1
(b)(i)	(when resistance of C > R_V,) $V^- > V^+$ **or** $V^+ < 3$ V **or** p.d. across R_V < p.d. across R/Y/3 V **or** p.d. across C > p.d. across R/ X/3 V	M1
	op-amp output is negative	M1
	(only) green	A1
(b)(ii)	resistance of C becomes less than R_V **or** $V^- < V^+$	B1
	green (LED) goes out	A1
	blue (LED) comes on	A1
(c)	changes/determines <u>temperature</u> at which LEDs switch	B1

249. 9702_w16_MS_41 Q: 6

(a) reference to input (voltage) and output (voltage) B1
there is no time delay between change in input and change in output B1 [2]

or

reference to rate at which output voltage changes (B1)
infinite rate of change (of output voltage) (B1)

(b) **(i)** $2.00 / 3.00 = 1.50 / R$ C1

or

$V_+ = (3.00 \times 4.5) / (2.00 + 3.00) = 2.7$
$2.7 = 4.5 \times R / (R + 1.50)$ (C1)

resistance = 2.25 kΩ A1 [2]

(ii) **1.** correct symbol for LED M1
two LEDs connected with opposite polarities between V_{OUT} and earth A1 [2]

2. below 24 °C, $R_T > 1.5$ kΩ or resistance of thermistor increases/high B1

$V_- < V_+$ or V_- decreases/low (must not contradict initial statement) M1

V_{OUT} is positive/+5 (V) <u>and</u> LED labelled as 'pointing' from V_{OUT} to earth A1 [3]

250. 9702_w16_MS_43 Q: 6

(a) reference to input (voltage) and output (voltage) B1
there is no time delay between change in input and change in output B1 [2]

or

reference to rate at which output voltage changes (B1)
infinite rate of change (of output voltage) (B1)

(b) (i) 2.00 / 3.00 = 1.50 / R C1

or

$V_+ = (3.00 \times 4.5) / (2.00 + 3.00) = 2.7$
$2.7 = 4.5 \times R / (R + 1.50)$ (C1)

resistance = 2.25 kΩ A1 [2]

(ii) 1. correct symbol for LED M1
two LEDs connected with opposite polarities between V_{OUT} and earth A1 [2]

2. below 24 °C, $R_T > 1.5$ kΩ or resistance of thermistor increases/high B1

$V_- < V_+$ or V_- decreases/low (must not contradict initial statement) M1

V_{OUT} is positive/+5 (V) <u>and</u> LED labelled as 'pointing' from V_{OUT} to earth A1 [3]

251. 9702_w21_MS_41 Q: 8

	Answer	Marks
(a)	newton per ampere per metre	**M1**
	where current/wire is perpendicular to magnetic field	**A1**
(b)(i)	$F = BIL\sin\theta$	**C1**
	$B = 1.0 / (5.0 \times 0.060 \times \sin 50°)$ $= 4.4$ mT	**A1**
(b)(ii)	(from Fleming's left-hand rule) force on wire is upwards, so reading decreases	**B1**
(b)(iii)	frame will rotate (so that PQ becomes perpendicular to the field)	**B1**

252. 9702_w21_MS_43 Q: 8

	Answer	Marks
(a)	newton per ampere per metre	**M1**
	where current/wire is perpendicular to magnetic field	**A1**
(b)(i)	$F = BIL\sin\theta$	**C1**
	$B = 1.0 / (5.0 \times 0.060 \times \sin 50°)$ $= 4.4$ mT	**A1**
(b)(ii)	(from Fleming's left-hand rule) force on wire is upwards, so reading decreases	**B1**
(b)(iii)	frame will rotate (so that PQ becomes perpendicular to the field)	**B1**

253. 9702_s20_MS_41 Q: 8

	Answer	Marks
(a)	magnetic field normal to current	B1
	newton per ampere	B1
	newton per metre	B1
(b)(i)	current in wire QL gives rise to a force **or** wire QL is perpendicular to the magnetic field	B1
	force on wire QL is vertical	B1
	force does not act through the pivot	B1
(b)(ii)	forces act through the same line **or** forces are horizontal	B1
	forces are equal (in magnitude) and opposite (in direction)	B1
(c)(i)	change = $mg \times (\Delta)L$	C1
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-5}$ N m^{-1}	A1
(c)(ii)	change = $B \times (\Delta)I \times L \times x$	C1
	$3.3 \times 10^{-5} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	C1
	$B = 0.058$ T	A1

254. 9702_s20_MS_43 Q: 8

	Answer	Marks
(a)	magnetic field normal to current	B1
	newton per ampere	B1
	newton per metre	B1
(b)(i)	current in wire QL gives rise to a force **or** wire QL is perpendicular to the magnetic field	B1
	force on wire QL is vertical	B1
	force does not act through the pivot	B1
(b)(ii)	forces act through the same line **or** forces are horizontal	B1
	forces are equal (in magnitude) and opposite (in direction)	B1
(c)(i)	change = $mg \times (\Delta)L$	C1
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-5}$ N m^{-1}	A1
(c)(ii)	change = $B \times (\Delta)I \times L \times x$	C1
	$3.3 \times 10^{-5} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	C1
	$B = 0.058$ T	A1

255. 9702_s18_MS_41 Q: 9

	Answer	Marks
(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$ $= 1.6 \times 10^{-3}$ N	A1
(b)(ii)	$F = 1.6 \times 10^{-3}$ N	A1
(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude 2.3×10^{-3} N	B1
	period 0.05 s	B1

256. 9702_s18_MS_43 Q: 9

	Answer	Marks
(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$ $= 1.6 \times 10^{-3}$ N	A1
(b)(ii)	$F = 1.6 \times 10^{-3}$ N	A1
(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude 2.3×10^{-3} N	B1
	period 0.05 s	B1

257. 9702_w18_MS_42 Q: 8

	Answer	Marks
(a)	force per unit current	B1
	force per unit length (of wire)	B1
	current normal to (magnetic) field	B1
(b)(i)	forces (on PQ and RS) are horizontal	B1
	(hence they create) no moment about the pivot	B1
	or	
	forces (on PQ and RS) are equal and opposite	(B1)
	(hence there is) no <u>net</u> force (on the two sections)	(B1)
(b)(ii)	realisation of the need to apply moments	C1
	$BILx = mgy$ $B \times 2.7 \times 1.2 \times 10^{-2} \times 7.5 = 45 \times 10^{-6} \times 9.81 \times 8.8$	C1
	$B = 1.6 \times 10^{-2}$ T	A1

258. 9702_w16_MS_42 Q: 9

(a) (by Newton's third law) force on wire is up(wards) M1
by (Fleming's) left-hand rule/right-hand slap rule to give current A1
in direction left to right shown on diagram A1 [3]

(b) force ∝ current *or* $F = BIL$ *or* $B (= 0.080/6.0L) = 1/75L$ C1

maximum current $= 2.5 \times \sqrt{2}$
$= 3.54$ A C1

maximum force in one direction $= (3.54/6.0) \times 0.080$
$= 0.047$ N C1

difference $(= 2 \times 0.047) = 0.094$ N
or
force varies from 0.047 N upwards to 0.047 N downwards A1 [4]

259. 9702_s21_MS_41 Q: 9

	Answer	Marks
(a)	region where there is a force exerted on	**M1**
	a current-carrying conductor **or** a moving charge **or** a magnetic material/magnetic pole	**A1**
(b)(i)	face PSWV shaded	**B1**
(b)(ii)	accumulating electrons cause an electric field (between the faces)	**B1**
	force due to electric field opposes force due to magnetic field	**B1**
	accumulation stops when magnetic force equals electric force	**B1**
(c)(i)	number density of charge carriers	**B1**
(c)(ii)	PV **or** QT **or** SW	**B1**
(d)	(for semiconductor,) n is (much) smaller so V_H (much) larger	**B1**

260. 9702_s21_MS_42 Q: 8

	Answer	Marks
(a)	• force per unit length • force per unit current • length/current perpendicular to field *1 mark for any two points, 2 marks for all three points*	**B2**
(b)	change in potential energy = change in kinetic energy **or** $qV = ½mv^2$	**B1**
	$v = \sqrt{(2qV / m)}$	**A1**
(c)(i)	magnetic force = centripetal force **or** $Bqv = mv^2 / r$	**M1**
	clear substitution of expression for v and correct algebra leading to $q / m = 2V / B^2r^2$	**A1**
(c)(ii)	$q / m = (2 \times 230) / [(0.38 \times 10^{-3})^2 \times 0.14^2]$	**C1**
	$= 1.6 \times 10^{11}$ C kg^{-1}	**A1**
(c)(iii)	(for α-particle,) q / m is (much) smaller	**B1**
	r would be much larger	**B1**

261. 9702_s21_MS_43 Q: 9

	Answer	Marks
(a)	region where there is a force exerted on	**M1**
	a current-carrying conductor **or** a moving charge **or** a magnetic material/magnetic pole	**A1**
(b)(i)	face PSWV shaded	**B1**
(b)(ii)	accumulating electrons cause an electric field (between the faces)	**B1**
	force due to electric field opposes force due to magnetic field	**B1**
	accumulation stops when magnetic force equals electric force	**B1**
(c)(i)	number density of charge carriers	**B1**
(c)(ii)	PV **or** QT **or** SW	**B1**
(d)	(for semiconductor,) n is (much) smaller so V_H (much) larger	**B1**

262. 9702_m20_MS_42 Q: 8

	Answer	Marks
(a)	a region where a magnet / magnetic material / moving charge / current carrying conductor experiences a force	B1
(b)	$B = F / Il$ e.g. $= 9 \times 10^{-3} / (5.0 \times 0.045)$	C1
	= **0.040** T	A1
(c)(i)	force is (always) perpendicular to the velocity / direction of motion	B1
	magnetic force provides the centripetal force *or* force perpendicular to motion causes circular motion	B1
	magnitude of force (due to the magnetic field) is constant *or* no work done by force *or* the force does not change the speed	B1
(c)(ii)	Applying the list rule, any 2 from: accelerating p.d. radius of path / radius of semicircle magnetic flux density	B2

263. 9702_s20_MS_42 Q: 9

	Answer	Marks
(a)(i)	force is downwards/down the page **or** current is (right) to left	B1
	by left-hand rule, field is into plane of paper	B1
(a)(ii)	magnetic force provides the centripetal force	C1
	$Bqv = mv^2 / r$	C1
	$v = Bqr / m$ $= (8.0 \times 10^{-4} \times 1.60 \times 10^{-19} \times 6.4 \times 10^{-2}) / (9.11 \times 10^{-31})$ $= 9.0 \times 10^{6}$ m s^{-1}	A1
9(b)(i)	arrow showing field direction down the page	B1
(b)(ii)	$Bqv = Eq$ **or** $v = E / B$	C1
	$E = 9.0 \times 10^{6} \times 8.0 \times 10^{-4}$ $= 7.2 \times 10^{3}$ N C^{-1}	A1
(c)	straight line/undeviated	B1
	condition for no deflection depends only on *v* **or** condition for no deflection does not depend on *m* or *q*	B1

264. 9702_s19_MS_42 Q: 8

	Answer	Marks
(a)(i)	v_N = 3.4 × 10^7 × sin 30° = 1.7 × 10^7 m s^{-1}	A1
(a)(ii)	$mv^2 / r = Bqv$ **or** $r = mv / Bq$	C1
	r = (9.11 × 10^{-31} × 1.7 × 10^7) / (3.2 × 10^{-3} × 1.60 × 10^{-19})	C1
	= 0.030 m	A1
(b)	zero	B1
(c)	helix/coil	B1

265. 9702_w19_MS_42 Q: 8

	Answer	Marks
(a)	magnitude: (force =) *Bqv*	B1
	direction: P→Q **or** E→F **or** S→R **or** H→G	B1
(b)(i)	EHSP and FGRQ	B1
(b)(ii)	PE **or** QF **or** RG **or** SH	B1
(c)(i)	*any one correct starting point from:* • (mass of 1 atom =) 27 × 1.66 × 10^{-27} • (amount of substance per unit volume =) 2.7 / 27 • 27 g (of substance) contains 6.02 × 10^{23} atoms • (2.7 g mass contains) 0.1 mol • (1 cm^3 volume contains) 0.1 mol • (1 m^3 volume contains) 10^5 mol	C1
	n = (2.7 × 10^3) / (27 × 1.66 × 10^{-27}) = 6.0 × 10^{28} **or** n = (2.7 / 27) × 10^6 × 6.02 × 10^{23} = 6.0 × 10^{28}	A1
(c)(ii)	V_H = (0.15 × 4.6) / (6.0 × 10^{28} × 0.090 × 10^{-3} × 1.60 × 10^{-19})	C1
	= 8.0 × 10^{-7} V	A1

266. 9702_m18_MS_42 Q: 9

	Answer	Marks
(a)(i)	PSYV <u>and</u> QRXW	B1
(a)(ii)	electron moving in magnetic field deflected towards face QRXW	M1
	so face PSYV is more positive	A1
(b)(i)	PV *or* SY *or* RX *or* QW	B1
(b)(ii)	number of charge carriers per unit volume	B1
(b)(iii)	negative and positive charge (carriers) would deflect in opposite directions	M1
	so no change in polarity	A1

267. 9702_s18_MS_42 Q: 8

	Answer	Marks
(a)	electric and magnetic fields at right-angles to one another *(may be shown on a clearly labelled diagram)*	B1
	particle enters fields (with velocity) normal to the (two) fields *(may be shown on a clearly labelled diagram)*	B1
	no deviation for particles with selected velocity	B1
(b)	magnetic force equals/is the centripetal force	C1
	$Bqv = mv^2 / r$	C1
	$M = Bqr / v$ $= (94 \times 10^{-3} \times 1.6 \times 10^{-19} \times 0.075) / (3.4 \times 10^4)$	M1
	division by 1.66×10^{-27} shown, to give $m = 20$ u	A1
(c)	sketch: semicircle clear (in same direction)	B1
	with larger radius	B1

268. 9702_w18_MS_41 Q: 8

	Answer	Marks
(a)	region where there is a force	M1
	experienced by a current-carrying conductor/moving charge/(permanent) magnet	A1
(b)(i)	single path, deflection in 'upward' direction	B1
	acceptable circular arc in whole field	B1
	no 'kinks' at start or end of curvature, and straight outside region of field	B1
(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	B1
(c)	magnetic force provides/is the centripetal force	B1
	$Bqv = mv^2 / r$ **or** $r = mv / Bq$	C1
	(if q is doubled), new speed = $2v$	A1

269. 9702_w18_MS_43 Q: 8

	Answer	Marks
(a)	region where there is a force	M1
	experienced by a current-carrying conductor/moving charge/(permanent) magnet	A1
(b)(i)	single path, deflection in 'upward' direction	B1
	acceptable circular arc in whole field	B1
	no 'kinks' at start or end of curvature, and straight outside region of field	B1
(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	B1
(c)	magnetic force provides/is the centripetal force	B1
	$Bqv = mv^2 / r$ **or** $r = mv / Bq$	C1
	(if q is doubled), new speed = $2v$	A1

270. 9702_m17_MS_42 Q: 8

	Answer	Marks
(a)	region (of space) where there is a force	M1
	produced by / on a magnet / magnetic pole / moving charge / current-carrying conductor	A1
(b)(i)	out of (the plane of) the paper / page	B1
(b)(ii)	the force on the particle is (always) perpendicular to the velocity / perpendicular to the direction of travel / towards the centre of path	B1
	no work is done by the force on the particle / there is no acceleration in the direction of the velocity / the acceleration is (always) perpendicular to the velocity	B1
(b)(iii)	$F = Bqv$ or $F = mv^2/r$	C1
	$mv^2/(d/2) = Bqv$ so $d = 2mv / Bq$	A1
(b)(iv)	time = distance / speed $T_{(F)} = \pi d / 2v$	C1
	$T_{(F)} = (\pi / 2v) \times (2mv / Bq)$ $T_{(F)} = \pi m / Bq$ and so $T_{(F)}$ independent of v	A1

271. 9702_s17_MS_41 Q: 7

	Answer	Marks
(a)	(magnetic) force (always) normal to velocity/direction of motion	M1
	(magnitude of magnetic) force constant **or** speed is constant/kinetic energy is constant	M1
	so provides the centripetal force	A1
(b)	increase in KE = loss in PE **or** $½mv^2 = qV$	M1
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	A1
(c)	$Bqv = mv^2 / r$ $mv = Bqr$ **or** $p = Bqr$	C1
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	C1
	$B = 5.0 \times 10^{-4}$ T	A1
(d)	greater momentum	M1
	($p = Bqr$ and) so r increased	A1

272. 9702_s17_MS_42 Q: 9

	Answer	Marks
(a)(i)	Hall voltage depends on thickness of slice	C1
	thinner slice, larger Hall voltage	A1
(a)(ii)	Hall voltage depends on current in slice	B1
(b)	sinusoidal wave, one cycle	B1
	at $\theta = 0$ and at $\theta = 360°$, $V_H = V_{MAX}$	B1
	at $\theta = 180°$, $V_H = -V_{MAX}$	B1

273. 9702_s17_MS_43 Q: 7

	Answer	Marks
(a)	(magnetic) force (always) normal to velocity/direction of motion	M1
	(magnitude of magnetic) force constant **or** speed is constant/kinetic energy is constant	M1
	so provides the centripetal force	A1
(b)	increase in KE = loss in PE **or** $\frac{1}{2} mv^2 = qV$	M1
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	A1
(c)	$Bqv = mv^2 / r$ $mv = Bqr$ **or** $p = Bqr$	C1
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	C1
	$B = 5.0 \times 10^{-4}$ T	A1
(d)	greater momentum	M1
	($p = Bqr$ and) so r increased	A1

274. 9702_w17_MS_41 Q: 8

	Answer	Marks
(a)	DERQ and CFSP	B1
(b)(i)	force (on charge) due to magnetic field = force due to electric field **or** $Bqv = Eq$ **or** $v = E / B$	B1
	$E = V_H / d$	B1
	$V_H = Bvd$	B1
(b)(ii)	use of $I = nAqv$ **and** $A = dt$	M1
	algebra clear leading to $V_H = BI / ntq$	A1
(c)	(in metal,) n is very large	M1
	(therefore) V_H is small	A1

275. 9702_w17_MS_42 Q: 8

	Answer	Marks
(a)(i)	DERQ and CFSP	B1
(a)(ii)	charge carriers moving normal to (magnetic) field	B1
	<u>charge carriers</u> experience a <u>force</u> normal to I (and B)	B1
	charge build-up sets up electric field across the slice **or** build-up of charges results in a p.d. across the slice	B1
	charge stops building up/V_H becomes constant when $F_B = F_E$	B1
(b)	V_H inversely proportional to n/number density of charge carriers	B1
	number density of charge carriers (n) lower in semiconductors so V_H larger for semiconductor slice	B1
	or	
	V_H proportional to v/drift velocity	(B1)
	(for same current) drift velocity (v) higher in semiconductors so V_H larger for semiconductor slice	(B1)

276. 9702_w17_MS_42 Q: 9

	Answer	Marks
(a)	region (of space)	B1
	where an object/particle experiences a force	B1
(b)	electric and magnetic fields normal to each other	B1
	velocity of particle normal to both fields	B1
	forces (on particle) due to fields are in opposite directions	B1
	forces are equal for particles with a particular speed/for a selected speed/for speed given by $v = E(q) / B(q)$	B1
(c)(i)	path labelled Q shown undeviated	B1
(c)(ii)	reasonable curve in field and no 'kink' on entering, labelled V	B1
	deviated 'upwards'	B1

277. 9702_w17_MS_43 Q: 8

	Answer	Marks
(a)	DERQ and CFSP	B1
(b)(i)	force (on charge) due to magnetic field = force due to electric field **or** $Bqv = Eq$ **or** $v = E / B$	B1
	$E = V_H / d$	B1
	$V_H = Bvd$	B1
(b)(ii)	use of $I = nAqv$ **and** $A = dt$	M1
	algebra clear leading to $V_H = BI / ntq$	A1
(c)	(in metal,) n is very large	M1
	(therefore) V_H is small	A1

278. 9702_w16_MS_41 Q: 7

(a) region (of space) where a force is experienced by a particle B1 [1]

(b) **(i)** gravitational B1

(ii) gravitational and electric B1

(iii) gravitational, electric and magnetic B1 [3]

(c) **(i)** force (always) normal to direction of motion M1

(magnitude of) force constant
or
speed is constant/kinetic energy is constant M1

magnetic force provides/is the centripetal force A1 [3]

(ii) $mv^2 / r = Bqv$ B1

momentum or p or $mv = Bqr$ B1 [2]

279. 9702_w16_MS_43 Q: 7

(a)		region (of space) where a force is experienced by a particle	B1	[1]
(b)	**(i)**	gravitational	B1	
	(ii)	gravitational and electric	B1	
	(iii)	gravitational, electric and magnetic	B1	[3]
(c)	**(i)**	force (always) normal to direction of motion	M1	
		(magnitude of) force constant *or* speed is constant/kinetic energy is constant	M1	
		magnetic force provides/is the centripetal force	A1	[3]
	(ii)	$mv^2 / r = Bqv$	B1	
		momentum or p or $mv = Bqr$	B1	[2]

280. 9702_w21_MS_42 Q: 8

	Answer	Marks
(a)(i)	arrow from Q pointing downwards, labelled B	**B1**
(a)(ii)	arrow from Q pointing towards P, labelled F	**B1**
(b)(i)	force is proportional to product of both currents (I and $2I$) **or** Newton's third law	**B1**
	forces are equal	**B1**
(b)(ii)	opposite	**B1**

281. 9702_w19_MS_41 Q: 8

	Answer	Marks
(a)	concentric circles (around the wire)	**M1**
	at least 3 circles shown, all with increasing separation	**A1**
	direction anticlockwise	**B1**
(b)(i)	$B = (4\pi \times 10^{-7} \times 6.2) / (2\pi \times 3.1 \times 10^{-2})$	**C1**
	$= 4.0 \times 10^{-5}$ T	**A1**
(b)(ii)	$F = BIL$ **or** $F / L = BI$	**C1**
	$F / L = 4.0 \times 10^{-5} \times 8.5$ $= 3.4 \times 10^{-4}$ N m^{-1}	**A1**
(c)	correct application of Newton's 3rd law to the forces **or** F / L is proportional to the product of the two currents	**M1**
	so same magnitude	**A1**

282. 9702_w19_MS_43 Q: 8

	Answer	Marks
(a)	concentric circles (around the wire)	M1
	at least 3 circles shown, all with increasing separation	A1
	direction anticlockwise	B1
(b)(i)	$B = (4\pi \times 10^{-7} \times 6.2) / (2\pi \times 3.1 \times 10^{-2})$	C1
	$= 4.0 \times 10^{-5}$ T	A1
(b)(ii)	$F = BIL$ **or** $F / L = BI$	C1
	$F / L = 4.0 \times 10^{-5} \times 8.5$ $= 3.4 \times 10^{-4}$ N m^{-1}	A1
(c)	correct application of Newton's 3rd law to the forces **or** F / L is proportional to the product of the two currents	M1
	so same magnitude	A1

283. 9702_m21_MS_42 Q: 8

	Answer	Marks
(a)(i)	at least one anticlockwise arrow and no clockwise arrows	B1
(a)(ii)	(force is to the) left	B1
(a)(iii)	force is the same	B1
	Newton's third law (of motion) *or* force depends on the product of the two currents	B1

	Answer	Marks
(b)(i)	frequency of radio waves is equal to natural frequency of protons	B1
	resonance of protons occurs / protons absorb energy	B1
(b)(ii)	in between pulses / when pulse stops	B1
	Any 1 from: • protons de-excite • protons emit r.f. pulses • emitted (r.f.) pulse (from proton) detected	B1

284. 9702_s19_MS_41 Q: 9

	Answer	Marks
(a)	nuclei precess	B1
	precession is about direction of magnetic field	B1
	frequency of precession depends on field strength **or** frequency of precession is in radio-frequency range	B1
(b)	Any two points from: • frequency (of precession) depends on position • to locate position of (spinning) nuclei • to change region where nuclei are detected	B2

285. 9702_s19_MS_43 Q: 9

	Answer	Marks
(a)	nuclei precess	B1
	precession is about direction of magnetic field	B1
	frequency of precession depends on field strength **or** frequency of precession is in radio-frequency range	B1
(b)	Any two points from: • frequency (of precession) depends on position • to locate position of (spinning) nuclei • to change region where nuclei are detected	B2

286. 9702_w19_MS_41 Q: 9

	Answer	Marks
(a)	nuclei precess	B1
	precession is about (direction of magnetic) field **or** frequency of precession is in radio-frequency range	B1
(b)	• frequency (of precession) depends on field strength • to locate/find position of (spinning) nuclei • to change region where nuclei are detected *any two points, one mark each*	B2

287. 9702_w19_MS_43 Q: 9

	Answer	Marks
(a)	nuclei precess	B1
	precession is about (direction of magnetic) field **or** frequency of precession is in radio-frequency range	B1
(b)	• frequency (of precession) depends on field strength • to locate/find position of (spinning) nuclei • to change region where nuclei are detected *any two points, one mark each*	B2

288. 9702_s17_MS_41 Q: 8

	Answer	Marks
	strong (uniform) magnetic field	B1
	* nuclei precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	B1
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	B1
	on relaxation/de-excitation, nuclei emit RF/pulse	B1
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	B1
	allows positions of (resonating) nuclei to be determined	B1
	* allows for position of detection to be changed/different slices to be studied	
	*max. 2 of additional detail points marked **	B2

289. 9702_s17_MS_43 Q: 8

	Answer	Marks
	strong (uniform) magnetic field	B1
	* nuclei precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	B1
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	B1
	on relaxation/de-excitation, nuclei emit RF/pulse	B1
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	B1
	allows positions of (resonating) nuclei to be determined	B1
	* allows for position of detection to be changed/different slices to be studied	
	*max. 2 of additional detail points marked **	B2

290. 9702_w16_MS_41 Q: 8

strong uniform magnetic field	B1	
nuclei precess/rotate about field (direction)	(1)	
radio-frequency pulse (applied)	B1	
R.F. or pulse is at Larmor frequency/frequency of precession	(1)	
causes resonance/excitation (of nuclei)/nuclei absorb energy	B1	
on relaxation/de-excitation, nuclei emit r.f./pulse	B1	
(emitted) r.f./pulse detected and processed	(1)	
non-uniform magnetic field	B1	
allows position of nuclei to be located	B1	
allows for location of detection to be changed/different slices to be studied	(1)	
any two of the points marked (1)	B2	[8]

291. 9702_w16_MS_42 Q: 10

nuclei emitting r.f. (pulse)	B1	
Larmor frequency/r.f. frequency emitted/detected depends on magnitude of magnetic field	B1	
nuclei can be located (within a slice)	B1	
changing field enables position of detection (slice) to be changed	B1	[4]

292. 9702_w16_MS_43 Q: 8

strong uniform magnetic field	B1	
nuclei precess/rotate about field (direction)	(1)	
radio-frequency pulse (applied)	B1	
R.F. or pulse is at Larmor frequency/frequency of precession	(1)	
causes resonance/excitation (of nuclei)/nuclei absorb energy	B1	
on relaxation/de-excitation, nuclei emit r.f./pulse	B1	
(emitted) r.f./pulse detected and processed	(1)	
non-uniform magnetic field	B1	
allows position of nuclei to be located	B1	
allows for location of detection to be changed/different slices to be studied	(1)	
any two of the points marked (1)	B2	[8]

293. 9702_m21_MS_42 Q: 9

	Answer	Marks
(a)	(magnetic) flux density × area × number of turns	M1
	area is perpendicular to (magnetic) field	A1
(b)	use of t = 1.2 s	C1
	$\varepsilon = \dfrac{\Delta BAN}{\Delta t}$ $= \dfrac{0.250 \times \pi \times 0.030^2 \times 540}{1.2}$	C1
	$= 0.32V$	A1
(c)(i)	light damping	B1

	Answer	Marks
(c)(ii)	sheet cuts (magnetic) flux and causes induced emf	B1
	(induced) emf causes (eddy) currents (in sheet)	B1
	either currents (in sheet) cause resistive force or currents (in sheet) dissipate energy	B1
	smaller currents in Y or larger currents in X, so dashed line is X	B1

294. 9702_s21_MS_41 Q: 10

	Answer	Marks
(a)	direction of (induced) e.m.f.	M1
	is such as to oppose the change causing it	A1
(b)	ring cuts (magnetic) flux and causes induced e.m.f. in ring	B1
	(induced) e.m.f. causes (eddy/induced) currents (in ring)	B1
	currents (in ring) cause magnetic field (around ring)	M1
	two fields interact to cause resistive/opposing force	A1
	or	
	current (in ring) is in a magnetic field	(M1)
	which causes resistive force	(A1)
	or	
	currents (in ring) dissipate thermal energy	(M1)
	(thermal) energy comes from energy of oscillations	(A1)
(c)	current cannot pass all the way around the ring	B1
	(induced) currents smaller	B1
	smaller resistive force (so more oscillations) **or** smaller rate of dissipation of energy (so more oscillations)	B1

295. 9702_s21_MS_42 Q: 9

	Answer	Marks
(a)	(particle is) stationary/not moving	B1
	(particle is) moving parallel to the (magnetic) field	B1
(b)	magnetic field around each coil is circular **or** each coil is normal to magnetic field due to adjacent coils	B1
	current in coil interacts with (magnetic) field to exert force (on coil)	B1
	force is normal to both coil and magnetic field **or** force parallel to axis (of coil)	B1
	forces between coils are attractive so spring contracts	B1
(c)	(oscillating) coils cut magnetic flux **or** as separation of coils changes, magnetic flux changes	B1
	cutting flux causes induced e.m.f. in coils	B1
	changing (induced) e.m.f. causes changing current (in coil)	B1

296. 9702_s21_MS_43 Q: 10

	Answer	Marks
(a)	direction of (induced) e.m.f.	**M1**
	is such as to oppose the change causing it	**A1**
(b)	ring cuts (magnetic) flux and causes induced e.m.f. in ring	**B1**
	(induced) e.m.f. causes (eddy/induced) currents (in ring)	**B1**
	currents (in ring) cause magnetic field (around ring)	**M1**
	two fields interact to cause resistive/opposing force	**A1**
	or	
	current (in ring) is in a magnetic field	**(M1)**
	which causes resistive force	**(A1)**
	or	
	currents (in ring) dissipate thermal energy	**(M1)**
	(thermal) energy comes from energy of oscillations	**(A1)**
(c)	current cannot pass all the way around the ring	**B1**
	(induced) currents smaller	**B1**
	smaller resistive force (so more oscillations) **or** smaller rate of dissipation of energy (so more oscillations)	**B1**

297. 9702_m20_MS_42 Q: 3

	Answer	Marks
(a)(i)	**0.050** m	**A1**
(a)(ii)	$\omega = v_0 / x_0$	**C1**
	$T = 2\pi / \omega$ $0.42 = (2\pi \times 0.050) / T$	**C1**
	T = **0.75** s	**A1**
(a)(iii)	one point labelled P where ellipse crosses displacement axis marked	**A1**
(b)(i)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
(b)(ii)	(there is) current in the circuit	**B1**
	either	
	current causes thermal energy (dissipated) in resistor	**B1**
	thermal energy comes from energy of magnet	**B1**
	or	
	current causes magnetic field around coil	**(B1)**
	two fields cause an opposing force on magnet	**(B1)**

298. 9702_s20_MS_41 Q: 9

	Answer	Marks
(a)(i)	e.m.f. = (Δ)$B \times AN / t$	C1
	= 45 × 10^{-3} × π × (1.8 × 10^{-2})^2 × 350 / 0.20 = 0.080 V	A1
(a)(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
	0.2 s to 0.4 s: zero	B1
	0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
	opposite polarity to 0 to 0.2 s line	B1
(b)	either disc cuts flux lines (of the magnet) **or** there is a changing flux in the disc	B1
	(by Faraday's law) e.m.f. is induced in the disc	B1
	e.m.f. causes (eddy) currents in the disc	B1
	current in the magnetic field (of the magnet) causes force on disc	B1

299. 9702_s20_MS_43 Q: 9

	Answer	Marks
(a)(i)	e.m.f. = (Δ)$B \times AN / t$	C1
	= 45 × 10^{-3} × π × (1.8 × 10^{-2})^2 × 350 / 0.20 = 0.080 V	A1
(a)(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
	0.2 s to 0.4 s: zero	B1
	0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
	opposite polarity to 0 to 0.2 s line	B1
(b)	either disc cuts flux lines (of the magnet) **or** there is a changing flux in the disc	B1
	(by Faraday's law) e.m.f. is induced in the disc	B1
	e.m.f. causes (eddy) currents in the disc	B1
	current in the magnetic field (of the magnet) causes force on disc	B1

300. 9702_m19_MS_42 Q: 10

	Answer	Marks
(a)	single straight line along full length of solenoid	B1
	at least two more parallel lines along full length of solenoid	B1
	correct direction – right to left	B1
(b)	(induced) e.m.f. proportional / equal to <u>rate</u>	M1
	of change of (magnetic) flux (linkage)	A1
(c)	increasing current causes increasing flux	B1
	increasing flux induces e.m.f. in coil	B1
	(induced) e.m.f. opposes growth of current	B1

301. 9702_s19_MS_41 Q: 8

	Answer	Marks
(a)(i)	region where a force is exerted on: a magnetic pole **or** a moving charge **or** a current-carrying wire	**B1**
(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	**B1**
(b)(i)	<u>direction</u> of induced e.m.f./current	**M1**
	(tends to) oppose the change causing it	**A1**
(b)(ii)	magnetic field in solenoid is increasing	**B1**
	field in coil in opposite direction to oppose increase	**B1**
	arrow inside or just above small coil pointing in opposite direction to P	**B1**
(c)	e.m.f. $= N\Delta\phi / \Delta t$	**C1**
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	**C1**
	$= 1.2 \times 10^{-3}$ V	**A1**

302. 9702_s19_MS_43 Q: 8

	Answer	Marks
(a)(i)	region where a force is exerted on: a magnetic pole **or** a moving charge **or** a current-carrying wire	**B1**
(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	**B1**
(b)(i)	<u>direction</u> of induced e.m.f./current	**M1**
	(tends to) oppose the change causing it	**A1**
(b)(ii)	magnetic field in solenoid is increasing	**B1**
	field in coil in opposite direction to oppose increase	**B1**
	arrow inside or just above small coil pointing in opposite direction to P	**B1**
(c)	e.m.f. $= N\Delta\phi / \Delta t$	**C1**
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	**C1**
	$= 1.2 \times 10^{-3}$ V	**A1**

303. 9702_m18_MS_42 Q: 10

	Answer	Marks
(a)(i)	*either* product of flux density and area	**M1**
	direction of flux normal to area	**A1**
	or flux density × area × $\sin\theta$	**(M1)**
	where θ is angle between direction of flux and area	**(A1)**
(a)(ii)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux linkage	**A1**
(b)	e.m.f. $= \Delta(\phi N) / \Delta t$ $= (6.8 \times 10^{-6} \times 2 \times 3.5 \times 96) / (2.4 \times 10^{-3})$	**C1**
	$=$ **1.9** V	**A1**

	Answer	Marks
(c)	alternating	C1
	with same frequency as supply	A1

304. 9702_s18_MS_41 Q: 10

	Answer	Marks
(a)	induced e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage) **or** of cutting (magnetic) flux	A1
(b)	current in coil produces flux	B1
	(by Faraday's law) changing flux induces e.m.f. in ring	B1
	current in ring causes field (around ring)	B1
	(by Lenz's law) field around ring opposes field around coil	B1

305. 9702_s18_MS_42 Q: 9

	Answer	Marks
(a)	(magnetic) flux density × area	B1
	magnetic flux density normal to area **or** reference to cross-sectional area **or** × sin (angle between *B* and *A*)	B1
	× number of turns on coil	B1
(b)	e.m.f. = *BAN*/ *t* **or** e.m.f = rate of change of flux linkage	C1
	$= (7.5 \times 10^{-3} \times \pi \times \{1.2 \times 10^{-2}\}^2 \times 160) / 0.15$ $= 3.6 \times 10^{-3}$ V	A1
(c)	sketch: zero for 0–0.10 s, 0.25–0.35 s, and 0.425–0.55 s, and non-zero outside these ranges	B1
	two horizontal steps, with zero voltage either side	B1
	with same polarity	B1
	correct values (1st step 3.6 mV and 2nd step 7.2 mV)	B1

306. 9702_s18_MS_43 Q: 10

	Answer	Marks
(a)	induced e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage) **or** of cutting (magnetic) flux	A1
(b)	current in coil produces flux	B1
	(by Faraday's law) changing flux induces e.m.f. in ring	B1
	current in ring causes field (around ring)	B1
	(by Lenz's law) field around ring opposes field around coil	B1

307. 9702_w18_MS_41 Q: 9

	Answer	Marks
(a)	(induced) e.m.f. proportional/equal to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	induced e.m.f. = $(\Delta B)AN / \Delta t$ = $(2 \times 0.19 \times 1.5 \times 10^{-4} \times 120) / 0.13$	C1
	= 0.053 V	A1
(b)(ii)	reading on voltmeter connected to coil C / V: 0 0.053 0 (*all three values required*)	A1
	reading on voltmeter connected to Hall probe / V: zero in middle column	B1
	final column correct sign (negative)	B1
	final column correct magnitude (0.20)	B1

308. 9702_w18_MS_42 Q: 9

	Answer	Marks
(a)	$0 \rightarrow t_1$ horizontal straight line at non-zero value of V_H **and** $t_3 \rightarrow t_4$ horizontal straight line at different non-zero V_H	B1
	$t_1 \rightarrow t_3$ straight diagonal line with negative gradient **and** graph line starts at $(0, V_0)$ and ends at $(t_4, -2V_0)$	B1
(b)	$E = 0$ for $0 \rightarrow t_1$ **and** $t_3 \rightarrow t_4$	B1
	E is non-zero at all points between $t_1 \rightarrow t_3$	M1
	E has constant magnitude between $t_1 \rightarrow t_3$	A1

309. 9702_w18_MS_43 Q: 9

	Answer	Marks
(a)	(induced) e.m.f. proportional/equal to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	induced e.m.f. = $(\Delta B)AN / \Delta t$ = $(2 \times 0.19 \times 1.5 \times 10^{-4} \times 120) / 0.13$	C1
	= 0.053 V	A1
(b)(ii)	reading on voltmeter connected to coil C / V: 0 0.053 0 (*all three values required*)	A1
	reading on voltmeter connected to Hall probe / V: zero in middle column	B1
	final column correct sign (negative)	B1
	final column correct magnitude (0.20)	B1

310. 9702_s17_MS_42 Q: 3

	Answer	Marks
(a)(i)	e.g. period = 6 / 2.5	C1
	frequency = 0.42 Hz	A1
(a)(ii)	energy $= \frac{1}{2} m \times 4\pi^2 f^2 y_0^2$	C1
	$= \frac{1}{2} \times 0.25 \times 4\pi^2 \times 0.42^2 \times (1.5 \times 10^{-2})^2$	C1
	$= 2.0 \times 10^{-4}$ J	A1
(b)(i)	(induced) e.m.f. proportional to rate of	M1
	change of magnetic flux (linkage) **or** cutting of magnetic flux	A1
(b)(ii)	coil cuts flux/field (of moving magnet) inducing e.m.f. in coil	B1
	(induced) current in resistor causes heating (effect)	M1
	thermal energy/heat derived from energy of oscillations (of magnet)	A1

311. 9702_w17_MS_41 Q: 5

	Answer	Marks
(a)(i)	force proportional to product of charges and inversely proportional to square of separation	A1
(a)(ii)	curve starting at (R, F_C)	B1
	passing through ($2R$, $0.25F_C$)	B1
	passing through ($4R$, $0.06F_C$)	B1
(b)	graph: E = 0 when current constant (0 to t_1, t_2 to t_3, t_4 to t_5)	B1
	stepped from t_1 to t_2 and t_3 to t_4	B1
	(steps) in opposite directions	B1
	later one larger in magnitude	B1

312. 9702_w17_MS_43 Q: 5

	Answer	Marks
(a)(i)	force proportional to product of charges and inversely proportional to square of separation	A1
(a)(ii)	curve starting at (R, F_C)	B1
	passing through ($2R$, $0.25F_C$)	B1
	passing through ($4R$, $0.06F_C$)	B1
(b)	graph: E = 0 when current constant (0 to t_1, t_2 to t_3, t_4 to t_5)	B1
	stepped from t_1 to t_2 and t_3 to t_4	B1
	(steps) in opposite directions	B1
	later one larger in magnitude	B1

313. 9702_m16_MS_42 Q: 10

(a) **(i)** change in flux linkage = $40 \times (5.0 - 3.0) \times 10^{-6}$
= $8(.0) \times 10^{-5}$ Wb — A1 [1]

(ii) time taken = $8.0 \times 10^{-5} / 5.0 \times 10^{-4}$
= 0.16 (s) — C1
speed = $3.0 \times 10^{-2} / 0.16$
= 0.19 (0.188) m s^{-1} — A1

or

$E = (\Delta\Phi / \Delta x) \times$ speed
speed = $5.0 \times 10^{-4} / (8.0 \times 10^{-5} / 3.0 \times 10^{-2})$ — (C1)
= 0.19 (0.188) m s^{-1} — (A1) [2]

(b) a constant non-zero value of E from 0 to 3 cm and
a different constant non-zero value of E from 3 to 6 cm — M1
E from 3–6 cm has the opposite sign to and larger value than E from 0–3 cm — A1 [2]

314. 9702_w16_MS_41 Q: 9

(a) (induced) e.m.f. proportional to rate — M1
of change of (magnetic) flux (linkage) — A1 [2]

(b) flux linkage = BAN

= $\pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4}$ Wb — B1 [1]

(c) e.m.f. = $\Delta N\Phi / \Delta t$

= $(6.0 \times 10^{-4} \times 2) / 0.30$ — C1

= 4.0 mV — A1 [2]

(d) sketch: $E = 0$ for $t = 0 \rightarrow 0.3$ s, 0.6 s $\rightarrow 1.0$ s, 1.6 s $\rightarrow 2.0$ s — B1

$E = 4$ mV for $t = 0.3$ s $\rightarrow 0.6$ s (either polarity) — B1

$E = 2$ mV for $t = 1.0$ s $\rightarrow 1.6$ s — B1

with opposite polarity — B1 [4]

315. 9702_w16_MS_43 Q: 9

(a) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) — M1, A1 [2]

(b) flux linkage $= BAN$

$= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4}$ Wb — B1 [1]

(c) e.m.f. $= \Delta N\Phi / \Delta t$

$= (6.0 \times 10^{-4} \times 2) / 0.30$ — C1

$= 4.0$ mV — A1 [2]

(d) sketch: $E = 0$ for $t = 0 \rightarrow 0.3$ s, 0.6 s $\rightarrow 1.0$ s, 1.6 s $\rightarrow 2.0$ s — B1

$E = 4$ mV for $t = 0.3$ s $\rightarrow 0.6$ s (either polarity) — B1

$E = 2$ mV for $t = 1.0$ s $\rightarrow 1.6$ s — B1

with opposite polarity — B1 [4]

316. 9702_s21_MS_42 Q: 10

	Answer	Marks
(a)	the steady current **or** the direct current	**M1**
	that produces the same heating effect (as the alternating current)	**A1**
(b)(i)	peak current = 2.6 A **and** r.m.s. current = 1.8 A	**A1**
(b)(ii)	peak current = 2.0 A **and** r.m.s. current = 2.0 A	**A1**
(c)(i)	$k = 2\pi f$	**C1**
	$= 2\pi \times 50$ $= 310$ rad s^{-1}	**A1**
(c)(ii)	power = V_{RMS}^2 / R **or** power = $V_0^2 / 2R$	**C1**
	$R = (240 / \sqrt{2})^2 / 3200$ **or** $R = 240^2 / (2 \times 3200)$ $R = 9.0\ \Omega$	**A1**

317. 9702_w21_MS_41 Q: 9

	Answer	Marks
(a)	constant voltage	**M1**
	that produces/dissipates same power as (the mean power of) the alternating voltage	**A1**
(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	**B1**
	(peak and hence) r.m.s. induced e.m.f. doubles	**B1**
(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	**B1**
	peak *E* shown as ± 34 V (*1 mark out of 2 awarded if peak E shown as* ± 17 V *or* ± 24 V)	**B2**
(c)	current in the coil results in forces that oppose its rotation **or** current in the resistor dissipates the energy of rotation	**B1**
	coil stops rotating	**B1**

318. 9702_w21_MS_43 Q: 9

	Answer	Marks
(a)	constant voltage	**M1**
	that produces/dissipates same power as (the mean power of) the alternating voltage	**A1**
(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	**B1**
	(peak and hence) r.m.s. induced e.m.f. doubles	**B1**
(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	**B1**
	peak *E* shown as ± 34 V (*1 mark out of 2 awarded if peak E shown as* ± 17 V *or* ± 24 V)	**B2**
(c)	current in the coil results in forces that oppose its rotation **or** current in the resistor dissipates the energy of rotation	**B1**
	coil stops rotating	**B1**

319. 9702_m19_MS_42 Q: 8

	Answer	Marks
(a)(i)	*Either* Newton's third law *or* equal and opposite forces	**B1**
	force on magnet is upwards	**B1**
	so force on wire downwards	**B1**
(a)(ii)	using (Fleming's) left-hand rule	**M1**
	current from B to A	**A1**
(b)	sinusoidal wave with at least 1 cycle	**B1**
	peaks at +6.4 mN and –6.4 mN	**B1**
	time period 25 ms	**B1**

320. 9702_w19_MS_42 Q: 11

	Answer	Marks
(a)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	any two from t_1, t_3, t_5, t_7	A1
(b)(ii)	t_2 **and** t_4 **or** t_4 **and** t_6	A1
(c)	e.m.f. = $N\Delta\Phi / \Delta t$	C1
	= $(2 \times 9.4 \times 10^{-4} \times 5.0 \times \pi \times (1.8 \times 10^{-2})^2 \times 63) / (6.0 \times 10^{-3})$	C1
	= 0.10 V	A1

321. 9702_w17_MS_41 Q: 10

	Answer	Marks
(a)	heating depends on current^2/I^2	B1
	and current^2/I^2 is always positive	B1
	or	
	a.c. changes direction (every half cycle)	(B1)
	but heating effect is independent of current direction	(B1)
	or	
	voltage and current are always in phase in a resistor	(B1)
	so $V \times I$ is always positive	(B1)
	or	
	sketch graph drawn showing power against time	(B1)
	comment that power is always positive	(B1)
(b)(i)	for same power (transmission, higher voltage) → lower current	B1
	lower current → less power loss in (transmission) cables	B1
(b)(ii)	• voltage can be (easily) stepped up/down • transformers only work with a.c. • generators produce a.c. • easier to rectify than invert *Two sensible suggestions, 1 mark each.*	B2

322. 9702_w17_MS_43 Q: 10

	Answer	Marks
(a)	heating depends on current²/I^2	**B1**
	and current²/I^2 is always positive	**B1**
	or	
	a.c. changes direction (every half cycle)	**(B1)**
	but heating effect is independent of current direction	**(B1)**
	or	
	voltage and current are always in phase in a resistor	**(B1)**
	so $V \times I$ is always positive	**(B1)**
	or	
	sketch graph drawn showing power against time	**(B1)**
	comment that power is always positive	**(B1)**
(b)(i)	for same power (transmission, higher voltage) → lower current	**B1**
	lower current → less power loss in (transmission) cables	**B1**
(b)(ii)	• voltage can be (easily) stepped up/down • transformers only work with a.c. • generators produce a.c. • easier to rectify than invert *Two sensible suggestions, 1 mark each.*	**B2**

323. 9702_m16_MS_42 Q: 3

(a) the (thermal) energy per unit mass to raise the temperature — M1
of a substance by one degree — A1 [2]

(*If ratio not clear for M1 mark, allow 1/2 marks for an otherwise correct answer*)

(b) **(i)** to allow for/determine/cancel heat transfer to/from tube/surroundings — B1 [1]

(*do not allow 'to stop/prevent' heat loss*)

(ii) *either* $P = mc\Delta\theta \pm h$
or $44.9 = 1.58 \times 10^{-3} \times c \times (25.5 - 19.5) \pm h$
or $33.3 = 1.11 \times 10^{-3} \times c \times (25.5 - 19.5) \pm h$ — B1
$(44.9 - 33.3) = (1.58 - 1.11) \times 10^{-3} \times c \times (25.5 - 19.5)$ — C1
$c = 4100\ (4110)\ \text{J kg}^{-1}\text{K}^{-1}$ — A1 [3]

(*allow 1/3 for use of only 33.3 W, 1.11 g s^{-1} leading to 5000 J kg^{-1} K^{-1}*)
(*allow 1/3 for use of only 44.9 W, 1.58 g s^{-1} leading to 4740 J kg^{-1} K^{-1}*)

(c) $V_0 = 27$ *or* $V_{rms} = 19.1$ — C1
$33.3 = 27^2/2R$ *or* $33.3 = 19.1^2/R$ — C1
$R = 11\ \Omega$ — A1 [3]

324. 9702_w21_MS_42 Q: 10

	Answer	Marks
(a)(i)	to increase the magnetic flux linkage (between the coils)	B1
(a)(ii)	to reduce energy losses	B1
	by reducing induced currents	B1
(b)(i)	maximum V_{OUT} = 12 000 × (625 / 25 000) = 300 V	A1
(b)(ii)	r.m.s. current = 300 / (640 × √2) = 0.33 A	A1
(b)(iii)	sketch: sinusoidal shape in positive half of the graph, sitting with 'minima' resting on the time-axis (at P = 0)	B1
	each 'cycle' shown repeating every 20 ms	B1
	maximum P shown as 140 W	B1
(c)	power curve is symmetrical about the midpoint (on the power axis)	B1
	mean power is half the peak power	B1

325. 9702_m20_MS_42 Q: 9

	Answer	Marks
(a)(i)	9.0 / √2 = **6.4** V	A1
(a)(ii)	ω = 20 ω = 2π / T T = 2π / 20	C1
	T = **0.31** s	A1
(b)	the r.m.s. voltages are different, so no	B1
(c)(i)	$P = V_{r.m.s.} \times I_{r.m.s.}$	C1
	= 120 × 0.64 = 76.8 W	C1
	efficiency = (76.8 / 80) × 100 = **0.96** or **96** %	A1
(c)(ii)	Any one from: • heat losses due to resistance of windings / coils • heat losses in magnetising and demagnetising core / hysteresis losses in core • heat losses due to eddy currents in (iron) core • loss of flux linkage	B1

326. 9702_s20_MS_42 Q: 10

	Answer	Marks
(a)	(induced) electromotive force is proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	to change magnitude of potential difference	B1
(b)(ii)	magnitude of e.m.f. varies as rate of change of flux changes	B1
	direction of e.m.f. changes when direction of change of flux reverses/when flux changes from increasing to decreasing	B1
	flux is continuously increasing and decreasing, so polarity of e.m.f. is continuously switching	B1
(b)(iii)	to reduce energy/power losses **or** to reduce eddy currents	B1

327. 9702_s19_MS_42 Q: 10

	Answer	Marks
(a)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)	current in primary coil gives rise to magnetic flux	B1
	changing (magnetic) flux in core links with secondary coil	B1
	induced e.m.f. (in secondary coil) causes current in load/resistor	B1
(c)	correct application of turns ratio: to peak voltage ratio, giving (V_0 / 220) = (450 / 2700) **or** to r.m.s. voltage ratio, giving ($V_{r.m.s.}$ / 156) = (450 / 2700)	C1
	correct application of √2 factor: to peak applied e.m.f., giving 220 / √2 **or** to peak output em.f., giving 37 / √2	C1
	$V_{r.m.s.}$ = 26 V	A1

328. 9702_m17_MS_42 Q: 9

	Answer	Marks
(a)(i)	increase flux linkage (with secondary coil) / to reduce flux loss	B1
(a)(ii)	e.m.f. (induced only) when flux (in core/coil) is changing	B1
	constant / direct voltage gives constant flux / field	B1
(b)(i)	N_S / N_P = V_S / V_P	C1
	N_S = (52 / 150) × 1200 = 416 turns	A1
(b)(ii)	0 ms or 7.5 ms or 15.0 ms or 22.5 ms	A1
(c)(i)	*either*	
	mean power = $V^2 / 2R$ and V = 52 (V)	C1
	R = $52^2 / (2 \times 1.2)$ = 1100 (1127) Ω	A1
	or	
	mean power = V^2 / R and $V = 52 / \sqrt{2}$ (= 36.8 V)	(C1)
	R = $36.8^2 / 1.2$ = 1100 Ω	(A1)
(c)(ii)	sinusoidal shape with troughs at zero power	B1
	only 3 'cycles'	B1
	each 'cycle' is 2.4 W high and zero power at correct times	B1

329. 9702_s17_MS_41 Q: 9

	Answer	Marks
(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	B1
(a)(ii)	reduces (size of eddy) currents in core	B1
	(so that) heating of core is reduced	B1
(b)	alternating voltage gives rise to changing magnetic flux in core	M1
	(changing) flux links the secondary coil	A1
	induced e.m.f. (in secondary) only when flux is changing/cut	B1

330. 9702_s17_MS_43 Q: 9

	Answer	Marks
(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	B1
(a)(ii)	reduces (size of eddy) currents in core	B1
	(so that) heating of core is reduced	B1
(b)	alternating voltage gives rise to changing magnetic flux in core	M1
	(changing) flux links the secondary coil	A1
	induced e.m.f. (in secondary) only when flux is changing/cut	B1

331. 9702_w16_MS_42 Q: 11

(a) (induced) e.m.f. proportional/equal to <u>rate</u> M1
of change of (magnetic) flux (linkage) A1 [2]

(b) (for same current) iron core gives large(r) (rates of change of) flux (linkage) B1
e.m.f induced in solenoid is greater (for same current) M1
induced e.m.f. opposes applied e.m.f. so current smaller/acts to reduce current A1 [3]

or

same supply so same induced e.m.f. balancing it (B1)
(rate of change of) flux linkage is same (M1)
smaller current for same flux when core present (A1)

e.g. (heating due to) <u>eddy currents in core</u>

(heating due to current in) <u>resistance of coils</u>

hysteresis losses/losses due to changing magnetic field in core

Any two of the above marking points, 1 mark each B2 [2]

332. 9702_m21_MS_42 Q: 10

	Answer	Marks
(a)	230 V	A1
(b)	$\omega = 100\pi$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi}$	C1
	$= 0.020\,s$	A1
(c)(i)	half-wave (rectification)	B1
(c)(ii)	sinusoidal half waves in positive V only or negative V only, peak at 320 V	B1
	line at zero for second half of cycle	B1
	two time periods shown, each of 0.020 s	B1
(c)(iii)	capacitor added in parallel with resistor	B1

333. 9702_s19_MS_41 Q: 10

	Answer	Marks
(a)	V_{MAX} = 15 V	A1
(b)	210 = 2π / T	C1
	T = 0.0299 s	C1
	$(t_2 - t_1)$ = 0.060 s	A1

334. 9702_s19_MS_43 Q: 10

	Answer	Marks
(a)	V_{MAX} = 15 V	A1
(b)	210 = 2π / T	C1
	T = 0.0299 s	C1
	$(t_2 - t_1)$ = 0.060 s	A1

335. 9702_w19_MS_41 Q: 10

	Answer	Marks
(a)(i)	lower right **and** upper left diodes circled	B1
(a)(ii)	maximum = 7.0√2 = 9.9 V	A1
(b)(i)	correct symbol for capacitor, shown connected in parallel with R	B1
(b)(ii)	**1.** (ripple) decreases	B1
	2. (ripple) increases	B1

336. 9702_w19_MS_43 Q: 10

	Answer	Marks
(a)(i)	lower right **and** upper left diodes circled	B1
(a)(ii)	maximum = 7.0√2 = 9.9 V	A1
(b)(i)	correct symbol for capacitor, shown connected in parallel with R	B1
(b)(ii)	**1.** (ripple) decreases	B1
	2. (ripple) increases	B1

337. 9702_w17_MS_42 Q: 11

	Answer	Marks
(a)(i)	circles drawn only around the top left and bottom right diodes	B1
(a)(ii)	B shown as (+)ve and A shown as (–)ve	B1
(b)(i)	$V_{r.m.s.}$ (= 5.6 / √2) = 4.0 V	A1
(b)(ii)	380 = 2π*f* **or** *f* = 60.5 Hz	C1
	number (= 2*f*) = 120	A1
(c)(i)	peak values (all) unchanged	B1
	(all) minima shown at 4.0 V	B1
	three lines from near peak showing concave curves after leaving dotted line not 'kinked' and not cutting the peak reaching candidate's minimum at the point where the decay meets the next dotted line	B1
	three lines drawn along the dotted lines showing rise in voltage from minima back to peak values	B1
(c)(ii)	mean p.d. is higher **or** r.m.s. p.d. is higher **or** capacitor supplies energy to resistor	M1
	so (mean) power increases	A1

338. 9702_s21_MS_41 Q: 12

	Answer	Marks
(a)	• frequency determines energy of photon • intensity determines number of photons (per unit time) • intensity does not determine energy of a photon *Any two points, 1 mark each*	B2
	kinetic energy (of the electron) depends on the energy of one photon	B1
(b)(i)	$E = hc / \lambda$ **or** $E = hf$ **and** $c = f\lambda$	C1
	$E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (250 \times 10^{-9})$	C1
	(= 7.96×10^{-19} J) = 5.0 eV	A1
(b)(ii)	E_{MAX} = photon energy – work function	C1
	work function = 5.0 – 1.4 = 3.6 eV	A1

339. 9702_s21_MS_43 Q: 12

	Answer	Marks
(a)	• frequency determines energy of photon • intensity determines number of photons (per unit time) • intensity does not determine energy of a photon *Any two points, 1 mark each*	B2
	kinetic energy (of the electron) depends on the energy of one photon	B1
(b)(i)	$E = hc / \lambda$ **or** $E = hf$ **and** $c = f\lambda$	C1
	$E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (250 \times 10^{-9})$	C1
	$(= 7.96 \times 10^{-19}$ J) = 5.0 eV	A1
(b)(ii)	E_{MAX} = photon energy – work function	C1
	work function = 5.0 – 1.4 = 3.6 eV	A1

340. 9702_w21_MS_42 Q: 9

	Answer	Marks
(a)(i)	emission of electrons (from a metal surface)	B1
	when electromagnetic radiation is incident (on electrons)	B1
a(ii)	minimum energy required for an electron to leave surface	B1
(b)(i)	threshold (frequency)	B1
(b)(ii)	• photons are (discrete) packets of energy • energy of photons depends on frequency (of EM radiation) • electrons can only absorb a single photon (of energy) *Any two points, 1 mark each*	B2
	emission only possible if photon energy is at least the work function	B1
(b)(iii)	work function = hf_0 $= 6.63 \times 10^{-34} \times 6.93 \times 10^{14}$	C1
	$= 4.59 \times 10^{-19}$ (J) $= 4.59 \times 10^{-19} / 1.60 \times 10^{-19}$ (eV) = 2.87 eV	A1

341. 9702_m20_MS_42 Q: 10

	Answer	Marks
(a)	energy of a photon required to remove an electron	B1
	either: energy to remove electron from a surface *or*: minimum energy to remove electron *or*: energy to remove electron with zero kinetic energy	B1
(b)(i)	Correct read off from graph of f as 5.45×10^{14} Hz when $E_{MAX} = 0$ $5.45 \times 10^{14} \times 6.63 \times 10^{-34}$	C1
	$= \mathbf{3.6 \times 10^{-19}}$ J	A1
(b)(ii)	$3.6 \times 10^{-19} / 1.6 \times 10^{-19} = 2.3$ eV so potassium	A1
(c)(i)	each photon has same energy so no change	B1
(c)(ii)	more photons (per unit time) so (rate of emission) increases	B1

342. 9702_s19_MS_43 Q: 11

	Answer	Marks
(a)	Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	B3
(b)(i)	photon energy $= hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (380 \times 10^{-9})$ $(= 5.23 \times 10^{-19}$ J)	C1
	= 3.3 eV	A1
(b)(ii)	photon energy must be greater than work function (energy)	B1
	so sodium and calcium	B1
(c)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (380 \times 10^{-9})$ $= 1.74 \times 10^{-27}$ N s	C1
	force $= 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12}$ N	A1

343. 9702_w19_MS_41 Q: 11

	Answer	Marks
(a)	energy (of photon) required to remove electron	M1
	from a surface **or** reference to <u>minimum</u> energy **or** reference to zero <u>kinetic</u> energy	A1
(b)(i)	**1.** photon energy $= hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19}$ J	A1
	2. electron energy $= (7.1 - 5.5) \times 10^{-19}$ J	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	C1
	$v = 5.9 \times 10^{5}$ m s^{-1}	A1
(b)(ii)	energy is required to bring electron to the surface	B1
(c)	no change — decreases increases — decreases	B4

344. 9702_w19_MS_43 Q: 11

	Answer	Marks
(a)	energy (of photon) required to remove electron	M1
	from a surface **or** reference to <u>minimum</u> energy **or** reference to zero <u>kinetic</u> energy	A1
(b)(i)	**1.** photon energy $= hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (280 \times 10^{-9})$ $= 7.1 \times 10^{-19}$ J	A1
	2. electron energy $= (7.1 - 5.5) \times 10^{-19}$ J	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	C1
	$v = 5.9 \times 10^{5}$ m s^{-1}	A1
(b)(ii)	energy is required to bring electron to the surface	B1
(c)	no change / decreases increases / decreases	B4

345. 9702_s18_MS_42 Q: 10

	Answer	Marks
(a)	emission of electron	B1
	when electromagnetic radiation incident (on surface)	B1
(b)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(ii)	$E = hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (420 \times 10^{-9})$ $= 4.7 \times 10^{-19}$ J	A1
(b)(iii)	sodium: yes zinc: no	B1

346. 9702_m17_MS_42 Q: 10

	Answer	Marks
(a)	packet / quantum of energy	M1
	of electromagnetic radiation	A1
(b)(i)	light is re-emitted in all directions / only part of the re-emitted light is in the direction of the beam	B1
(b)(ii)	an arrow between –3.40 eV and –1.51 eV <u>and</u> an arrow between –3.40 eV and –0.85 eV	B1
	all arrows shown point 'upwards'	B1
(b)(iii)	$E = hc / \lambda$ or $E = hf$ <u>and</u> $c = f\lambda$	C1
	$2.60 \times 1.60 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$	C1
	$\lambda = 4.8 \times 10^{-7}$ m	A1

347. 9702_s17_MS_42 Q: 10

	Answer	Marks
(a)	two from: • frequency below which electrons not ejected • maximum energy of electron depends on frequency • maximum energy of electrons does not depend on intensity • instantaneous emission of electrons	B2
(b)(i)	(λ_0 is the) threshold wavelength **or** wavelength corresponding to threshold frequency **or** maximum wavelength for emission of electrons	B1
(b)(ii)1.	intercept = $1/\lambda_0 = 2.2 \times 10^6\,\text{m}^{-1}$ $\lambda_0 = 4.5 \times 10^{-7}$ m or 450 nm	A1
(b)(ii)2.	gradient = hc	C1
	gradient = 2.0×10^{-25} or correct substitution into gradient formula	C1
	$h = (2.0 \times 10^{-25}) / (3.0 \times 10^8) = 6.7 \times 10^{-34}$ J s	A1
(c)	line: same gradient	B1
	straight line, positive gradient, intercept at greater than 2.2×10^6 when candidate's line extrapolated	B1

348. 9702_m16_MS_42 Q: 11

(a) minimum frequency for electron(s) to be emitted (from surface) M1
reference to frequency of electromagnetic radiation / photon A1

or

frequency causing emission of electron(s)
from surface with zero kinetic energy (M1)
reference to frequency of electromagnetic radiation / photon (A1) [2]

(b) (i)	positive intercept on $(1/\lambda)$-axis (when extrapolated)	B1	
	straight line with positive gradient	B1	[2]
(ii)	gradient = hc where c is the speed of light	B1	[1]
(iii)	maximum kinetic energy when electron emitted from surface	B1	
	energy is required to bring an electron to the surface	B1	[2]
(iv)	each photon has more energy	M1	
	fewer photons per unit time	M1	
	fewer electrons per unit time / less current	A1	[3]

349. 9702_w16_MS_41 Q: 10

(a)	electromagnetic radiation/photons incident on a surface	B1	
	causes emission of electrons (from the surface)	B1	[2]
(b)	$E = hc / \lambda$		
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (436 \times 10^{-9})$	C1	
	$= 4.56 \times 10^{-19}$ J (4.6×10^{-19} J)	A1	[2]
(c) (i)	$\Phi = hc / \lambda_0$		
	$\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.4 \times 1.60 \times 10^{-19})$	C1	
	$= 890$ nm	A1	[2]
(ii)	$\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (4.5 \times 1.60 \times 10^{-19})$		
	$= 280$ nm	A1	[1]
(d)	caesium: wavelength of photon less than threshold wavelength (or v.v.) *or* $\lambda_0 = 890$ nm > 436 nm so yes	A1	
	tungsten: wavelength of photon greater than threshold wavelength (or v.v.) *or* $\lambda_0 = 280$ nm < 436 nm so no	A1	[2]

350. 9702_w16_MS_43 Q: 10

(a) electromagnetic radiation/photons incident on a surface — B1

causes emission of electrons (from the surface) — B1 [2]

(b) $E = hc / \lambda$

$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (436 \times 10^{-9})$ — C1

$= 4.56 \times 10^{-19}$ J (4.6×10^{-19} J) — A1 [2]

(c) (i) $\Phi = hc / \lambda_0$

$\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.4 \times 1.60 \times 10^{-19})$ — C1

$= 890$ nm — A1 [2]

(ii) $\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (4.5 \times 1.60 \times 10^{-19})$

$= 280$ nm — A1 [1]

(d) caesium:
wavelength of photon less than threshold wavelength (or v.v.)
or
$\lambda_0 = 890$ nm > 436 nm
so yes — A1

tungsten:
wavelength of photon greater than threshold wavelength (or v.v.)
or
$\lambda_0 = 280$ nm < 436 nm
so no — A1 [2]

351. 9702_s21_MS_42 Q: 11

	Answer	Marks
(a)	to produce a 3-dimensional image of structure/body	**B1**
(b)	X-rays (are used)	**B1**
	scanning in sections	**B1**
	scanning from many angles	**B1**
	image of each section is 2-dimensional	**B1**
	scanning repeated for many sections **or** images of many sections combined together	**B1**

352. 9702_s21_MS_42 Q: 12

	Answer	Marks
(b)(ii)	$p = h / \lambda$	C1
	$= (6.63 \times 10^{-34}) / (2.2 \times 10^{-12})$ $= 3.0 \times 10^{-22}$ N s	A1
	or	
	$p = E / c$	**(C1)**
	$= (0.57 \times 10^{6} \times 1.60 \times 10^{-19}) / (3.00 \times 10^{8})$ $= 3.0 \times 10^{-22}$ N s	**(A1)**
(c)(i)	mass (of Sm-157 nucleus) = $157 \times 1.66 \times 10^{-27}$ **or** mass (of Sm-157 nucleus) = $0.157 / (6.02 \times 10^{23})$	C1
	recoil speed = $(3.00 \times 10^{-22}) / (157 \times 1.66 \times 10^{-27})$ $= 1.2 \times 10^{3}$ m s^{-1}	A1
(c)(ii)	$(1.2 \times)\ 10^{3}$ m s^{-1} is <u>much</u> less than $(3.0 \times)\ 10^{8}$ m s^{-1}	B1

353. 9702_w21_MS_41 Q: 10

	Answer	Marks
(a)(i)	photoelectric effect	B1
(a)(ii)	electron diffraction	B1
(b)(i)	$\lambda = h / p$	M1
	h is the Planck constant	A1
(b)(ii)	de Broglie (wavelength)	B1
(c)(i)	$\frac{1}{2}mv^2 = eV$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ <u>so</u> $v = 4.1 \times 10^{7}$ m s^{-1}	A1
(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^{7})$	C1
	$= 1.8 \times 10^{-11}$ m	A1

354. 9702_w21_MS_43 Q: 10

	Answer	Marks
(a)(i)	photoelectric effect	B1
(a)(ii)	electron diffraction	B1
(b)(i)	$\lambda = h / p$	M1
	h is the Planck constant	A1
(b)(ii)	de Broglie (wavelength)	B1
(c)(i)	$\frac{1}{2}mv^2 = eV$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ <u>so</u> $v = 4.1 \times 10^{7}$ m s^{-1}	A1
(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^{7})$	C1
	$= 1.8 \times 10^{-11}$ m	A1

355. 9702_s19_MS_41 Q: 11

	Answer	Marks
(a)	Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	B3
(b)(i)	photon energy $= hc / \lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (380 \times 10^{-9})$ $(= 5.23 \times 10^{-19}$ J)	C1
	= 3.3 eV	A1
(b)(ii)	photon energy must be greater than work function (energy)	B1
	so sodium and calcium	B1
(c)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (380 \times 10^{-9})$ $= 1.74 \times 10^{-27}$ N s	C1
	force $= 1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ $= 1.3 \times 10^{-12}$ N	A1

356. 9702_s19_MS_42 Q: 11

	Answer	Marks
(a)	packet/quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	$E = hc / \lambda$	C1
	$1.18 \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$ $\lambda = 1.05 \times 10^{-12}$ m	A1
(b)(ii)	$\lambda = h / p$ **or** $E = pc$	C1
	$p = (6.63 \times 10^{-34}) / (1.05 \times 10^{-12})$ **or** $p = (1.18 \times 1.60 \times 10^{-13}) / (3.00 \times 10^{8})$ leading to $p = 6.3 \times 10^{-22}$ N s	B1
(c)	$6.3 \times 10^{-22} = 60 \times 1.66 \times 10^{-27} \times v$	C1
	$v = 6.3 \times 10^{3}$ m s^{-1}	A1

357. 9702_w17_MS_41 Q: 11

	Answer	Marks
(a)	packet/quantum of energy of electromagnetic/EM radiation	B1
(b)(i)	$E = hf$ $1.1 \times 10^6 \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times f$	C1
	$f = 2.7 \times 10^{20} (2.65 \times 10^{20})$ Hz	A1
(b)(ii)	$p = h/\lambda = hf/c$ $= (6.63 \times 10^{-34} \times 2.65 \times 10^{20})/(3.00 \times 10^8)$ **or** $p = E/c$ $= (1.1 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)$	C1
	$p = 5.9 \times 10^{-22}$ (5.87×10^{-22}) N s	A1
(c)	$123 \times 1.66 \times 10^{-27} \times v = 5.87 \times 10^{-22}$	C1
	$v = 2.9 \times 10^3$ m s^{-1}	A1

358. 9702_w17_MS_42 Q: 10

	Answer	Marks
(a)	λ_0 marked and graph line passing through $E_{MAX} = 0$ at $\lambda = \lambda_0$	B1
	graph line with λ always < λ_0	B1
	negative gradient with correct concave curvature	B1
(b)	curve with negative gradient and correct concave curvature	M1
	not touching either axis	A1

359. 9702_w17_MS_43 Q: 11

	Answer	Marks
(a)	packet/quantum of energy of electromagnetic/EM radiation	B1
(b)(i)	$E = hf$ $1.1 \times 10^6 \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times f$	C1
	$f = 2.7 \times 10^{20} (2.65 \times 10^{20})$ Hz	A1
(b)(ii)	$p = h/\lambda = hf/c$ $= (6.63 \times 10^{-34} \times 2.65 \times 10^{20})/(3.00 \times 10^8)$ **or** $p = E/c$ $= (1.1 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)$	C1
	$p = 5.9 \times 10^{-22}$ (5.87×10^{-22}) N s	A1
(c)	$123 \times 1.66 \times 10^{-27} \times v = 5.87 \times 10^{-22}$	C1
	$v = 2.9 \times 10^3$ m s^{-1}	A1

360. 9702_w18_MS_42 Q: 11

	Answer	Marks
(a)	discrete amount/quantum/packet of energy	M1
	of electromagnetic radiation	A1
(b)	mostly dark/dark background	B1
	coloured lines	B1
(c)(i)	6	A1
(c)(ii)	**1.** maximum photon energy = 13.6 – 0.85 (= 12.75 eV)	C1
	maximum kinetic energy = (13.6 – 0.85) – 5.6 = 7.2 eV	A1
	2. energy = hc/λ	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / [(13.6 - 0.85) \times 1.60 \times 10^{-19}]$	C1
	$= 9.8 \times 10^{-8}$ m	A1

361. 9702_s17_MS_41 Q: 11

	Answer	Marks
(a)	electrons (in gas atoms/molecules) interact with photons	B1
	photon energy causes electron to move to higher energy level/to be excited	B1
	photon energy = difference in energy of (electron) energy levels	B1
	when electrons de-excite, photons emitted in all directions (so dark line)	B1
(b)(i)	photon energy $\propto 1/\lambda$	C1
	energy = 1.68 eV	A1
	or	
	$E = hc/\lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19}$ J	(C1)
	energy = 1.68 eV	(A1)
(b)(ii)	3.4 eV → 1.5 eV 3.4 eV → 0.85 eV 3.4 eV → 0.54 eV *all correct and none incorrect 2/2* *2 correct and 1 incorrect or only 2 correctly drawn 1/2*	B2

362. 9702_s17_MS_42 Q: 11

	Answer	Marks
(a)	loss of (electric) potential energy = gain in kinetic energy **or** $qV = ½ mv^2$ **or** $E_K = p^2 / 2m = qV$	**B1**
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	**B1**
(b)(i)	particle/electron has a wavelength (associated with it)	**B1**
	dependent on its momentum **or** when/because particle is moving	**B1**
(b)(ii)	$p = (2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2}$	**C1**
	$\lambda = (6.63 \times 10^{-34}) / (5.91 \times 10^{-24})$	**C1**
	$= 1.12 \times 10^{-10}$ m	**A1**
(c)	wavelength is similar to separation of atoms	**M1**
	so diffraction observed	**A1**

363. 9702_s17_MS_43 Q: 11

	Answer	Marks
(a)	electrons (in gas atoms/molecules) interact with photons	**B1**
	photon energy causes electron to move to higher energy level/to be excited	**B1**
	photon energy = difference in energy of (electron) energy levels	**B1**
	when electrons de-excite, photons emitted in all directions (so dark line)	**B1**
(b)(i)	photon energy $\propto 1 / \lambda$	**C1**
	energy = 1.68 eV	**A1**
	or	
	$E = hc / \lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19}$ J	**(C1)**
	energy = 1.68 eV	**(A1)**
(b)(ii)	3.4 eV → 1.5 eV 3.4 eV → 0.85 eV 3.4 eV → 0.54 eV *all correct and none incorrect 2/2* *2 correct and 1 incorrect or only 2 correctly drawn 1/2*	**B2**

364. 9702_w16_MS_42 Q: 12

(a) (i)	electron diffraction/electron microscope (allow other sensible suggestions)	B1	[1]
(ii)	photoelectric effect/Compton scattering (allow other sensible suggestions)	B1	[1]
(b) (i)	arrow clear from –0.54 eV to –3.40 eV	B1	[1]
(ii)	$E = hc/\lambda$ *or* $E = hf$ and $c = f\lambda$	C1	
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / [(3.40 - 0.54) \times 1.60 \times 10^{-19}] = 4.35 \times 10^{-7}$ m	A1	[2]
(c) (i)	wavelength associated with a particle	M1	
	that is moving/has momentum/has speed/has velocity	A1	[2]
(ii)	$\lambda = h/mv$		
	$v = (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 4.35 \times 10^{-7})$	C1	
	$= 1.67 \times 10^{3}$ m s^{-1}	A1	[2]

365. 9702_s20_MS_41 Q: 10

	Answer	Marks
(a)	• photon gives energy to electron (in an inner shell) **or** electron (in an inner shell) absorbs a photon • electron moves (from lower) to higher energy level • energy (of photon) is equal to difference in energy levels • electron de-excites giving off photon (of same energy) • photons emitted in all directions *Any four points, 1 mark each*	**B4**
(b)	(in light) photons gives energy to electrons in VB **or** (in light) electrons in VB absorb photons	**B1**
	electron crosses FB/jumps to CB	**B1**
	(positive) holes left/created in VB	**B1**
	low intensity: few electrons in CB/most electrons in VB **or** high intensity: more photons so more electrons in CB **or** electron-hole pairs are charge carriers	**B1**
	more charge carriers results in lower resistance	**B1**

366. 9702_s20_MS_42 Q: 11

	Answer	Marks
(a)	conduction band and valence band overlap	B1
	number (density) of charge carriers does not vary	B1
	increase in temperature gives rise to increased lattice vibrations	B1
	(lattice) vibrations hinder movement of charge carriers so resistance increases	B1
(b)	$mv = h / \lambda$	C1
	$v = (6.63 \times 10^{-34}) / [(2.6 \times 10^{-11}) \times (9.11 \times 10^{-31})]$ $(= 2.80 \times 10^{7}\ \text{m s}^{-1})$	C1
	$qV = ½mv^2$	C1
	$V = [9.11 \times 10^{-31} \times (2.80 \times 10^{7})^2] / [2 \times 1.60 \times 10^{-19}]$ $= 2.2 \times 10^{3}\ \text{V}$	A1

367. 9702_s20_MS_43 Q: 10

	Answer	Marks
(a)	• photon gives energy to electron (in an inner shell) **or** electron (in an inner shell) absorbs a photon • electron moves (from lower) to higher energy level • energy (of photon) is equal to difference in energy levels • electron de-excites giving off photon (of same energy) • photons emitted in all directions *Any four points, 1 mark each*	B4
(b)	(in light) photons gives energy to electrons in VB **or** (in light) electrons in VB absorb photons	B1
	electron crosses FB/jumps to CB	B1
	(positive) holes left/created in VB	B1
	low intensity: few electrons in CB/most electrons in VB **or** high intensity: more photons so more electrons in CB **or** electron-hole pairs are charge carriers	B1
	more charge carriers results in lower resistance	B1

368. 9702_m19_MS_42 Q: 11

	Answer		Marks
(a)	quantum / packet / discrete amount of energy		M1
	of electromagnetic radiation		A1
(b)	$E = hc / \lambda$		C1
	$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (540 \times 10^{-9})$		C1
	$= (3.68 \times 10^{-19}) / (1.6 \times 10^{-19})$ $= 2.3\ \text{eV}$		A1
(c)	Any 4 from: photon absorbed by electron in valence band	(1)	B4
	photon energy > energy of forbidden band	(1)	
	electron promoted to conduction band	(1)	
	hole left in valence band	(1)	
	more charge carriers so lower resistance	(1)	

369. 9702_w19_MS_42 Q: 10

	Answer	Marks
(a)	(as temperature rises) electrons in valence band gain energy	B1
	electrons jump to conduction band	B1
	holes are left in the valence band	B1
	increased number (density) of charge carriers causes lower resistance	B1
(b)(i)	$V^- = V^+$	C1
	$1.50 / 1.20 = R_T / 1.76$	C1
	$R_T = 2.2$ (kΩ)	C1
	temperature = 14 °C	A1
(b)(ii)	(For LED to conduct,) V_{OUT} must be negative	B1
	$V^- > V^+$	B1
	R_T must be lower so temperature must be above **(b)(i)** value	B1

370. 9702_m18_MS_42 Q: 11

	Answer	Marks
(a)	no forbidden band / valence and conduction bands overlap	B1
	no change in number of charge carriers (as temperature rises)	B1
	increased lattice vibrations so resistance increases	B1
(b)	photons captured / absorbed by electrons in valence band	B1
	electrons promoted to conduction band	B1
	leaving holes in the valence band	B1
	more holes and / or electrons so resistance decreases	B1

371. 9702_s18_MS_41 Q: 11

	Answer	Marks
(a)(i)	packet/quantum/discrete amount of energy	M1
	of electromagnetic radiation	A1
(a)(ii)	(maximum) energy of emitted electrons is independent of intensity **or** no emission of electrons below the threshold frequency regardless of intensity **or** no emission of electrons when photon energy is less than work function (energy) regardless of intensity	B1
(b)	in darkness: conduction band empty so high resistance	B1
	in daylight: electrons in valence band absorb photons	B1
	in daylight: electrons 'jump' to conduction band	B1
	this leaves holes in valence band	B1
	more charge carriers in daylight so resistance decreases	B1

372. 9702_s18_MS_43 Q: 11

	Answer	Marks
(a)(i)	packet/quantum/discrete amount of energy	M1
	of electromagnetic radiation	A1
(a)(ii)	(maximum) energy of emitted electrons is independent of intensity **or** no emission of electrons below the threshold frequency regardless of intensity **or** no emission of electrons when photon energy is less than work function (energy) regardless of intensity	B1
(b)	in darkness: conduction band empty so high resistance	B1
	in daylight: electrons in valence band absorb photons	B1
	in daylight: electrons 'jump' to conduction band	B1
	this leaves holes in valence band	B1
	more charge carriers in daylight so resistance decreases	B1

373. 9702_w18_MS_41 Q: 10

	Answer	Marks
	Any five points from: • as temperature rises electrons gain energy • electrons enter conduction band • (positively charged) holes left in valence band • more charge carriers (so resistance decreases) • (as temperature rises,) lattice vibrations increase • effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)	B5

374. 9702_w18_MS_43 Q: 10

	Answer	Marks
	Any five points from: • as temperature rises electrons gain energy • electrons enter conduction band • (positively charged) holes left in valence band • more charge carriers (so resistance decreases) • (as temperature rises,) lattice vibrations increase • effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)	B5

375. 9702_m17_MS_42 Q: 11

	Answer	Marks
	any **five** from: • electrons need energy to enter conduction band (from valence band) • (positively-charged) holes are left in valence band • moving charge carriers / holes / electrons are current • (increase of temperature leads to) more (positive and negative) charge carriers / more holes / more electrons so more current • more charge carriers / holes / electrons gives rise to less resistance • (increase of temperature causes) greater (amplitude of) vibrations of atoms / ions / lattice • effect of more charge carriers/holes/electrons is greater than effect of greater vibrations (and so resistance decreases)	B5

376. 9702_w16_MS_41 Q: 11

in metal, conduction band overlaps valence band/no forbidden band/no band gap	B1	
as temperature rises, no increase in number of free electrons/charge carriers	B1	
as temperature rises, lattice vibrations increase	M1	
(lattice) vibrations restrict movement of electrons/charge carriers	M1	
(current decreases) so resistance increases	A1	[5]

377. 9702_w16_MS_43 Q: 11

in metal, conduction band overlaps valence band/no forbidden band/no band gap	B1	
as temperature rises, no increase in number of free electrons/charge carriers	B1	
as temperature rises, lattice vibrations increase	M1	
(lattice) vibrations restrict movement of electrons/charge carriers	M1	
(current decreases) so resistance increases	A1	[5]

378. 9702_m21_MS_42 Q: 11

	Answer	Marks
(a)(i)	electrons decelerate (on hitting target) so X-ray photons produced	B1
	range of decelerations	B1
	photon energy depends on (magnitude of) deceleration	B1
(a)(ii)	$eV = \frac{hc}{\lambda}$	C1
	$\lambda = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.6\times10^{-19}\times15000}$	C1
	$= 8.3\times10^{-11} m$	A1
	or *E* = *hf* <u>and</u> *c* = *f*λ <u>and</u> electron energy = eV *or* *E* = *hc* / λ <u>and</u> electron energy = eV electron energy = $1.6 \times 10^{-19} \times 15000$ $= 2.4 \times 10^{-15}$	(C1)
	$\lambda = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{2.4\times10^{-15}}$	(C1)
	$\lambda = 8.3\times10^{-11} m$	(A1)
(b)(i)	μ = – gradient *or* $\ln (I / I_0) = -\mu x$	C1
	(e.g. 2.08 / 10.0) = **0.21** cm^{-1}	A1

	Answer	Marks
(b)(ii)	$\ln(0.05) = -\mu x$	C1
	$x = \frac{\ln 0.05}{-\mu}$ e.g. $x = 14\,cm$	A1

379. 9702_s21_MS_41 Q: 11

	Answer	Marks
(a)	intensity: vary filament current/p.d. across filament	B1
	hardness: vary accelerating potential difference	B1
(b)(i)	$I = I_0 e^{-\mu x}$	C1
	$I_S = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4}\,I_0$	A1
(b)(ii)	$I_C = [\exp(-0.92 \times 6.0) \times \exp(-2.9 \times 3.0)]\,I_0$	C1
	$= 6.7 \times 10^{-7}\,I_0$	A1
(c)	conclusion consistent with values in **(b)(i)** and **(b)(ii)** e.g. $I_S \gg I_C$ so good contrast	B1

380. 9702_s21_MS_43 Q: 11

	Answer	Marks
(a)	intensity: vary filament current/p.d. across filament	B1
	hardness: vary accelerating potential difference	B1
(b)(i)	$I = I_0 e^{-\mu x}$	C1
	$I_S = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4}\,I_0$	A1
(b)(ii)	$I_C = [\exp(-0.92 \times 6.0) \times \exp(-2.9 \times 3.0)]\,I_0$	C1
	$= 6.7 \times 10^{-7}\,I_0$	A1
(c)	conclusion consistent with values in **(b)(i)** and **(b)(ii)** e.g. $I_S \gg I_C$ so good contrast	B1

381. 9702_w21_MS_41 Q: 11

	Answer	Marks
(a)(i)	ease with which edges can be distinguished	B1
(a)(ii)	difference in degrees of blackening	B1
(b)	$I = I_0 \exp(-\mu x)$	C1
	$0.12 = \exp(-\mu \times 2.3)$ $\ln 0.12 = -2.3 \times \mu$	C1
	$\mu = 0.92\ \text{cm}^{-1}$	A1
(c)	advantage: produces 3-dimensional image	B1
	disadvantage: (much) greater exposure to radiation	B1

382. 9702_w21_MS_43 Q: 11

	Answer	Marks
(a)(i)	ease with which edges can be distinguished	B1
(a)(ii)	difference in degrees of blackening	B1
(b)	$I = I_0 \exp(-\mu x)$	C1
	$0.12 = \exp(-\mu \times 2.3)$ $\ln 0.12 = -2.3 \times \mu$	C1
	$\mu = 0.92\ \text{cm}^{-1}$	A1
(c)	advantage: produces 3-dimensional image	B1
	disadvantage: (much) greater exposure to radiation	B1

383. 9702_m20_MS_42 Q: 11

	Answer	Marks
(a)	$eV = hf$ $f = 1.60 \times 10^{-19} \times 100\,000 / 6.63 \times 10^{-34}$	C1
	$= \mathbf{2.41 \times 10^{19}}$ Hz	A1
(b)	(aluminium filter) absorbs (most) low energy X-rays	B1
	Any 2 from • X-ray beam contains many wavelengths • so low energy X-rays are not absorbed in the body • low energy X-rays can can cause harm but do not contribute to the image	B2
(c)(i)	$I / I_0 = e^{-\mu x}$ $e^{-0.23 \times 0.80} = 0.83$	C1
	17% absorbed	A1
(c)(ii)	bone is seen as lighter / muscle is seen as darker	B1
	either bone has a higher μ value so absorbs more *or* muscle has a lower μ value so transmits more	B1

384. 9702_m19_MS_42 Q: 9

	Answer	Marks
	X-rays (are used)	B1
	(object is) scanned in sections / slices	B1
	either: scans taken at many angles / directions *or* images of each section / slice are 2-dimensional	B1
	scans of many sections / slices are combined	B1
	(to give) 3-dimensional image (of whole structure)	B1

385. 9702_w19_MS_42 Q: 7

	Answer	Marks
	X-rays are used	B1
	section (of object) is scanned	B1
	scans/images taken at many angles/directions **or** images of each section are 2-dimensional	B1
	images of (many) sections are combined	B1
	(to give) 3-dimensional image of (whole) structure	B1

386. 9702_m18_MS_42 Q: 12

	Answer	Marks
(a)	Any 2 from: scattering of X-ray beam / no lead grid lack of collimation of beam / aperture large anode area large beam p.d. low / photon energy low / X-ray soft	B2
(b)(i)	$0.81 = (e^{-1.5 \times 0.32}) / (e^{-1.5 \times x})$	C1
	x = **1.8** mm	A1
(b)(ii)	ratio/dB = 10 lg(0.81)	C1
	= (–) **0.92** dB	A1

387. 9702_s18_MS_41 Q: 12

	Answer	Marks
(a)(i)	$I = I_0 e^{-\mu x}$	C1
	$= I_0 \exp(-0.90 \times 2.8)$ $= 0.080 I_0$	A1
(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	C1
	$= I_0 (0.259 \times 0.20)$ $= 0.0052 I_0$	A1
(b)(i)	difference in degrees of blackening	M1
	between structures	A1
(b)(ii)	large difference in intensities so good contrast	B1

388. 9702_s18_MS_42 Q: 11

	Answer	Marks
(a)	X-ray image(s) taken of one slice	M1
	(many images) taken from different angles	A1
	(computer) produces 2D image of slice	B1
	(this is) repeated for (many) slices	M1
	to build up a 3D image (of structure)	A1
(b)(i)	combining of images involves (very) large number of calculations	B1
(b)(ii)	CT scan consists of (very) many (single X-ray) images	B1

389. 9702_s18_MS_43 Q: 12

	Answer	Marks
(a)(i)	$I = I_0 e^{-\mu x}$	C1
	$= I_0 \exp(-0.90 \times 2.8)$ $= 0.080 I_0$	A1
(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	C1
	$= I_0\ (0.259 \times 0.20)$ $= 0.0052 I_0$	A1
(b)(i)	difference in degrees of blackening	M1
	between structures	A1
(b)(ii)	large difference in intensities so good contrast	B1

390. 9702_w18_MS_42 Q: 10

	Answer	Marks
(a)	$V_0 = \sqrt{2} \times V_{r.m.s.} = \sqrt{2} \times 9.9$ (= 14 V) **and** $\omega = 2\pi f = 2\pi \times 50$ (= 314 rad s^{-1})	C1
	$V = 14 \sin 314t$	A1
(b)	enables (resonating) nuclei to be located	B1
	resonant frequency depends on magnetic field strength	B1
	Any one from: • non-uniform field is (accurately) calibrated • (non-uniform) field may be varied to enable detection in different positions • unique (magnetic) field strength/frequency at each point	B1
(c)	$I = I_0 \exp(-\mu x)$	C1
	$I = I_0\ [\exp(-\mu x)_{bone} \times \exp(-\mu x)_{soft\ tissue}]$ $I = I_0\ [\exp(-2.9 \times 0.40) \times \exp(-0.92 \times 1.4)]$	C1
	$I / I_0 = 0.0865$	C1
	ratio / dB = 10 lg 0.0865 = –11 dB	A1

391. 9702_s17_MS_41 Q: 10

	Answer	Marks
(a)(i)	penetration of beam	M1
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	A1
(a)(ii)	greater accelerating potential difference **or** greater p.d. between anode and cathode	B1
(b)	$I = I_0 \exp(-\mu x)$ ratio = (exp {–1.5 × 2.9}) / (exp {–4.0 × 0.95}) (= exp {–0.55})	C1
	= 0.58	A1

392. 9702_s17_MS_43 Q: 10

	Answer	Marks
(a)(i)	penetration of beam	M1
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	A1
(a)(ii)	greater accelerating potential difference **or** greater p.d. between anode and cathode	B1
(b)	$I = I_0 \exp(-\mu x)$ ratio = (exp {–1.5 × 2.9}) / (exp {–4.0 × 0.95}) (= exp {–0.55})	C1
	= 0.58	A1

393. 9702_w17_MS_41 Q: 9

	Answer	Marks
(a)	image of one slice/section	(B1)
	images (of one slice) taken from different angles	(M1)
	to give 2D image (of one slice)	(A1)
	(repeated for) many slices	(M1)
	to build up 3D image (of whole body/structure)	(A1)
	Max. 4 marks total	4
(b)	evidence of subtraction of background (–26)	C1
	evidence of division by three	C1
	7	11 6	2	A1

394. 9702_w17_MS_43 Q: 9

	Answer	Marks
(a)	image of one slice/section	(B1)
	images (of one slice) taken from different angles	(M1)
	to give 2D image (of one slice)	(A1)
	(repeated for) many slices	(M1)
	to build up 3D image (of whole body/structure)	(A1)
	Max. 4 marks total	4
(b)	evidence of subtraction of background (–26)	C1
	evidence of division by three	C1
	7 11 / 6 2	A1

7	11
6	2

395. 9702_m16_MS_42 Q: 12

(a) **(i)** the penetration of the beam B1 [1]

(ii) *either* decrease the accelerating voltage
or decrease voltage between cathode and anode B1 [1]

(b) advantage: image gives depth / image is 3D / final image can be viewed from any angle B1
disadvantage: greater exposure / more risk to health / more expensive / person must remain stationary B1 [2]

396. 9702_w16_MS_42 Q: 13

X-ray image of a (single) slice/cross-section (through the patient) M1
taken from different angles/rotating X-ray (beam) A1

computer is used to form/process/build up/store image B1
2D image (of the slice) B1

repeated for many/different (neighbouring) slices M1
to build up 3D image A1 [6]

397. 9702_s20_MS_41 Q: 11

	Answer	Marks
(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$ $= 8.2 \times 10^{-14}$ J	A1
(a)(ii)	$p = h / \lambda$ **and** $E = hc / \lambda$ **or** $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$ $= 2.7 \times 10^{-22}$ N s	A1
(b)	total momentum (before and after interaction) is zero **or** momentum must be conserved (in the interaction) **or** momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

398. 9702_s20_MS_42 Q: 12

	Answer	Marks
(a)	difference between mass of nucleus and mass of (constituent) nucleons	M1
	where nucleons are separated to infinity	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934$ MeV	A1
(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ (= 0.030376)	B1
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09$ MeV	A1
(c)	binding energy per nucleon is much greater	M1
	so would require a large amount of energy to separate the nucleons in helium	A1
	or	
	amount of energy released in forming hydrogen isotopes	(M1)
	is less than energy required to break apart helium nucleus	(A1)

399. 9702_s20_MS_43 Q: 11

	Answer	Marks
(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$ $= 8.2 \times 10^{-14}$ J	A1
(a)(ii)	$p = h / \lambda$ **and** $E = hc / \lambda$ **or** $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$ $= 2.7 \times 10^{-22}$ N s	A1
(b)	total momentum (before and after interaction) is zero **or** momentum must be conserved (in the interaction) **or** momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

400. 9702_m19_MS_42 Q: 12

	Answer	Marks
(a)(i)	fission	B1
(a)(ii)	*either* ${}^{0}_{-1}\text{e}$ *or* ${}^{0}_{-1}\beta$	M1
	7	A1
(b)(i)	energy $= c^2 \Delta m$ $= 0.223 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	C1
	$= 3.33 \times 10^{-11}$ J	A1

	Answer	Marks
(b)(ii)	Any 2 from: kinetic energy of products gamma photons neutrinos	B2

401. 9702_w19_MS_41 Q: 12

	Answer	Marks
(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27}$ (= 1.49×10^{-10} J)	M1
	= $(1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8$ = 934 MeV	A1
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	(M1)
	binding energy / mass defect = $(8.443 \times 95) / 0.859$ = 934 MeV	(A1)
(b)(i)	binding energy = 1.865×934 (= 1741.91 MeV)	C1
	binding energy per nucleon = 1741.91 / 235 = 7.41 (MeV)	A1
(b)(ii)	less (than)	B1
(c)	energy = $\{(1.219 + 0.859) - 1.865)\} \times 934$ **or** energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	C1
	= 199 MeV	A1
(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ = 7.22×10^{16}	C1
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13}$ (= 3.18×10^{-11} J)	C1
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ = 9.2×10^7 W	A1

402. 9702_w19_MS_43 Q: 12

	Answer	Marks
(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27}$ (= 1.49×10^{-10} J)	M1
	= $(1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8$ = 934 MeV	A1
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	(M1)
	binding energy / mass defect = $(8.443 \times 95) / 0.859$ = 934 MeV	(A1)
(b)(i)	binding energy = 1.865×934 (= 1741.91 MeV)	C1
	binding energy per nucleon = 1741.91 / 235 = 7.41 (MeV)	A1
(b)(ii)	less (than)	B1
(c)	energy = $\{(1.219 + 0.859) - 1.865\} \times 934$ **or** energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	C1
	= 199 MeV	A1
(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ = 7.22×10^{16}	C1
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13}$ (= 3.18×10^{-11} J)	C1
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ = 9.2×10^7 W	A1

403. 9702_m18_MS_42 Q: 3

	Answer	Marks
(a)	reasonably shaped circle or oval surrounding the origin	B1
	closed loop passing through $(0,\pm v_0)$ and $(\pm x_0,0)$	B1
(b)	line from (0,0) to (90, F_0)	B1
	curve with decreasing positive gradient, zero gradient at θ = 90	B1
(c)	reasonable sinusoidal wave, one cycle, period 4.0 ms	B1
	amplitude at 4.0 V	B1
(d)	U near right-hand end of line with Ba between U and peak of graph	B1
	Ba on right hand side of peak and Kr between Ba and peak of graph	B1

404. 9702_w18_MS_41 Q: 11

	Answer	Marks
(a)	discrete amount/quantum/packet of energy	M1
	of electromagnetic radiation	A1
(b)(i)	energy = hc/λ	C1
	λ = $(6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (0.51 \times 10^{6} \times 1.60 \times 10^{-19})$ = 2.4×10^{-12} m	A1
(b)(ii)	$p = h/\lambda$ = $(6.63 \times 10^{-34}) / (2.44 \times 10^{-12})$ **or** $p = E/c$ = $(0.51 \times 1.60 \times 10^{-13}) / (3.00 \times 10^{8})$	C1
	$p = 2.7 \times 10^{-22}$ N s	A1
(c)(i)	$E = c^2 \Delta m$	C1
	Δm = $(0.51 \times 1.60 \times 10^{-13}) / (3.00 \times 10^{8})^2$ = 9.1×10^{-31} kg	A1
(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	B1

405. 9702_w18_MS_42 Q: 12

	Answer	Marks
(a)	fusion: two nuclei combine to form a (single) nucleus	B1
	fission: a (single) large nucleus divides to form (smaller) nuclei	B1
	Any one from: • fusion is initiated by (very) high temperatures • fission is initiated by neutron bombardment • resulting nuclei in fission are of similar size • (both processes) release energy • binding energy per nucleon increases • total binding energy increases • fission involves release of neutrons	B1
12(b)(i)	neutron	B1
12(b)(ii)	**1.** zero	A1
	2. $(4 \times 11.3290 \times 10^{-13}) - (2 \times 1.7813 \times 10^{-13}) - (3 \times 4.5285 \times 10^{-13})$	C1
	energy change = $45.316 \times 10^{-13} - 17.148 \times 10^{-13}$ = 2.82×10^{-12} J	A1
(b)(iii)	1.0 mol or N_A nuclei of each energy = $2.817 \times 10^{-12} \times 6.02 \times 10^{23}$ = 1.7×10^{12} J	A1

406. 9702_w18_MS_43 Q: 11

	Answer	Marks
(a)	discrete amount/quantum/packet of energy	M1
	of electromagnetic radiation	A1
(b)(i)	energy = hc/λ	C1
	λ = $(6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(0.51 \times 10^{6} \times 1.60 \times 10^{-19})$ = 2.4×10^{-12} m	A1
(b)(ii)	$p = h/\lambda$ = $(6.63 \times 10^{-34})/(2.44 \times 10^{-12})$ **or** $p = E/c$ = $(0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})$	C1
	$p = 2.7 \times 10^{-22}$ N s	A1
(c)(i)	$E = c^2\Delta m$	C1
	Δm = $(0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^{8})^2$ = 9.1×10^{-31} kg	A1
(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	B1

407. 9702_m17_MS_42 Q: 12

	Answer	Marks
(a)	*either*	
	(minimum) energy required / work done to separate the nucleons (in a nucleus)	M1
	to infinity	A1
	or	
	energy released when nucleons come together (to form a nucleus)	(M1)
	from infinity	(A1)
(b)(i)	(total) binding energy of thorium and helium (nuclei) greater than binding energy of uranium (nucleus)	B1
(b)(ii)1	change in mass = 238.05076 – (234.04357 + 4.00260) = 4.59×10^{-3} u	A1
(b)(ii)2	*either*	
	$E = mc^2$ = $4.59 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^2$	C1
	= 6.9×10^{-13} J	A1
	or	
	1u = 931 MeV E = $4.59 \times 10^{-3} \times 931 \times 10^{6} \times 1.6 \times 10^{-19}$	(C1)
	= 6.8×10^{-13} J	(A1)
(b)(iii)	Th nucleus / He nucleus / product nucleus has kinetic energy	M1
	energy of gamma photon must be less than energy released	A1

408. 9702_s17_MS_41 Q: 12

	Answer	Marks
(a)	$x = 7$	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10}$ J	C1
	division by 1.6×10^{-13} clear to give 934 MeV	A1
(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ **or** $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053$ u	C1
	energy $= 0.21053 \times 934$ $= 197$ MeV	A1
(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ–ray photon energy	B1

409. 9702_s17_MS_42 Q: 12

	Answer	Marks
(a)	$7\,{}^{0}_{-1}e$	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	M1
	$= 1.494 \times 10^{-10}$ J division by 1.60×10^{-13} clear to give 934 MeV	A1
(b)(ii)	$\Delta m = (82 \times 1.00863\text{u}) + (57 \times 1.00728\text{u}) - 138.955\text{u}$ $= (-)\ 1.16762$ (u)	C1
	energy $= 1.16762 \times 934$	C1
	energy per nucleon $= (1.16762 \times 934) / 139$ $= 7.85$ MeV	A1
(c)	above $A = 56$, binding energy per nucleon decreases as A increases	B1
	U-235 has larger nucleon number	M1
	so less (binding energy per nucleon)	A1
	or	
	fission takes place with uranium	(B1)
	fission reaction releases energy	(M1)
	binding energy per nucleon less (for uranium than for products)	(A1)

410. 9702_s17_MS_43 Q: 12

	Answer	Marks
(a)	$x = 7$	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10}$ J	C1
	division by 1.6×10^{-13} clear to give 934 MeV	A1
(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ **or** $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053$ u	C1
	energy $= 0.21053 \times 934$ $= 197$ MeV	A1
(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ–ray photon energy	B1

411. 9702_m16_MS_42 Q: 9

(a) direction of force due to electric field opposite to force due to magnetic field B1
electric field is up the page B1 [2]

(b) force due to electric field = force due to magnetic field or $Eq = Bqv$ B1
$E = Bv$ C1
$= 9.7 \times 10^{-2} \times 1.6 \times 10^5$
$= 1.6\ (1.55) \times 10^4\ \text{V m}^{-1}$ A1 [3]

(c) $q/m = v/Br$ C1
$= 1.6 \times 10^5 / (9.7 \times 10^{-2} \times 4.0 \times 10^{-2})$ C1
$= 4.1\ (4.12) \times 10^7\ \text{C kg}^{-1}$ A1 [3]

(d) **(i)** $m = (3 \times 1.60 \times 10^{-19}) / (4.12 \times 10^7)$ C1
$m = 1.16 \times 10^{-26} / 1.66 \times 10^{-27}$
$= 7(.0)$ u (*allow* 7.1 u) A1 [2]

(ii) 3 protons, 4 neutrons A1 [1]

412. 9702_w16_MS_42 Q: 14

(a) (i) $^{4}_{2}He$ or $^{4}_{2}\alpha$ B1 [1]

(ii) $^{1}_{0}n$ B1 [1]

(b) (i) Δm = (29.97830 +1.00867) – (26.98153 + 4.00260) C1

= 30.98697 – 30.98413

= 2.84×10^{-3} u C1 [2]

(ii) $E = c^2\Delta m$ or mc^2 C1

= $(3.0 \times 10^8)^2 \times 2.84 \times 10^{-3} \times 1.66 \times 10^{-27}$

= 4.2×10^{-13} J A1 [2]

(c) mass of products is greater than mass of A*l* plus α
or
reaction causes (net) increase in (rest) mass (of the system) B1

α-particle must have at least this amount of kinetic energy B1 [2]

413. 9702_m21_MS_42 Q: 12

	Answer	Marks
(a)	1 not affected by external factors	B1
	2 cannot predict when a (particular) nucleus will decay *or* cannot predict which nucleus will decay (next)	B1
(b)(i)	Number of atoms = $\dfrac{1.0\times10^{-9}}{90\times1.66\times10^{-27}}$ *or* $\dfrac{1.0\times10^{-9}\times6.02\times10^{23}}{90\times10^{-3}}$ $=6.693\times10^{15}$	C1
	$A = \lambda N$ $\lambda = \dfrac{5.2\times10^{6}}{6.693\times10^{15}}$	C1
	$\lambda = 7.8\times10^{-10}$ s^{-1}	A1
(b)(ii)	daughter nucleus is unstable	B1

414. 9702_s21_MS_41 Q: 6

	Answer	Marks
(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through ($2r$, $E_0 / 4$) and ($3r$, $E_0 / 9$)	B1
(b)	from $p = p_0 / 2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through (½p_0, 2λ_0)	B1
(c)	from $t = 0$ to $t = 45$ s: curve with positive gradient of decreasing magnitude starting at (0, 0)	B1
	line passing through (15, ½N_0)	B1
	line passing through (30, 0.75N_0) <u>and</u> (45, 0.88N_0)	B1

415. 9702_s21_MS_42 Q: 5

	Answer	Marks
(a)	from $x = 0$ to $x = r$: horizontal line at $V = 1.0V_0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude starting at (r, 1.0V_0)	B1
	line passing through ($2r$, ½V_0) and ($3r$, ⅓V_0)	B1
(b)	line with negative gradient from λ = ⅓λ_0 to $\lambda = \lambda_0$	B1
	line passing through (λ_0, 0)	B1
	curve with negative gradient of decreasing magnitude passing through (½λ_0, E_{MAX}) and (⅓λ_0, 2E_{MAX})	B1
(c)	1.0$T_{½}$ shown at ½N_0 **and** 2.0$T_{½}$ shown at ¼N_0	B1
	line starting at (0, 0) and reaching (T, N_0–N)	B1
	line starting at (0, 0) and reaching original curve at (1.0$T_{½}$, ½N_0)	B1

416. 9702_s21_MS_43 Q: 6

	Answer	Marks
(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through ($2r$, $E_0 / 4$) and ($3r$, $E_0 / 9$)	B1
(b)	from $p = p_0 / 2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through (½p_0, 2λ_0)	B1
(c)	from $t = 0$ to $t = 45$ s: curve with positive gradient of decreasing magnitude starting at (0, 0)	B1
	line passing through (15, ½N_0)	B1
	line passing through (30, 0.75N_0) <u>and</u> (45, 0.88N_0)	B1

417. 9702_w21_MS_41 Q: 12

	Answer	Marks
(a)	probability of decay (of a nucleus)	**M1**
	per unit time	**A1**
(b)	$A = \lambda N$	**C1**
	N = mass / (nucleon number × u)	**C1**
	$2.92 \times 10^{9} = (\lambda \times 5.87 \times 10^{-10}) / (131 \times 1.66 \times 10^{-27})$ $\lambda = 1.08 \times 10^{-6}$ s^{-1}	**A1**
(c)	• sample emits radiation in all directions • some radiation is absorbed by air/detector window • self-absorption within the source • dead time/inefficiency of detector *Any two points, 1 mark each*	**B2**

418. 9702_w21_MS_42 Q: 12

	Answer	Marks
(a)(i)	cannot predict when a particular nucleus will decay **or** cannot predict which nucleus will decay next	**B1**
(a)(ii)	(decay is) not affected by external (environmental) factors	**B1**
(b)(i)	$A = A_0 \exp(-\lambda t)$ and so $\ln A = \ln A_0 - \lambda t$ gradient of line = (–)λ	**C1**
	λ = (36.4 – 35.0) / (20 – 0) (= 0.07(0) min^{-1})	**C1**
	half-life = ln 2 / λ = ln 2 / 0.070 = 10 min	**A1**
	or	
	$A_0 = \exp(-36.4) = 6.43 \times 10^{15}$ (Bq)	**(C1)**
	$A_0 / 2 = 3.21 \times 10^{15}$ (Bq), so $\ln(A_0/2) = 35.7$	**(C1)**
	read off half-life = 10 min	**(A1)**
	or	
	(at one half-life,) ln A = 36.4 – ln 2	**(C1)**
	= 35.7	**(C1)**
	read off half-life = 10 min	**(A1)**

	Answer	Marks
(b)(ii)	$A = \lambda N$	C1
	N = mass / (nucleon number × u) **or** N = (mass / nucleon number) × N_A	C1
	exp(36.4) = (1.17 × 10^{-3} × 5.66 × 10^{-7}) / (nucleon number × 1.66 × 10^{-27}) **or** exp(36.4) = (1.17 × 10^{-3} × 5.66 × 10^{-4} × 6.02 × 10^{23}) / nucleon number nucleon number = 62	A1

419. 9702_w21_MS_43 Q: 12

	Answer	Marks
(a)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	N = mass / (nucleon number × u)	C1
	2.92 × 10^9 = (λ × 5.87 × 10^{-10}) / (131 × 1.66 × 10^{-27}) λ = 1.08 × 10^{-6} s^{-1}	A1
(c)	• sample emits radiation in all directions • some radiation is absorbed by air/detector window • self-absorption within the source • dead time/inefficiency of detector *Any two points, 1 mark each*	B2

420. 9702_m20_MS_42 Q: 12

	Answer	Marks
(a)	(minimum) energy required to separate the nucleons	M1
	to infinity	A1
(b)(i)	**37** **2**	B1
(b)(ii)	fission	B1
(b)(iii)	binding energy per nucleon smaller for U than for Cs	B1
(c)	Current ratio 2 Y to 1 Zr, so initially 3 Y 2 = 3 $e^{-\lambda t}$ λ = 0.693 / 2.7	C1
	ln(2 / 3) = – (ln 2 / 2.7)t	C1
	t = **1.6** days	A1
	or	
	$(½)^n$ = 2 / 3	(C1)
	n = 0.585	(C1)
	time = 0.585 × 2.7 = **1.6** days	(A1)

421. 9702_s20_MS_41 Q: 12

	Answer	Marks
(a)(i)	time at which a nucleus will decay cannot be predicted **or** constant probability of decay of a nucleus	**B1**
(a)(ii)	decay (of a nucleus) not affected by environmental factors	**B1**
(b)	$A = A_0 e^{-\lambda t}$ **and** $\lambda = \ln 2 / t_{½}$	**C1**
	$= 3.6 \times 10^5 \times \exp[-(2 \times \ln 2) / 1.4]$	**C1**
	or	
	$A = A_0 \times 0.5^N$	**(C1)**
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	**(C1)**
	$A = 1.3 \times 10^5$ Bq	**A1**
(c)(i)	smooth curve, starting at (0, 3.6×10^5) and passing through (1.4, 1.8×10^5) and (2.0, 1.3×10^5)	**B1**
(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	**C1**
	the decay product (of isotope X) is radioactive	**A1**

422. 9702_s20_MS_43 Q: 12

	Answer	Marks
(a)(i)	time at which a nucleus will decay cannot be predicted **or** constant probability of decay of a nucleus	**B1**
(a)(ii)	decay (of a nucleus) not affected by environmental factors	**B1**
(b)	$A = A_0 e^{-\lambda t}$ **and** $\lambda = \ln 2 / t_{½}$	**C1**
	$= 3.6 \times 10^5 \times \exp[-(2 \times \ln 2) / 1.4]$	**C1**
	or	
	$A = A_0 \times 0.5^N$	**(C1)**
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	**(C1)**
	$A = 1.3 \times 10^5$ Bq	**A1**
12(c)(i)	smooth curve, starting at (0, 3.6×10^5) and passing through (1.4, 1.8×10^5) and (2.0, 1.3×10^5)	**B1**
(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	**C1**
	the decay product (of isotope X) is radioactive	**A1**

423. 9702_s19_MS_41 Q: 12

	Answer	Marks
(a)(i)	$\Delta N / \Delta T$	**B1**
(a)(ii)	$\Delta N / N$	**B1**
(a)(iii)	$\Delta N / (N \Delta T)$	**B1**
(b)(i)	**1.** mass change = 5.60×10^{-3} u	**A1**
	2. energy $= (\Delta)mc^2$	**C1**
	$= 5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $(= 8.36 \times 10^{-13}$ J)	**C1**
	= 0.84 pJ	**A1**
(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	**B1**
	energy of γ-ray photon	**B1**

424. 9702_s19_MS_42 Q: 12

	Answer	Marks
(a)	energy required to separate the nucleons (in a nucleus)	M1
	to infinity	A1
	or	
	energy released when nucleons come together (to form nucleus)	(M1)
	from infinity	(A1)
(b)	mass defect = 140.911 – (57 × 1.007) – (84 × 1.009)	C1
	= 140.911 – 142.155 = (–)1.244 (u)	C1
	energy = $c^2(\Delta)m$	C1
	= $(3.00 \times 10^8)^2 \times 1.244 \times 1.66 \times 10^{-27}$ = 1.9×10^{-10} J	A1
(c)(i)	$A = A_0e^{-\lambda t}$ **and** $\ln 2 = \lambda t_{½}$	C1
	0.40 = exp(–ln 2 × t / 3.9)	C1
	or	
	$(0.5)^n = 0.40$	(C1)
	n = 1.32 **and** t = 1.32 × 3.9	(C1)
	t = 5.2 hours	A1
(c)(ii)	daughter product may be radioactive **or** random nature of decay	B1

425. 9702_s19_MS_43 Q: 12

	Answer	Marks
(a)(i)	$\Delta N / \Delta T$	B1
(a)(ii)	$\Delta N / N$	B1
(a)(iii)	$\Delta N / (N \Delta T)$	B1
(b)(i)	**1.** mass change = 5.60×10^{-3} u	A1
	2. energy = $(\Delta)mc^2$	C1
	= $5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ (= 8.36×10^{-13} J)	C1
	= 0.84 pJ	A1
(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ-ray photon	B1

426. 9702_w19_MS_42 Q: 12

	Answer	Marks
(a)(i)	(decay is) unpredictable/cannot be predicted	B1
(a)(ii)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	(for 1.00 m^3) $A = 0.600 / 4.80 \times 10^{-3}$ (= 125 Bq)	C1
	$N = 125 / ([7.55 \times 10^{-3}] / 3600)$ (= 5.96×10^7)	C1
	so ratio = $(2.52 \times 10^{25}) / (5.96 \times 10^7)$	C1
	or	
	(for 4.80×10^{-3} m^3) N for air = $2.52 \times 10^{25} \times 4.80 \times 10^{-3}$ (= 1.21×10^{23})	(C1)
	N for radon = $0.600 / ([7.55 \times 10^{-3}] / 3600)$ (= 2.86×10^5)	(C1)
	so ratio = $(1.21 \times 10^{23}) / (2.86 \times 10^5)$	(C1)
	ratio = 4.2×10^{17}	A1

427. 9702_m18_MS_42 Q: 13

	Answer	Marks
(a)(i)	probability of decay (of a nucleus)	M1
	per unit time	A1
(a)(ii)	$A = A_0 e^{-\lambda t}$ after one half-life, $½A_0 = A_0 e^{-\lambda t1/2}$	M1
	$½ = \exp(-\lambda t_{½})$ and hence taking logs, $\ln 2 = \lambda t_{½}$	A1
(b)	activity = $3.8 \times 10^4 \exp(-\ln 2 \times 36 / 15)$	C1
	= 7200 Bq	C1
	or activity = $3.8 \times 10^4 / 2^{2.4}$	(C1)
	= 7200 Bq	(C1)
	volume = $(7200 / 1.2) \times 5.0$	C1
	= 3.0×10^4 cm^3	A1
	OR activity of 5.0 cm^3 = $1.2 \times 2^{2.4}$	(C1)
	= 6.3336 Bq	(C1)
	volume = $(3.8 \times 10^4 / 6.3336) \times 5.0$	(C1)
	= 3.0×10^4 cm^3	(A1)

428. 9702_s18_MS_41 Q: 13

	Answer	Marks
(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60)$ (s^{-1})	C1
	N at 14 minutes $= 4.4 \times 10^7$ **and** $A = \lambda N$	C1
	activity $= 4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ $= 3.6 \times 10^4$ Bq	A1
	or	
	correct tangent drawn at time t = 14 minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity $= 3.6 \times 10^4$ Bq	(A1)
(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ **or** $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4}\ s^{-1}$	A1

429. 9702_s18_MS_42 Q: 12

	Answer	Marks
(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	P – the curve that starts with a high number D – the curve with the peak S – the curve that increases from zero throughout *(one correct 1 mark, all three correct 2 marks)*	B2
(b)(ii)	$\lambda t_{½} = 0.693$ $\lambda = 0.693 / (60.0 \times 60)$	C1
	$= 1.93 \times 10^{-4}\ s^{-1}$	A1
(c)	half-life of F is much shorter than half-life of E	B1
	nuclei of F decay (almost) as soon as they are produced	B1

430. 9702_s18_MS_43 Q: 13

	Answer	Marks
(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60)$ (s^{-1})	C1
	N at 14 minutes = 4.4×10^7 **and** $A = \lambda N$	C1
	activity $= 4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ $= 3.6 \times 10^4$ Bq	A1
	or	
	correct tangent drawn at time t = 14 minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = 3.6×10^4 Bq	(A1)
(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ **or** $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4}\ s^{-1}$	A1

431. 9702_w18_MS_41 Q: 12

	Answer	Marks
(a)	unstable nucleus	B1
	emission of particles/photons	B1
	emission is spontaneous **or** (particles/radiation) are ionising	B1
(b)(i)	tangent drawn and gradient calculation attempted	B1
	activity = 1.3×10^6 Bq (*1 mark for answer within* ±0.2×10^6 Bq, *2 marks for answer within* ±0.1×10^6 Bq)	A2
(b)(ii)	$A = \lambda N$	C1
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5}\ s^{-1}$ ($\approx 4 \times 10^{-5}\ s^{-1}$)	A1
(c)	$A = A_0 e^{-\lambda t}$ $1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	C1
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	C1
	$t = 2.78 \times 10^6$ s = 32 days	A1

432. 9702_w18_MS_43 Q: 12

	Answer	Marks
(a)	unstable nucleus	B1
	emission of particles/photons	B1
	emission is spontaneous **or** (particles/radiation) are ionising	B1
(b)(i)	tangent drawn and gradient calculation attempted	B1
	activity = 1.3×10^6 Bq (*1 mark for answer within* $\pm 0.2 \times 10^6$ Bq, *2 marks for answer within* $\pm 0.1 \times 10^6$ Bq)	A2
(b)(ii)	$A = \lambda N$	C1
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5}\,s^{-1}$ ($\approx 4 \times 10^{-5}\,s^{-1}$)	A1
(c)	$A = A_0 e^{-\lambda t}$ $1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	C1
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	C1
	$t = 2.78 \times 10^6$ s = 32 days	A1

433. 9702_w17_MS_41 Q: 12

	Answer	Marks
(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation *Any two points.*	B2
(b)(i)	curve is not smooth **or** curve fluctuates/curve is jagged	B1
(b)(ii)	clear evidence of allowance for background	B1
	half-life determined at least twice	B1
	half-life = 1.5 hours (*1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6*)	A2
(c)	**1.** half-life: no change	M1
	because decay is spontaneous/independent of environment	A1
	2. count rate (likely to be or could be) different/is random/cannot be predicted	B1

434. 9702_w17_MS_42 Q: 12

	Answer	Marks
(a)(i)	nucleus emits particles/EM radiation/ionising radiation	B1
	emission/release from unstable nucleus **or** emission from nucleus is random and/or spontaneous	B1
(a)(ii)	probability of decay (of a nucleus) **or** fraction of (number of undecayed) nuclei that will decay	M1
	per unit time	A1
(b)	energy is shared with another particle	B1
	mention of antineutrino	B1
(c)(i)	number $= [(1.2 \times 10^{-9}) / 131] \times 6.02 \times 10^{23}$ **or** number $= (1.2 \times 10^{-3} \times 10^{-9}) / (131 \times 1.66 \times 10^{-27})$ $(= 5.51 \times 10^{12})$	C1
	$A = \lambda N$	C1
	$= [0.086 / (24 \times 3600)] \times 5.51 \times 10^{12}$ $= 5.5 \times 10^{6}$ Bq	A1
(c)(ii)	$1 / 50 = \exp(-0.086t)$ **or** $1 / 50 = 0.5^{n}$	C1
	$t = 45$ days	A1

435. 9702_w17_MS_43 Q: 12

	Answer	Marks
(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation *Any two points.*	B2
(b)(i)	curve is not smooth **or** curve fluctuates/curve is jagged	B1
(b)(ii)	clear evidence of allowance for background	B1
	half-life determined at least twice	B1
	half-life = 1.5 hours (*1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6*)	A2
(c)	**1.** half-life: no change	M1
	because decay is spontaneous/independent of environment	A1
	2. count rate (likely to be or could be) different/is random/cannot be predicted	B1

436. 9702_m16_MS_42 Q: 13

(a)	$\lambda = \ln 2 / T_{½}$		
	$= \ln 2 / (53.3 \times 24 \times 60 \times 60) = 1.5 \times 10^{-7}\ s^{-1}$	A1	[1]
(b)	$A = \lambda N$	C1	
	$N = 39 \times 10^{-3} / 1.5 \times 10^{-7} = 2.6 \times 10^{5}$		
	$m = (2.6 \times 10^{5} / 6.0 \times 10^{23}) \times 7 \times 10^{-3}$ *or* $2.6 \times 10^{5} \times 1.66 \times 10^{-27} \times 7$	C1	
	$= 3.0 \times 10^{-21}$ kg	A1	[3]
(c)	$2/39 = \exp(-1.5 \times 10^{-7} \times t)$ *or* $2/39 = (1/2)^{[t/(53.3 \times 24 \times 3600)]}$	C1	
	$t = 2.0 \times 10^{7}$ s	A1	[2]

437. 9702_w16_MS_41 Q: 12

(a) (i)	time for number of atoms/nuclei or activity to be reduced to one half	M1	
	reference to (number of…) original nuclide/single isotope *or* reference to half of original value/initial activity	A1	[2]
(ii)	$A = A_0 \exp(-\lambda t)$ and either $t = t_{½}$, $A = ½A_0$ or $½A_0 = A_0 \exp(-\lambda t_{½})$	M1	
	so $\ln 2 = \lambda t_{½}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{½}$	A1	[2]
(b)	$A = \lambda N$		
	$N = 200 / (2.1 \times 10^{-6})$	C1	
	$= 9.52 \times 10^{7}$	C1	
	mass $= (9.52 \times 10^{7} \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$ *or* mass $= 9.52 \times 10^{7} \times 222 \times 1.66 \times 10^{-27}$	C1	
	$= 3.5 \times 10^{-17}$ kg	A1	[4]

438. 9702_w16_MS_43 Q: 12

(a)	**(i)**	time for number of atoms/nuclei or activity to be reduced to one half	M1	
		reference to (number of…) original nuclide/single isotope *or* reference to half of original value/initial activity	A1	[2]
	(ii)	$A = A_0 \exp(-\lambda t)$ <u>and</u> either $t = t_{½}$, $A = ½A_0$ or $½A_0 = A_0 \exp(-\lambda t_{½})$	M1	
		so $\ln 2 = \lambda t_{½}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{½}$	A1	[2]
(b)		$A = \lambda N$		
		$N = 200 / (2.1 \times 10^{-6})$	C1	
		$= 9.52 \times 10^{7}$	C1	
		mass $= (9.52 \times 10^{7} \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$ *or* mass $= 9.52 \times 10^{7} \times 222 \times 1.66 \times 10^{-27}$	C1	
		$= 3.5 \times 10^{-17}$ kg	A1	[4]