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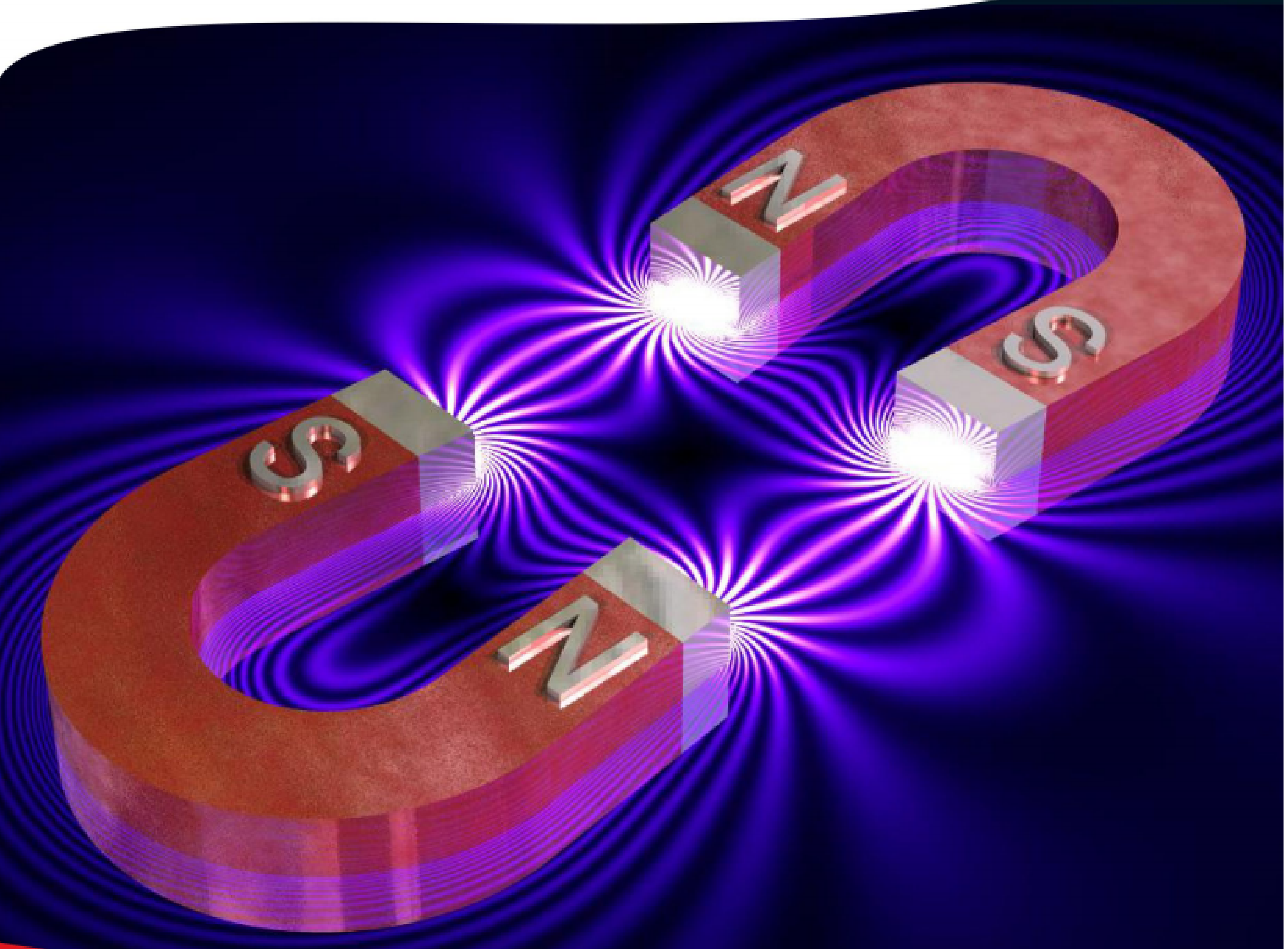
Cambridge International AS & A Level

PHYSICS (9702) P2

TOPIC WISE QUESTIONS + ANSWERS | COMPLETE SYLLABUS



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Appendix A

Answers

1. 9702_m19_qp_22 Q: 1

	Answer	Mark
(a)	kilogram / kg	B1
	kelvin / K	B1
(b)	units for *v*: m s^{-1} <u>and</u> units for *F*: kg m s^{-2}	C1
	units for *e*: A s	C1
	units for μ: m s^{-1} A s / kg m s^{-2} = A kg^{-1} s^2	A1

2. 9702_s18_qp_22 Q: 1

	Answer	Mark
(a)	rate of change of momentum	B1
(b)	kg m s^{-2}	A1
(c)	units for *Q*: A s **and** for *r*: m	C1
	units for ε = (A s × A s) / (kg m s^{-2} × m^2) = A^2 kg^{-1} m^{-3} s^4	A1

3. 9702_w17_qp_23 Q: 1

	Answer	Mark
(a)(i)	work (done) / time (taken) **or** energy (transferred) / time (taken)	B1
(a)(ii)	Correct substitution of base units of all quantities into any correct equation for power. Examples: ($P = E / t$ or W / t gives) kg m^2 s^{-2} / s = kg m^2 s^{-3} ($P = Fs / t$ or mgh / t gives) kg m s^{-2} m / s = kg m^2 s^{-3} ($P = ½mv^2 / t$ gives) kg (m s^{-1})^2 / s = kg m^2 s^{-3} ($P = Fv$ gives) kg m s^{-2} m s^{-1} = kg m^2 s^{-3} ($P = VI$ gives) kg m^2 s^{-2} A^{-1} s^{-1} A = kg m^2 s^{-3}	A1
(b)(i)	units of *A*: m^2 **and** units of *T*: K	C1
	units of *k*: kg m^2 s^{-3} / m^2 K^4 = kg s^{-3} K^{-4}	A1
(b)(ii)	curve from the origin with increasing gradient	B1

4. 9702_s15_qp_21 Q: 1

(a)	power = work / time or energy / time or (force × distance) / time	B1	
	= kg m s^{-2} × m s^{-1} = kg m^2 s^{-3}	A1	[2]
(b)	power = *VI* [or V^2/R **and** $V = IR$ or I^2R **and** $V = IR$]	B1	
	(units of *V*:) kg m^2 s^{-3} A^{-1}	B1	[2]

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5. 9702_w15_qp_23 Q: 1

(a) energy or *W*: kg m^2 s^{-2}
or
power or *P*: kg m^2 s^{-3} — M1

intensity or *I*: kg m^2 s^{-2} m^{-2} s^{-1} (from use of energy expression)
or
kg m^2 s^{-3} m^{-2} (from use of power expression)

indication of simplification to kg s^{-3} — A1 [2]

(b) (i) ρ: kg m^{-3}, *c*: m s^{-1}, *f*: s^{-1}, x_0: m — M1

substitution of terms in an appropriate equation and simplification to show *K* has no units — A1 [2]

(ii) $I = 20 \times 1.2 \times 330 \times (260)^2 \times (0.24 \times 10^{-9})^2$ — C1

$= 3.1 \times 10^{-11}$ (W m^{-2}) — C1

= 31 (30.8) pW m^{-2} — A1 [3]

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6. 9702_w19_qp_22 Q: 1

	Answer	Mark
(a)	scalar quantity has (only) magnitude	**B1**
	vector quantity has magnitude and direction	**B1**
(b)(i)	*E* = *F* / *Q*	**C1**
	= kg m s^{-2} / A s = kg m A^{-1} s^{-3}	**A1**
(b)(ii)	*b* = *Q* / x^2E	**C1**
	= A s / m^2 kg m A^{-1} s^{-3}	
	= A^2 s^4 kg^{-1} m^{-3}	**A1**

7. 9702_s18_qp_21 Q: 1

	Answer	Mark
(a)	a scalar has magnitude (only)	B1
	a vector has magnitude and direction	B1
(b)	power: scalar temperature: scalar momentum: vector *(two correct 1 mark, all three correct 2 marks)*	B2
(c)(i)	arrow labelled R in a direction from 5° to 20° north of west	B1
(c)(ii)	$v^2 = 28^2 + 95^2 - (2 \times 28 \times 95 \times \cos 115°)$ **or** $v^2 = [(95 + 28\cos 65°)^2 + (28\sin 65°)^2]$	C1
	$v = 110\ \text{ms}^{-1}$ ($109.8\ \text{ms}^{-1}$)	A1
	or (scale diagram method)	
	triangle of velocities drawn	(C1)
	$v = 110\ \text{ms}^{-1}$ (allow 108–112 ms^{-1})	(A1)

8. 9702_s17_qp_23 Q: 1

	Answer	Mark
(a)(i)	$R = 7(.0)$ N	B1
(a)(ii)	$R = 13$ N	B1
(b)(i)	forces resolved: 18 sin 65° (vertical) **and** 55 + 18 cos 65° (horizontal) **or** scale drawing: correct triangle drawn for forces	B1
	$F = [(18 \sin 65°)^2 + (55 + 18 \cos 65°)^2]^{1/2} = 65$ (64.7) N **or** scale drawing: scale given, length of resultant given correctly, ± 1 N	A1
(b)(ii)	angle = $\tan^{-1}$[18 sin 65° / (55 + 18 cos 65°)] = $\tan^{-1}$(16.3 / 62.6) **or** scale drawing: correct angle measured/direction correct on diagram below the 55 N force	C1
	angle = 15 (14.6)° (below the 55 N force) **or** scale drawing: angle = 15° ± 1°	A1
(c)	(resultant) force = mass × acceleration	C1
	80 – 65 = 2.7a	C1
	$a = 5.6\ \text{m s}^{-2}$ [5.7 if 64.7 N used from **(i)**]	A1

9. 9702_s16_qp_23 Q: 1

(a)	scalars: energy, power and time	A1	
	vectors: momentum and weight	A1	[2]
(b) (i)	triangle with right angles between 120 m and 80 m, arrows in correct direction and result displacement from start to finish arrow in correct direction and labelled R	B1	[1]
(ii) 1.	average speed (= 200 / 27) = 7.4 m s^{-1}	A1	[1]
2.	resultant displacement (= $[120^2 + 80^2]^{1/2}$) = 144 (m)	C1	
	average velocity (= 144 / 27) = 5.3(3) m s^{-1}	A1	
	direction (= $\tan^{-1}$ 80 / 120) = 34° (33.7)	A1	[3]

10. 9702_w15_qp_22 Q: 1

(a)	$v = f\lambda$	C1	
	$\lambda = (3.0 \times 10^8)/(4.6 \times 10^{20})$	C1	
	$(= 6.52 \times 10^{-13} =)$ 0.65(2) pm	A1	[3]
(b)	$t = (8.5 \times 10^{16})/(3.0 \times 10^8)$	C1	
	$(= 2.83 \times 10^8 =)$ 0.28(3) Gs	A1	[2]
(c)	mass, power and temperature all underlined and no others	B1	[1]
(d) (i)	arrow in the direction 30° to 40° south of east	B1	[1]
(ii)	triangle of velocities completed (i.e. correct scale diagram) or correct working given e.g. $[14^2 + 8.0^2 - 2(14)(8.0)\cos 60°]^{1/2}$ **or** $[(14 - 8.0\cos 60°)^2 + (8.0\sin 60°)^2]^{1/2}$	C1	
	resultant velocity = 12(.2) (or 12.0 to 12.4 from scale diagram) m s^{-1}	A1	[2]

11. 9702_m20_qp_22 Q: 1

	Answer	Mark
(a)	time (electric) current *allow* amount of substance *allow* luminous intensity *any two of the above quantities, 1 mark each*	**B2**
(b)(i)	$g = (4\pi^2 \times 1.50) / (2.48^2)$ $= 9.63\ \text{m s}^{-2}$	**A1**
(b)(ii)	percentage uncertainty = 2 + (3 × 2) or fraction uncertainty = 0.02 + (0.03 × 2)	**C1**
	percentage uncertainty = 8%	**A1**
(b)(iii)	absolute uncertainty = 0.08 × 9.6 $= 0.8\ \text{m s}^{-2}$	**A1**

12. 9702_s20_qp_21 Q: 1

	Answer	Mark
(a)	(work =) force × displacement	**C1**
	units: $\text{kg m s}^{-2} \times \text{m} = \text{kg m}^2\,\text{s}^{-2}$	**A1**
(b)(i)	units of *Q*: As	**C1**
	units of *C*: $\text{kg}^{-1}\,\text{m}^{-2}\,\text{A}^2\,\text{s}^4$	**A1**
(b)(ii)	**1.** e.g. reading scale from different angles (wrongly) interpolating between scale readings/divisions	**B1**
	2. e.g. zero error wrongly calibrated scale	**B1**

13. 9702_s19_qp_22 Q: 1

	Answer	Mark
(a)	absolute uncertainty = (1.6 / 100) × 0.0125 $= 2 \times 10^{-4}\ \text{m}$	**A1**
(b)(i)	$p = (4 \times 0.38) / (\pi \times 0.0125^2)$ $= 3100\ \text{N m}^{-2}$	**A1**
(b)(ii)	percentage uncertainty = 2.8 + (2 × 1.6) (= 6%) **or** fractional uncertainty = 0.028 + (2 × 0.016) (= 0.06)	**C1**
	absolute uncertainty = 0.06 × 3100 $= 190\ \text{N m}^{-2}$ (*allow to 1 significant figure*)	**A1**

14. 9702_w19_qp_21 Q: 1

	Answer	Mark
(a)(i)	mass in range 1–20 g	A1
(a)(ii)	wavelength in range 1×10^{-8} m to 4×10^{-7} m	A1
(b)(i)	$T = 2\pi \times (200 \times 10^{-3} / 25)^{0.5}$ = 0.56 s	A1
(b)(ii)	percentage uncertainty = (2% + 8%) / 2 (= 5%) **or** fractional uncertainty = (0.02+0.08) / 2 (= 0.05)	C1
	ΔT = 0.56 × 0.05 = 0.028 (s)	C1
	T = (0.56 ± 0.03) s	A1

15. 9702_s18_qp_23 Q: 1

	Answer	Mark
(a)(i)	zero error **or** wrongly calibrated scale	B1
(a)(ii)	reading scale from different angles **or** wrongly interpolating between scale readings/divisions	B1
(b)(i)	$P = V^2 / R$ **or** $P = VI$ <u>and</u> $V = IR$	C1
	$P = 5.0^2 / 125$ **or** 5.0×0.04 **or** $(0.04)^2 \times 125$ = 0.20 W	A1
(b)(ii)	$\%V = 2\%$ **or** $\Delta V / V = 0.02$	C1
	$\%P = (2 \times 2\%) + 3\%$ **or** $\%P = (2 \times 0.02 + 0.03) \times 100$ = 7%	A1
(b)(iii)	absolute uncertainty in P = (7 / 100) × 0.20 = 0.014	C1
	power = 0.20 ± 0.01 W **or** $(2.0 \pm 0.1) \times 10^{-1}$ W	A1

16. 9702_s17_qp_21 Q: 1

	Answer	Mark
(a)	(stress =) force / area **or** kg m s^{-2} / m^2	B1
	= kg m^{-1} s^{-2}	A1
(b)(i)	$0.58 = 2\pi \times [(4 \times 0.500 \times 0.600^3) / (E \times 0.0300 \times 0.00500^3)]^{0.5}$	C1
	$E = [4\pi^2 \times 4 \times 0.500 \times (0.600)^3] / [(0.58)^2 \times 0.0300 \times (0.00500)^3]$ = 1.35×10^{10} (Pa)	C1
	= 14 (13.5) GPa	A1
(b)(ii)1.	(accuracy determined by) the closeness of the value(s)/measurement(s) to the true value	B1
	(precision determined by) the range of the values/measurements	B1
(b)(ii)2.	l is (cubed so) 3 × (percentage/fractional) uncertainty **and** T is (squared so) 2 × (percentage / fractional) uncertainty **and** (so) l contributes more	B1

17. 9702_s17_qp_22 Q: 1

	Answer	Mark
(a)	kelvin, mole, ampere, candela *any two*	B1
(b)	use of resistivity = RA / l **and** $V = IR$ (to give $\rho = VA / Il$)	C1
	units of V: (work done / charge) $kg\,m^2\,s^{-2}\,(A\,s)^{-1}$	C1
	units of resistivity: $(kg\,m^2\,s^{-3}\,A^{-1}\,A^{-1}\,m)$ $= kg\,m^3\,s^{-3}\,A^{-2}$	A1
	or	
	use of $R = \rho L / A$ and $P = I^2R$ (gives $\rho = PA / I^2L$)	**(C1)**
	units of P: $kg\,m^2\,s^{-3}$	**(C1)**
	units of resistivity: $(kg\,m^2\,s^{-3} \times m^2) / (A^2 \times m)$ $= kg\,m^3\,s^{-3}\,A^{-2}$	**(A1)**
(c)(i)	$\rho = (RA / l)$	C1
	$= (0.03 \times 1.5 \times 10^{-6}) / 2.5$ $(= 1.8 \times 10^{-8})$	C1
	$= 18\,n\Omega\,m$	A1
(c)(ii)	**1.** precision is determined by the range in the measurements/values/readings/data/results	B1
	2. metre rule measures to ± 1 mm and micrometer to ± 0.01 mm (so there is less (percentage) uncertainty/random error)	B1

18. 9702_w17_qp_22 Q: 1

	Answer	Mark
(a)(i)	micrometer (screw gauge)/digital calipers	B1
(a)(ii)	take several readings (and average)	M1
	along the wire **or** around the circumference	A1
(b)(i)	$\sigma = 4 \times 25 / [\pi \times (0.40 \times 10^{-3})^2] = 1.99 \times 10^8\,N\,m^{-2}$ **or** $\sigma = 25 / [\pi \times (0.20 \times 10^{-3})^2] = 1.99 \times 10^8\,N\,m^{-2}$	A1
(b)(ii)	$\%F = 2\%$ **and** $\%d = 5\%$ **or** $\Delta F / F = \frac{0.5}{25}$ **and** $\Delta d / d = \frac{0.02}{0.4}$	C1
	$\%\sigma = 2\% + (2 \times 5\%)$ **or** $\%\sigma = [0.02 + (2 \times 0.05)] \times 100$ $\%\sigma = 12\%$	A1
(b)(iii)	absolute uncertainty $= (12 / 100) \times 1.99 \times 10^8$ $= 2.4 \times 10^7$	C1
	$\sigma = 2.0 \times 10^8 \pm 0.2 \times 10^8\,N\,m^{-2}$ **or** $2.0 \pm 0.2 \times 10^8\,N\,m^{-2}$	A1

19. 9702_m16_qp_22 Q: 1

(a) metre rule / tape measure B1

(b) **(i)** $v = [(1.8 \times 126 \times 10^{-2}) / 5.1 \times 10^{-3}]^{1/2}$ C1
$= 21.1\,(\text{m s}^{-1})$ A1

(ii) percentage uncertainty = 4% **or** fractional uncertainty = 0.04 C1
$\Delta v = 0.04 \times 21.1$
$= 0.84$ C1
$v = 21.1 \pm 0.8\,(\text{m s}^{-1})$ A1

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20. 9702_s16_qp_21 Q: 1

(a) **(i)** $(50 \text{ to } 200) \times 10^{-3}$ kg or (0.05 to 0.2) kg B1 [1]

(ii) (50 to 300) cm^3 B1 [1]

(b) density = mass / volume or $\rho = M / V$ C1

$V = [\pi(0.38 \times 10^{-3})^2 \times 25.0 \times 10^{-2}] / 4$ $(= 2.835 \times 10^{-8}\ \text{m}^3)$ C1

$\rho = (0.225 \times 10^{-3}) / 2.835 \times 10^{-8}$
$= 7940\ (\text{kg m}^{-3})$ A1

$\Delta\rho / \rho = 2(0.01/0.38) + (0.1/25.0) + (0.001/0.225)$ [= 0.061]
or
$\%\rho = 5.3\% + 0.40\% + 0.44\%$ (= 6.1%) C1

$\Delta\rho = 0.061 \times 7940 = 480\ (\text{kg m}^{-3})$

density = $(7.9 \pm 0.5) \times 10^3\ \text{kg m}^{-3}$ or $(7900 \pm 500)\ \text{kg m}^{-3}$ A1 [5]

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21. 9702_s16_qp_23 Q: 2

(a) systematic: the reading is larger or smaller than (or varying from) the true reading by a constant amount B1

random: scatter in readings about the true reading B1 [2]

(b) precision: the size of the smallest division (on the measuring instrument)
or
0.01 mm for the micrometer B1

accuracy: how close (diameter) value is to the true (diameter) value B1 [2]

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22. 9702_s15_qp_23 Q: 4

(a)	**(i)** diameter and extension: micrometer (screw gauge) or digital calipers	B1	
	length: tape measure or metre rule	B1	
	load: spring balance or Newton meter	B1	[3]
	(ii) to reduce the effect of random errors **or** to plot a graph to check for zero error in measurement of extension **or** to see if limit of proportionality is exceeded	B1	[1]
(b)	plot a graph of *F* against *e* and determine the gradient	B1	
	$E = (\text{gradient} \times l) / [\pi d^2 / 4]$	B1	[2]

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23. 9702_w15_qp_21 Q: 1

(a)	temperature	B1	
	current	B1	[2]
	(allow amount of substance, luminous intensity)		
(b)	**(i)** **1.** E = (stress / strain =) [force / area] / [extension / original length]		
	units of stress: $kg\,m\,s^{-2} / m^2$ and no units for strain	B1	
	units of *E*: $kg\,m^{-1}\,s^{-2}$	A0	[1]
	2. units for *T*: s, *l*: m and *M*: kg		
	$K^2 = T^2 E / M l^3$ hence units: $s^2\,kg\,m^{-1}\,s^{-2} / kg^3$ (= m^{-4})	C1	
	units of *K*: m^{-2}	A1	[2]
	(ii) % uncertainty in *E* = 4% (for T^2) + 0.6% (for l^3) + 0.1% (for *M*) + 3% (for K^2) = 7.7%	B1	
	$E = [(1.48 \times 10^5)^2 \times 0.2068 \times (0.892)^3] / (0.45)^2 = 1.588 \times 10^{10}$	C1	
	7.7% of $E = 1.22 \times 10^9$	C1	
	$E = (1.6 \pm 0.1) \times 10^{10}\ kg\,m^{-1}\,s^{-2}$	A1	[4]

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24. 9702_s20_qp_23 Q: 1

	Answer	Mark
(a)	similarity: both have magnitude	**B1**
	difference: distance is a scalar/does not have direction **or** displacement is a vector/has direction	**B1**
(b)(i)	the measurements have a small range	**B1**
(b)(ii)	the (average of the) measurements is not close to the true value	**B1**

25. 9702_w20_qp_22 Q: 1

	Answer	Mark
(a)	density and temperature indicated as scalars	B1
	acceleration and momentum indicated as vectors	B1
(b)(i)	decelerates **or** speed/velocity decreases	B1
(b)(ii)	speed = (Δ)*d* / (Δ)*t* **or** gradient	C1
	= e.g. (0.56 – 0.20) / 1.5 = 0.24 m s^{-1}	A1
(c)	displacement is zero (so) average velocity is zero	B1

26. 9702_s19_qp_21 Q: 1

	Answer	Mark
(a)	(velocity =) change in displacement / time (taken)	B1
(b)(i)	k = [1.29 × $(3.3 \times 10^2)^2$] / 9.9 × 10^4	C1
	= 1.4	A1
(b)(ii)	percentage uncertainty = (3 × 2) + 4 + 2 (= 12%) **or** fractional uncertainty = (0.03 × 2) + 0.04 + 0.02 (= 0.12)	C1
	Δk = 0.12 × 1.42 = 0.17 (*allow to 1 significant figure*)	C1
	k = 1.4 ± 0.2	A1

27. 9702_w19_qp_22 Q: 2

	Answer	Mark
(a)	change in velocity / time (taken)	A1
(b)(i)	weight ≫ (force due to) air resistance **or** (force due to) air resistance is negligible <u>compared to weight</u>	B1
(b)(ii)	$s = ut + ½at^2$ 0.280 = ½ × 9.81 × t^2	C1
	t = 0.24 s	A1

	Answer	Mark
(b)(iii)	total distance fallen = 0.280 + 0.080 = 0.360 $0.360 = ½ \times 9.81 \times t^2$ *t* = 0.27 s	C1
	time taken = 0.27 – 0.24 = 0.03 s	A1
	or	
	$v = 9.81 \times 0.239$ **or** $(2 \times 9.81 \times 0.280)^{0.5}$ **or** $(2 \times 0.280) / 0.239$ = 2.34 ($m s^{-1}$)	(C1)
	$0.080 = 2.34t + ½ \times 9.81 \times t^2$ solving quadratic equation gives *t* = 0.03 s *allow any correct method using equations of uniform accelerated motion*	(A1)
(c)	(average) resultant force/acceleration/speed/velocity (of low-density ball) is less	B1
	(so) time interval is longer	B1

28. 9702_m18_qp_22 Q: 1

	Answer	Mark
(a)	acceleration: vector speed: scalar power: scalar *All three correct scores 2 marks. Only two correct scores 1 mark.*	B2
(b)(i)	time = 0.43 / 1.1 = 0.39 s	A1
(b)(ii)	$s = ut + ½at^2$ $= ½ \times 9.81 \times 0.39^2$	C1
	= 0.75 m	A1
(b)(iii)	1 horizontal line at a non-zero value of *a*.	B1
	2 curved line from origin with increasing gradient.	B1
(c)	acceleration (of free fall) is unchanged / not dependent on mass and so no effect (on time taken).	A1

29. 9702_w17_qp_21 Q: 2

	Answer	Mark
(a)	$30\,ms^{-1} = 108\,km\,h^{-1}$ **or** $100\,km\,h^{-1} = 28\,m\,s^{-1}$ **and** so exceeds speed limit	B1
(b)	acceleration = gradient **or** $\Delta v/(\Delta)t$ **or** $(v - u)/t$	C1
	e.g. acceleration = (24 – 20) / 12 [other points on graph line may be used] $= 0.33\,m\,s^{-2}$	A1
(c)	distance travelled by Q = ½ × 12 × 30 (= 180 m)	C1
	distance travelled by P = ½ × (20 + 24) × 12 (= 264 m)	C1
	distance between cars = 264 – 180 = 84 m	A1
(d)	$30 - 24 = 6\,m\,s^{-1}$ 'extra' time T = 84/6 (= 14 s) **or** $180 + 30T = 264 + 24T$ 'extra' time T = 84/6 (= 14 s)	C1
	t = 12 + 14 = 26 s	A1

30. 9702_s16_qp_21 Q: 2

(a) (i) horizontal component (= 12 cos 50°) = $7.7\,m\,s^{-1}$ A1 [1]

(ii) vertical component (= 12 sin 50° or 7.7 tan 50°) = $9.2\,m\,s^{-1}$ A1 [1]

(b) $v^2 = u^2 + 2as$ and $v = 0$ or $mgh = ½mv^2$ or $s = v^2\sin^2\theta/2g$ C1

$9.2^2 = 2 \times 9.81 \times h$ hence h = 4.3 (4.31) m A1 [2]

alternative methods using time to maximum height of 0.94 s:

$s = ut + ½at^2$ and t = 0.94 (s) (C1)
$s = 9.2 \times 0.94 - ½ \times 9.81 \times 0.94^2$ hence s = 4.3 m (A1)

or
$s = vt - ½at^2$ and t = 0.94 (s) (C1)
$s = ½ \times 9.81 \times 0.94^2$ hence s = 4.3 m (A1)

or
$s = ½(u + v)t$ and t = 0.94 (s) (C1)
$s = ½ \times 9.2 \times 0.94$ hence s = 4.3 m (A1)

(c) t (= 9.2 / 9.81) = 0.94 (0.938) s C1

horizontal distance = 0.938 × 7.7 (= 7.23 m) C1

displacement = $[4.3^2 + 7.23^2]^{1/2}$ C1

= 8.4 m A1 [4]

31. 9702_s15_qp_21 Q: 2

(a)	speed = distance / time and velocity = displacement / time	B1	
	speed is a scalar as distance has no direction **and** velocity is a vector as displacement has direction	B1	[2]
(b) (i)	constant acceleration or linear/uniform increase in velocity until 1.1 s	B1	
	rebounds or bounces or changes direction	B1	
	decelerates to zero velocity at the same acceleration as initial value	B1	[3]
(ii)	$a = (v - u) / t$ or use of gradient implied	C1	
	= (8.8 + 8.8) / 1.8 or appropriate values from line or = (8.6 + 8.6) / 1.8	B1	
	= 9.8 (9.78) m s^{-2} or = 9.6 m s^{-2}	A1	[3]
(iii)	**1.** distance = first area above graph + second area below graph	C1	
	= (1.1 × 10.8) / 2 + (0.9 × 8.8) / 2 (= 5.94 + 3.96)	C1	
	= 9.9 m	A1	[3]
	2. displacement = first area above graph – second area below graph	C1	
	= (1.1 × 10.8) / 2 – (0.9 × 8.8) / 2		
	= 2.0 (1.98) m	A1	[2]
(iv)	correct shape with straight lines and all lines above the time axis or all below	M1	
	correct times for zero speeds (0.0, 1.15 s, 2.1 s) and peak speeds (10.8 m s^{-1} at 1.1 s and 8.8 m s^{-1} at 1.2 s and 3.0 s)	A1	[2]

32. 9702_s15_qp_23 Q: 1

(a)	150 or 1.5 × 10^2 Gm	A1	[1]
(b)	distance = 2 × (42.3 – 6.38) × 10^6 (= 7.184 × 10^7 m)	C1	
	(time =) 7.184 × 10^7 / (3.0 × 10^8) = 0.24 (0.239) s	A1	[2]
(c)	units of pressure P: kg m s^{-2} / m^2 = kg m^{-1} s^{-2}	M1	
	units of density ρ: kg m^{-3} and speed v: m s^{-1}	M1	
	simplification for units of C: $C = v^2 \rho / P$ units: (m^2 s^{-2} kg m^{-3}) / kg m^{-1} s^{-2} and cancelling to give no units for C	A1	[3]
(d)	energy and power *(both underlined and no others)*	A1	[1]
(e) **(i)**	vector triangle of correct orientation	M1	
	three arrows for the velocities in the correct directions	A1	[2]
(ii)	length measured from scale diagram 5.2 ± 0.2 cm or components of boat speed determined parallel and perpendicular to river flow	C1	
	velocity = 2.6 m s^{-1} (allow ± 0.1 m s^{-1})	A1	[2]

33. 9702_w20_qp_21 Q: 3

	Answer	Mark
(a)	(force =) rate of change of momentum	**B1**
(b)(i)	$E = \frac{1}{2}mv^2$ **or** ½ × 0.062 × 3.8^2 **or** ½ × 0.062 × 1.7^2	**C1**
	loss of KE = ½ × 0.062 × (3.8^2 – 1.7^2) = 0.36 J	**A1**
(b)(ii)	$p = mv$ **or** 0.062 × 3.8 **or** 0.062 × 1.7	**C1**
	change in momentum = 0.062 × (1.7 + 3.8) = 0.34 N s	**A1**
(b)(iii)	(average resultant force =) 0.34 / 0.081 = 4.2 (N) **or** (average resultant force =) 0.062 × (1.7 + 3.8) / 0.081 = 4.2 (N)	**A1**
(b)(iv)	**1.** average force = 4.2 + (0.062 × 9.81) = 4.8 N	**A1**
	2. average force = 4.8 N	**A1**

34. 9702_s19_qp_21 Q: 2

	Answer	Mark
(a)	(momentum =) mass × velocity	B1
(b)(i)	time = 40 ms	A1
(b)(ii)	**1.** (the magnitude of the acceleration is) constant	B1
	2. (the magnitude of the acceleration is) zero	B1
(c)	$F = \Delta p / (\Delta)t$ **or** F = gradient	C1
	e.g. $F = 0.50 / 40 \times 10^{-3}$ $= 13$ N	A1
(d)	horizontal line from (0, 0.40) to (60, 0.40)	B1
	straight line from (60, 0.40) to (100, –0.10)	B1
	horizontal line from (100, –0.10) to (160, –0.10)	B1

35. 9702_w17_qp_21 Q: 1

	Answer	Mark
(a)	units of F: kg m s^{-2}	C1
	units of ρ: kg m^{-3} **and** units of v: m s^{-1}	C1
	units of K: kg m s^{-2} / [kg m^{-3} (m s^{-1})^2] = m^2	A1
(b)(i)	$K\rho = 1.5 / 33^2$	C1
	$= 1.38 \times 10^{-3}$ $F_D = 1.38 \times 10^{-3} \times 25^2$ **or** $F_D / 1.5 = 25^2 / 33^2$ $F_D = 0.86$ N	A1
(b)(ii)	$a = (1.5 - 0.86) / (1.5 / 9.81)$ **or** $a = 9.81 - [0.86 / (1.5 / 9.81)]$	C1
	$a = 4.2$ m s^{-2}	A1
(c)	initial acceleration is g/9.81 (m s^{-2})/acceleration of free fall	B1
	acceleration decreases	B1
	final acceleration is zero	B1

36. 9702_s20_qp_22 Q: 2

	Answer	Mark
(a)(i)	area = $ut + ½(v – u)t$ **or** area = $vt – ½(v – u)t$ **or** area = $½(u + v)t$	A1
(a)(ii)	displacement	A1
(b)(i)	u = 15 sin 60° (= 13 m s^{-1})	C1
	t = 15 sin 60° / 9.81	C1
	= 1.3 s	A1
(b)(ii)	the force in the horizontal direction is zero	B1
(b)(iii)	(velocity =) 15 cos 60° = 7.5 (m s^{-1}) **or** (velocity =) 15 sin 30° = 7.5 (m s^{-1})	A1
(c)(i)	$p = mv$ **or** 0.40 × 7.5 **or** 0.40 × 4.3	C1
	Δp = 0.40 (7.5 + 4.3) = 4.7 kg m s^{-1}	A1
(c)(ii)	force = 4.7 / 0.12 **or** 0.40 × [(7.5 + 4.3) / 0.12] = 39 N	A1

37. 9702_w20_qp_23 Q: 3

	Answer	Mark
(a)	$s = ½at^2$	C1
	57 = ½ × 9.81 × t^2 **and** t = 3.4 (s)	A1
(b)	horizontal distance = 41 × 3.4 = 140 m	A1
(c)	(displacement)^2 = 57^2 + 140^2	C1
	displacement = (57^2 + 140^2)$^{0.5}$ = 150 m	A1
(d)	straight line from the origin with positive gradient	B1
(e)	(1480 – m) × 0.340 = m × 41.0	C1
	m = 12.2 kg	A1
	or	
	m_c 0.34 = m_b 41 **and** m_c + m_b = 1480	(C1)
	m_c = (41 / 0.34)m_b (41 / 0.34)m_b + m_b = 1480 m_b = 12.2 kg	(A1)
(f)	acceleration (of free fall) is unchanged/is not dependent on mass	M1
	(so) no change (to the graph)	A1

38. 9702_w18_qp_21 Q: 2

	Answer	Mark
(a)	($p =$) mv **or** 4.0×45 **or** 2.0×85 **or** $89v$	C1
	$(4.0 \times 45) - (2.0 \times 85) = 89\,v$ $v = 0.11\,\text{m s}^{-1}$	A1
(b)(i)	**1.** speed of approach = $47\,\text{m s}^{-1}$ **and** **2.** speed of separation = 0	A1
(b)(ii)	speed of separation less than/not equal to speed of approach **and** so inelastic collision	A1
(c)	force is equal to rate of change of momentum	B1
	force on ball (by block) equal and opposite to force on block (by ball) so rates of change of momentum are equal and opposite	B1
	or	
	force on ball (by block) equal and opposite to force on block (by ball)	(B1)
	force is equal to rate of change of momentum so rates of change of momentum are equal and opposite	(B1)

39. 9702_s17_qp_23 Q: 2

	Answer	Mark
(a)	(resultant) force is proportional/equal to the rate of change of momentum	B1
(b)(i)	change in momentum $= m(v_2 - v_1)$ $= 0.84 \times (8.8 - 4.2)$	C1
	$= 3.9\ (3.86)\ \text{kg m s}^{-1}$	A1
(b)(ii)	$F = (3.9 / 4.0) = 0.97\ (0.965)$ N	A1
(c)(i)	change in momentum for A: $0.84 \times (4.7 - 8.8) = -3.4\ (3.44)$ change in momentum for B: $0.73 \times (4.7 - 0) = 3.4\ (3.43)$	M1
	change in momentum for B is equal and opposite to A	A1
(c)(ii)	change in momentum equal (for A and B)	M1
	force is change in momentum / time and time (of collision) is the same hence force on A and B equal and opposite as for Newton's third law	A1
(c)(iii)	inelastic as relative speed of approach not equal to relative speed of separation	B1

40. 9702_w17_qp_23 Q: 3

	Answer	Mark
(a)	sum/total momentum (of system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	M1
	for an isolated system/no (resultant) external force	A1
(b)(i)	$p = mv$	C1
	$(4.0 \times 6.0 \times \sin\theta) - (12 \times 3.5 \times \sin 30°) = 0$ **or** $(m_A v_A \times \sin\theta) - (m_B v_B \times \sin 30°) = 0$	M1
	$\theta = 61°$	A1

	Answer	Mark
(b)(ii)	shows the horizontal <u>momentum</u> component of ball A or of ball B as (4.0 × 6.0 × cos θ) **or** (12 × 3.5 × cos 30°)	C1
	(4.0 × 6.0 × cos 61°) + (12 × 3.5 × cos 30°) = 4.0v so v = 12 (m s^{-1})	A1
(b)(iii)	initial E_K (= ½ × 4.0 × 12^2) = 290 (288) (J)	M1
	final E_K (= ½ × 4.0 × 6.0^2 + ½ × 12 × 3.5^2) = 150 (145.5) (J)	M1
	(initial E_K > final E_K) so inelastic [both M1 marks required to award this mark]	A1

41. 9702_s16_qp_23 Q: 5

(a) the <u>total</u> momentum of a system (of colliding particles) remains constant — M1

provided there is no resultant external force acting on the system/isolated or closed system — A1 [2]

(b) **(i)** the <u>total</u> kinetic energy before (the collision) is equal to the total kinetic energy after (the collision) — B1 [1]

(ii) p (= mv = 1.67 × 10^{-27} × 500) = 8.4 (8.35) × 10^{-25} N s — A1 [1]

(iii) **1.** $mv_A \cos 60° + mv_B \cos 30°$ or $m(v_A^{\ 2} + v_B^{\ 2})^{1/2}$ — B1

2. $mv_A \sin 60° + mv_B \sin 30°$ — B1 [2]

(iv) 8.35 × 10^{-25} or 500m = $mv_A \cos 60° + mv_B \cos 30°$
and
0 = $mv_A \sin 60° + mv_B \sin 30°$
or using a vector triangle — C1

v_A = 250 m s^{-1} — A1

v_B = 430 (433) m s^{-1} — A1 [3]

42. 9702_s15_qp_21 Q: 3

(a) 4.5 × 50 – 2.8 × M (= ...) — C1

(...) = –1.8 × 50 + 1.4 × M — C1

(M =) 75 g — A1 [3]

(b) <u>total</u> initial kinetic energy/KE not equal to the total final kinetic energy/KE

or <u>relative</u> speed of approach is not equal to relative speed of separation

so not elastic or is inelastic — B1 [1]

(c) force on X is equal and opposite to force on Y (Newton III) — M1

force equals/is proportional to rate of change of momentum (Newton II) — M1

time of collision same for both balls hence change in momentum is the same — A1 [3]

43. 9702_s18_qp_21 Q: 3

	Answer	Mark
(a)	mass is the property (of a body/object) resisting changes in motion **or** mass is the quantity of matter (in a body)	B1
(b)(i)	force on A (by B) equal and opposite to force on B (by A) **or** both A and B exert equal and opposite forces on each other	B1
	force is rate of change of momentum and time (of contact) is same	B1
(b)(ii)	$p = mv$ **or** $3M \times 0.40$ **or** $M \times 0.25$ **or** $3M \times 0.2$ **or** Mv	C1
	$(3M \times 0.40) - (M \times 0.25) = (3M \times 0.2) + Mv$	C1
	$v = (3 \times 0.40) - 0.25 - (3 \times 0.2)$ $= 0.35\,\text{m s}^{-1}$	A1
(b)(iii)	**1.** relative speed of approach $= 0.40 + 0.25$ $= 0.65\,\text{m s}^{-1}$	A1
	2. relative speed of separation $= 0.35 - 0.20$ $= 0.15\,\text{m s}^{-1}$	A1
(b)(iv)	(relative) speed of separation not equal to/less than (relative) speed of approach **or** answers (to (b)(iii) are) not equal **and** so inelastic collision	B1

44. 9702_m17_qp_22 Q: 1

	Answer	Mark
(a)	scalars: kinetic energy, power, work	A1
	vectors: acceleration, force, momentum	A1
(b)(i)	mass = volume × density *or* $m = V \times \rho$ $= 4/3\,\pi\,(23 \times 10^{-2})^3 \times 82$	C1
	weight $= 4/3\,\pi\,(23 \times 10^{-2})^3 \times 82 \times 9.8 = 41\,\text{N}$	A1
(b)(ii)	vertical component of tension = 290 sin75° or 290 cos15° (= 280)	C1
	upthrust = 290 sin75° + 41 = 320 (321) N	A1
(b)(iii)	the water pressure is greater than the air pressure *or* the pressure on lower surface (of sphere) is greater than the pressure on upper surface (of sphere)	B1

45. 9702_s16_qp_21 Q: 3

(a)	**(i)**	force (= *mg* = 0.15 × 9.81) = 1.5 (1.47) N	A1	[1]
	(ii)	resultant force (on ball) is zero so normal contact force = weight *or* the forces are in opposite directions so normal contact force = weight *or* normal contact force up = weight down	A1	[1]
(b)	**(i)**	(resultant) force proportional/equal to rate of change of momentum	B1	[1]
	(ii)	change in momentum = 0.15 × (6.2 + 2.5) (= 1.305 N s)	C1	
		magnitude of force = 1.305 / 0.12 = 11 (10.9) N	A1	
		or		
		(average) acceleration = (6.2 + 2.5) / 0.12 (= 72.5 m s^{-2})	(C1)	
		magnitude of force = 0.15 × 72.5 = 11 (10.9) N	(A1)	
		(direction of force is) upwards/up	B1	[3]
	(iii)	there is a change/gain in momentum of the floor	M1	
		this is equal (and opposite) to the change/loss in momentum of the ball so momentum is conserved	A1	[2]
		or		
		change of (total) momentum of <u>ball and floor</u> is zero so momentum is conserved	(M1) (A1)	
		or		
		(total) momentum of <u>ball and floor</u> before is equal to the (total) momentum of <u>ball and floor</u> after so momentum is conserved	(M1) (A1)	

46. 9702_w19_qp_22 Q: 4

	Answer	Mark
(a)(i)	(vertically) upwards/up	B1
(a)(ii)	increases (with time/velocity/depth)	B1
(b)(i)	for a body in (rotational) equilibrium	B1
	sum/total of clockwise moments about a point = sum/total of anticlockwise moments about the (same) point	B1
(b)(ii)	$(F_B \times 5.0)$ **or** (380×2.5) **or** (750×1.6)	C1
	$(F_B \times 5.0) = (380 \times 2.5) + (750 \times 1.6)$ $F_B = 430$ N	A1
(b)(iii)	taking moments about C: $(380 \times 2.5) = 750 \times (2.0 - x)$	C1
	$(2.0 - x) = 1.3$ $x = 0.7$ m	A1
	or	
	moments may be taken about other points, e.g. about D: $(380 \times 4.5) + (750 \times x) = 1130 \times 2.0$	(C1)
	$x = 0.7$ m	(A1)

47. 9702_w19_qp_23 Q: 1

	Answer	Mark
(a)	base units: $\text{kg m s}^{-2} \times \text{m}$ $= \text{kg m}^2 \text{s}^{-2}$	A1
(b)(i)	distance of COG from P (= GP) $= 17 \cos 45° - 4.0$ **or** $(144.5)^{½} - 4.0$ (= 8.0 cm)	C1
	moment $= 0.15 \times 8.0 \times 10^{-2}$ $= 1.2 \times 10^{-2}$ N m	A1
(b)(ii)	(line of action of) weight acts through pivot/P **or** distance between (line of action of) weight and pivot/P is zero	B1
	(so) weight does not have a moment about pivot/P	B1

48. 9702_w17_qp_22 Q: 2

	Answer	Mark
(a)	force × perpendicular distance (of line of action of force) to/from a point	B1
(b)(i)	$2.4r$ **or** $(1.2 \times 2r)$ **or** $(1.2r + 1.2r)$	A1
(b)(ii)	(anticlockwise moment =) $6.0 \times r/2 \times \sin\theta$	C1
	$6.0 \times r/2 \times \sin\theta = 2.4r$ $\theta = 53°$	A1
(b)(iii)	6.0 N	A1

49. 9702_s20_qp_23 Q: 2

	Answer	Mark
(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)	distance = [½ × (2.0 + 4.4) × 3.0] + [4.4 × 2.0]	C1
	= 9.6 + 8.8 = 18 m	A1
(b)(ii)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$	C1
	e.g. a = (4.4 – 2.0) / 3.0 = 0.80 m s^{-2}	A1
(b)(iii)	**1.** force = 240 cos 28° **or** 240 sin 62° = 210 N	A1
	2. resultant force = 89 × 0.80 (= 71.2 N)	C1
	R = 210 – 71 = 140 N	A1
(b)(iv)	T sin 45° = mg	C1
	T = (89 × 9.81) / sin 45° = 1200 N	A1

50. 9702_w20_qp_22 Q: 4

	Answer	Mark
(a)	(component =) 96 sin 38° = 59 (N) **or** 96 cos 52° = 59 (N)	A1
(b)	(45 × 2.9) **or** (T × 1.8) **or** (59 × 1.5)	C1
	(45 × 2.9) = (T × 1.8) + (59 × 1.5)	C1
	T = 23 N	A1

51. 9702_w20_qp_23 Q: 2

	Answer	Mark
(a)	point where (all) the weight (of the body)	M1
	is considered/seems to act	A1
(b)(i)	horizontal component of force = 38 cos 60° **or** 38 sin 30° = 19 N	A1
(b)(ii)	(T × 1.2) **or** (19 × 0.9) **or** 17	C1
	(T × 1.2) = (19 × 0.9) T = 14 N	A1
(b)(iii)	F = 45 + 38 sin 60° = 78 N	A1

52. 9702_w18_qp_22 Q: 2

	Answer	Mark
(a)	ampere kelvin (**allow** mole, candela) *any two correct answers, 1 mark each*	**B2**
(b)(i)	frictional (force)/friction	**B1**
(b)(ii)	$W\cos 31° \times 3.0$ **or** 90×6.0	**C1**
	$W\cos 31° \times 3.0 = 90 \times 6.0$ $W = 210$ N	**A1**
(b)(iii)	$X = 90 \sin 31°$ $= 46$ N	**A1**

53. 9702_s15_qp_22 Q: 3

(a) **(i)** (vertical component = 44 sin 30° =) 22 N A1 [1]

(ii) (horizontal component = 44 cos 30° =) 38(.1) N A1 [1]

(b) $W \times 0.64 = 22 \times 1.60$ C1

(W =) 55 N A1 [2]

(c) F has a horizontal component (not balanced by W)
or F has 38 N acting horizontally
or 38 N acts on wall
or vertical component of F does not balance W
or F and W do not make a closed triangle of forces B1 [1]

(d) line from P in direction towards point on wire vertically above W and direction up B1 [1]

54. 9702_w15_qp_22 Q: 4

(a) product of the force and the perpendicular distance to/from a point/pivot B1 [1]

(b) **(i)** $4000 \times 2.8 \times \sin 30°$ **or** $500 \times 1.4 \times \sin 30°$ **or** $T \times 2.8$
or 4000×1.4 **or** 500×0.7 B1

$4000 \times 2.8 \times \sin 30° + 500 \times 1.4 \times \sin 30° = T \times 2.8$ M1
hence $T = 2100$ (2125) N A0 [2]

(ii) ($T_v = 2100 \cos 60°$ =) 1100 (1050) N A1 [1]

(iii) there is an upward (vertical component of) force at A B1

upward force at A + T_v = sum of downward forces/weight+load/4500 N B1 [2]

55. 9702_w20_qp_21 Q: 1

	Answer	Mark
(a)(i)	force × perpendicular distance (of line of action of force to the point)	B1
(a)(ii)	units: kg m s^{-2} m = kg m^2 s^{-2}	A1
(b)	$W = \rho Vg$ **or** $W = \rho ALg$	C1
	$A = 5.2 / (790 \times 2.4 \times 9.81)$ (= 2.8×10^{-4} (m^2))	C1
	= 2.8×10^2 mm^2	A1
(c)(i)	(component =) 5.2 sin 56° = 4.3 (N) **or** 5.2 cos 34° = 4.3 (N)	A1
(c)(ii)	($T \times 2.4$) **or** (4.3×1.2) **or** (4.6×1.8)	C1
	($T \times 2.4$) + (4.3×1.2) = (4.6×1.8)	C1
	T = 1.3 N	A1

56. 9702_w20_qp_22 Q: 2

	Answer	Mark
(a)(i)	$(\Delta)p = \rho g(\Delta)h$ $520 = 1000 \times 9.81 \times h$	C1
	h = 0.053 m	A1
(a)(ii)	(upthrust =) $(\Delta)p \times A$ = $(\Delta)p \times \pi(d/2)^2$ **or** $(\Delta)p \times \pi r^2$	C1
	= $520 \times \pi(0.031/2)^2$ = 0.39 (N)	A1
(a)(iii)	T = 0.84 – 0.39 = 0.45 N	A1

	Answer	Mark
(b)(i)	$a = (v - u) / t$ **or** $(\Delta)v / (\Delta)t$ **or** gradient	C1
	= e.g. $8.0 \times 10^{-2} / 2.0$ = 4.0×10^{-2} m s^{-2}	A1
(b)(ii)	distance = (½ × 2.5 × 0.10) + (½ × 1.5 × 0.10) **or** (½ × 4.0 × 0.10) (= 0.20 (m))	C1
	depth = 0.32 – 0.20 = 0.12 m	A1
(c)(i)	viscous (force)	B1
(c)(ii)	viscous force increases (with speed/time/depth)	B1
	(so) acceleration decreases	B1

57. 9702_w18_qp_22 Q: 3

	Answer	Mark
(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	M1
	for an isolated system **or** no (resultant) external force	A1
(b)(i)	$m = \rho V$	C1
	$= 1.3 \times \pi \times 0.045^2 \times 1.8 \times 2.0 = 0.030$ (kg)	A1
(b)(ii)	**1.** $(\Delta)p = (\Delta)mv$	C1
	$= 0.030 \times 1.8$ $= 0.054$ N s	A1
	2. $F = 0.054/2.0$ **or** $0.030 \times 1.8/2.0$ $= 0.027$ N	A1
(b)(iii)	force on air (by propeller) equal to force on propeller (by air)	M1
	and opposite (in direction)	A1
(b)(iv)	resultant force $= 0.20 \times 0.075$ (= 0.015 N) frictional force $= 0.027 - 0.015$	C1
	$= 0.012$ N	A1

58. 9702_w18_qp_23 Q: 3

	Answer	Mark
(a)	(resultant) force proportional/equal to rate of change of momentum	B1
(b)(i)	$\rho = m / V$	C1
	$V = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2$ ($= 4.59 \times 10^{-4}$ m^3) $m = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2 \times 1000 = 0.46$ kg	A1
(b)(ii)	**1.** $(\Delta)p = (\Delta m)v$	C1
	$(\Delta)p = 0.46 \times 13$ $= 6.0$ N s	A1
	2. $F = 6.0/0.20$ $= 30$ N	A1
(b)(iii)	force on water (by rocket/nozzle) equal to force on rocket/nozzle (by water)	M1
	in the opposite direction	A1
(b)(iv)	**1.** mass = 0.40 + 0.70 – 0.46 = 0.64 kg	A1
	2. acceleration = [30 – (0.64 × 9.81)] / 0.64 **or** 30 / 0.64 – 9.81	C1
	$= 37$ m s^{-2}	A1

59. 9702_s17_qp_21 Q: 3

	Answer	Mark
(a)	$\rho = m / V$	C1
	$V = \pi d^2 L / 4$ **or** $\pi r^2 L$	C1
	weight = $2.7 \times 10^3 \times \pi (1.2 \times 10^{-2})^2 \times 5.0 \times 10^{-2} \times 9.81 = 0.60$ N	A1
(b)(i)	the point from where (all) the weight (of a body) seems to act	B1
(b)(ii)	$W \times 12$	C1
	$(0.25 \times 8) + (0.6 \times 38)$	C1
	$W = (2 + 22.8) / 12$ $= 2.1$ (2.07) N	A1
(c)(i)	pressure changes with depth (in water) **or** pressure on bottom (of cylinder) different from pressure on top	B1
	pressure on bottom of cylinder greater than pressure on top **or** force (up) on bottom of cylinder greater than force (down) on top	B1
(c)(ii)	anticlockwise moment reduced and reducing the weight of X reduces clockwise moment **or** anticlockwise moment reduced so clockwise moment now greater than (total) anticlockwise moment	B1

60. 9702_s16_qp_22 Q: 2

(a) $p = F / A$ M1

use of $m = \rho V$ and use of $V = Ah$ and use of $F = mg$ M1

correct substitution to obtain $p = \rho g h$ A1 [3]

(b) **(i)** (when h is zero the pressure is not zero due to) pressure from the air/atmosphere B1 [1]

(ii) gradient = ρg or $P - 1.0 \times 10^5 = \rho g h$ C1

e.g. $\rho g = 1.0 \times 10^5 / 0.75$ (= 133333)

$\rho = 133\,333 / 9.81$

$= 14\,000$ (13 592) kg m^{-3} A1 [2]

61. 9702_s16_qp_23 Q: 4

(a) (resultant force = 0) (equilibrium)

therefore: weight – upthrust = force from thin wire (allow tension in wire)
or
5.3 (N) – upthrust = 4.8 (N) B1 [1]

(b) difference in weight = upthrust or upthrust = 0.5 (N)

$0.5 = \rho ghA$ or $m = 0.5/9.81$ and $V = 5.0 \times 13 \times 10^{-6}$ (m^3) C1

$\rho = 0.5/(9.81 \times 5.0 \times 13 \times 10^{-6})$ C1

$= 780$ (784) kg m^{-3} A1 [3]

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62. 9702_w16_qp_21 Q: 1

(a) (density =) mass / volume B1 [1]

(b) **(i)** $d = [(6 \times 7.5)/(\pi \times 8100)]^{1/3}$

$= 0.12(1)$ m A1 [1]

(ii) percentage uncertainty = (4 + 5) / 3 (= 3%)
or
fractional uncertainty = (0.04 + 0.05) / 3 (= 0.03) C1

absolute uncertainty (= 0.03 × 0.121) = 0.0036 C1

$d = 0.121 \pm 0.004$ m A1 [3]

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63. 9702_w16_qp_22 Q: 1

(a) **(i)** force / area (normal to the force) B1 [1]

(ii) ($p = F/A$ so) units: kg m s^{-2} / m^2 = kg m^{-1} s^{-2} A1 [1]

allow use of other correct equations:
e.g. ($\Delta p = \rho g \Delta h$ so) kg m^{-3} m s^{-2} m = kg m^{-1} s^{-2}
e.g. ($p = W/\Delta V$ so) kg m s^{-2} m / m^3 = kg m^{-1} s^{-2}

(b) units for m: kg, t: s and ρ: kg m^{-3} C1

units of C: kg / s (kg m^{-3} kg m^{-1} s^{-2})$^{1/2}$
or
units of C^2: kg^2 / s^2 kg m^{-3} kg m^{-1} s^{-2} C1

units of C: m^2 A1 [3]

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64. 9702_w16_qp_23 Q: 1

(a) (density =) mass / volume B1 [1]

(b) (i) $d = [(6 \times 7.5)/(\pi \times 8100)]^{1/3}$

$= 0.12(1)$ m A1 [1]

(ii) percentage uncertainty = (4 + 5) / 3 (= 3%)
or
fractional uncertainty = (0.04 + 0.05) / 3 (= 0.03) C1

absolute uncertainty (= 0.03 × 0.121) = 0.0036 C1

d = 0.121 ± 0.004 m A1 [3]

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65. 9702_s15_qp_22 Q: 4

(a) (*p* =) *mv* C1

Δp (= – 6.64 × 10^{-27} × 1250 – 6.64 × 10^{-27} × 1250) = 1.66 × 10^{-23} N s A1 [2]

(b) (i) molecule collides with wall/container **and** there is a change in momentum B1

change in momentum / time is force or $\Delta p = Ft$ B1

many/all/sum of molecular collisions over surface/area of container produces pressure B1 [3]

(ii) more collisions per unit time so greater pressure B1 [1]

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66. 9702_w15_qp_21 Q: 4

(a) density = mass / volume C1

mass = 7900 × 4.5 × 24 × 10^{-6} = 0.85 (0.853) kg M1 [2]

(b) pressure = force / area C1

force = $W \cos 40°$ C1

pressure = (0.85 × 9.81 cos 40°) / 24 × 10^{-4}

= 2.7 (2.66) × 10^{3} Pa A1 [3]

(c) $F = ma$ C1

$W \sin 40° – f = ma$ C1

0.85 × 9.81 × sin 40° – *f* = 0.85 × 3.8

f (= 5.36 – 3.23) = 2.1 N [5.38 – 3.242 if 0.8532 kg is used for the mass] A1 [3]

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67. 9702_w15_qp_23 Q: 7

(a) stress or $\sigma = F/A$ C1

max. tension = UTS × A = 4.5 × 10^8 × 15 × 10^{-6} = 6800 (6750) N A1 [2]

(b) $\rho = m/V$ C1

weight = $mg = \rho Vg = \rho ALg$
6750 = 7.8 × 10^3 × 15 × 10^{-6} × L × 9.81 C1

L = 5.9 (5.88) × 10^3 m A1

or

maximum mass = 6750/9.81 = 688 kg (C1)
mass per unit length = ρA = 0.117 kg m^{-1} (C1)
L = 688/0.117 = 5.9 × 10^3 m (A1)

or

maximum mass = 6750/9.81 = 688 kg (C1)
volume = m/ρ = 0.0882 m^3 = LA (C1)
L = 0.0882/15 × 10^{-6} = 5.9 × 10^3 m (A1) [3]

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68. 9702_s20_qp_21 Q: 2

	Answer	Mark
(a)	(resultant) force proportional to rate of change of momentum	B1
(b)(i)	arrow drawn vertically downwards from point X	B1
(b)(ii)	$s = ut + ½at^2$ h = ½ × 9.81 × 0.81^2	C1
	= 3.2 m	A1
(b)(iii)	d = 5.4 × 0.81 = 4.4 m	A1
(c)(i)	downward pointing arrow labelled weight	B1
	upward pointing arrow labelled air resistance	B1
(c)(ii)	air resistance increases	B1
	weight constant or resultant force decreases	B1
	(so) acceleration decreases	B1
(c)(iii)	gravitational potential energy to thermal/internal energy	B1

69. 9702_s17_qp_22 Q: 4

	Answer	Mark
(a)	a body/mass/object continues (at rest or) at constant/uniform velocity unless acted on by a resultant force	B1
(b)(i)	initial momentum = final momentum $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$	C1
	0.60 × 100 – 0.80 × 200 = –0.40 × 100 + *v* × 200 *v* = (–) 0.3(0) m s^{-1}	A1
(b)(ii)	kinetic energy is not conserved/is lost (but) total energy is conserved/constant **or** some of the (initial) kinetic energy is transformed into other forms of energy	B1

70. 9702_w17_qp_23 Q: 2

	Answer	Mark
(a)	$\rho = m / V$ **or** $\rho = m / Ah$	B1
	$p = F / A$ **or** $p = W / A$	B1
	$p = [\rho Ahg] / A$ **or** $p = [\rho Vg] / [V / h]$ (so) $p = \rho gh$	A1

	Answer	Mark
(b)(i)	**1.** weight/gravitational (force) upthrust (force)/buoyancy (force) drag/viscous/frictional (force)/fluid resistance/resistance	B1
	2. weight = upthrust + viscous (force)	B1
(b)(ii)	• decrease in (gravitational) potential energy (of sphere) due to decrease in height (since $E_p = mgh$) • increase in thermal energy due to work done against viscous force/drag • loss/change of (total) E_p equal to gain/change in thermal energy *Any 2 points.*	B2
(c)(i)	atmospheric pressure = 9.1(0) × 10^4 Pa	A1
(c)(ii)	$(\Delta)p = \rho g(\Delta)h$ (9.15 – 9.10) × 10^4 = ρ × 9.81 × (0.17 – 0.10)	C1
	ρ = 730 (728) kg m^{-3}	A1

71. 9702_s15_qp_22 Q: 2

(a)	speed decreases/stone decelerates to rest/zero at 1.25 s	B1	
	speed then increases/stone accelerates (in opposite direction)	B1	[2]
(b) (i)	$v = u + at$ (or $s = ut + ½at^2$ **and** $v^2 = u^2 + 2as$)	C1	
	$= 0 + (3.00 – 1.25) \times 9.81$	C1	
	$= 17.2\ (17.17)\ \text{m s}^{-1}$	A1	[3]
(ii)	$s = ut + ½at^2$		
	$s = ½ \times 9.81 \times (1.25)^2$ [= 7.66]	C1	
	$s = ½ \times 9.81 \times (1.75)^2$ [= 15.02]	C1	
	(distance = 7.66 + 15.02)		
	[$v = u + at = 0 + 9.81 \times (2.50 – 1.25) = 12.26\ \text{m s}^{-1}$]		
	or		
	$s = ½ \times 9.81 \times (1.25)^2$ [= 7.66]	(C1)	
	$s = 12.26 \times 0.50 + ½ \times 9.81 \times (3.00 – 2.50)^2$ [= 7.36]	(C1)	
	(distance = 2 × 7.66 + 7.36)		
	Example alternative method:		
	$s = (v^2 – u^2)/2a = (12.26^2 – 0)/2 \times 9.81$ [= 7.66]	(C1)	
	$s = (v^2 – u^2)/2a = (17.17^2 – 12.26^2)/2 \times 9.81$ [= 7.36]	(C1)	
	(distance = 2 × 7.66 + 7.36)		
	22.7 (22.69 or 23) m	A1	[3]
(iii)	(s = 15.02 – 7.66 =) 7.4 (7.36) m *(ignore sign in answer)*	A1	
	down	A1	[2]
(c)	straight line from positive value of v to t axis	M1	
	same straight line crosses t axis at t = 1.25 s	A1	
	same straight line continues with same gradient to t = 3.0 s	A1	[3]

72. 9702_w15_qp_23 Q: 4

(a) **(i)** reaction/vertical force = weight – P cos 60° C1

= 180 – 35 cos 60°

= 160 (163) N A1 [2]

(ii) work done = 35 sin 60° × 20 C1

= 610 (606) J A1 [2]

(b) **(i)** work done by force P = work done against frictional force B1 [1]

(ii) horizontal component of P is equal and opposite to frictional force B1

vertical component of P + normal reaction force equal and opposite to weight B1 [2]

73. 9702_s20_qp_21 Q: 3

	Answer	Mark
(a)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(b)(i)	**1.** $T \sin 53° = 2.4$ $T = 3.0$ N	A1
	2. $F = T \cos 53°$ **or** $F^2 = T^2 - 2.4^2$ $F = 1.8$ N	A1
(b)(ii)	$\sigma = T / A$ **or** $\sigma = F / A$	C1
	$A = \pi d^2 / 4$ **or** $A = \pi r^2$	C1
	$\sigma = 3.0 \times 4 / [\pi \times (0.50 \times 10^{-3})^2]$ $= 1.5 \times 10^7$ Pa	A1
(c)(i)	$h = 75 - 75 \sin 53° = 15$ cm	A1
(c)(ii)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	$(\Delta)E = 2.4 \times 15 \times 10^{-2}$ $= 0.36$ J	A1
(c)(iii)	$E = ½mv^2$	B1
	$0.36 = ½ \times (2.4 / 9.81) \times v^2$	C1
	$v = 1.7$ m s^{-1}	A1

74. 9702_s20_qp_22 Q: 3

	Answer	Mark
(a)	(work done =) force × displacement in direction of the force	B1
(b)(i)	**1.** $(\Delta)E = mg(\Delta)h$	C1
	$= 0.42 \times 9.81 \times 78$ $= 320$ J	A1
	2. $E = ½mv^2$	C1
	$(\Delta)E = ½ \times 0.42 \times 23^2$ $= 110$ J	A1
(b)(ii)	work done = 320 – 110 (= 210 N)	C1
	average resistive force = 210 / 78 = 2.7 N	A1
(c)	downward sloping line from (0, *g*) to a non-zero value on the time axis	M1
	line is curved with a gradient that becomes less negative **and** the line meets *t*-axis at time $t < T$	A1

75. 9702_w20_qp_21 Q: 2

	Answer	Mark
(a)	constant gradient	B1
(b)	(displacement until 0.20 s =) ½ × 1.96 × 0.20 (= 0.196 m) **or** (displacement after 0.20 s =) ½ × 6.86 × 0.70 (= 2.401 m)	C1
	height = 2.401 – 0.196	C1
	= 2.2 m (*alternative methods are possible using equations of uniformly accelerated motion*)	A1
(c)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$(\Delta)E = 0.86 \times 2.2$ $= 1.9$ J	A1
(d)	curved line from the origin	M1
	gradient of curved line decreases and is zero at $t = 0.20$ s only	A1
(e)	acceleration (of free fall) is unchanged/is not dependent on mass <u>and</u> (so) no effect	B1

76. 9702_m19_qp_22 Q: 2

	Answer	Mark
(a)(i)	distance in a specified direction (from a point)	B1
(a)(ii)	change in velocity / time (taken)	B1
(b)(i)	constant velocity so no resultant force	B1
	no resultant force so in equilibrium	B1
(b)(ii)	(difference in height =) 47 × 2.8 × 60 × sin24° = 3200 m	A1

	Answer	Mark
(b)(iii)	1 $(\Delta)E = mg(\Delta)h$ $= 85 \times 9.81 \times 3200$	C1
	$= 2.7 \times 10^6$ J	A1
	2 <u>In terms of energy</u>: work done = 2.7×10^6 J force = $2.7 \times 10^6 / (47 \times 2.8 \times 60)$	C1
	= 340 N	A1
	<u>In terms of forces</u>: component of weight along path = force due to air resistance force = $85 \times 9.81 \times \sin 24°$	(C1)
	= 340 N	(A1)
(b)(iv)	$(\Delta)p = \rho g(\Delta)h$ $(92 - 63) \times 10^3 = \rho \times 9.81 \times 3200$	C1
	$\rho = 0.92$ kg m^{-3}	A1

77. 9702_m19_qp_22 Q: 3

	Answer	Mark
(a)	$(m \times 3.0)$ or $(2.5 \times 9.6 \times \cos 60°)$	C1
	$(m \times 3.0) - (2.5 \times 9.6 \times \cos 60°) = 0$ so $m = 4.0$ (kg)	A1

	Answer	Mark
(b)	$2.5 \times 9.6 \times \sin 60° = (4.0 + 2.5) \times V$	C1
	$V = 3.2$ m s^{-1}	A1
	or use of momentum vector triangle: $(4.0 \times 3.0)^2 + [(4.0 + 2.5) \times V]^2 = (2.5 \times 9.6)^2$	(C1)
	$V = 3.2$ m s^{-1}	(A1)
(c)	$E = ½mv^2$ difference in $E_K = ½ \times 2.5 \times (9.6)^2 - ½ \times 4.0 \times (3.0)^2$	C1
	= 97 J	A1

78. 9702_s19_qp_22 Q: 3

	Answer	Mark
(a)	the point where (all) the weight (of the body) is taken to act	B1
(b)(i)	vertical component = 54 sin 35° = 31 N	A1
(b)(ii)	the (line of action of the) force (at B) passes through (point) A **or** the (line of action of the) force (at B) has zero (perpendicular) distance from (point) A	B1
(b)(iii)	54 sin 35° × 0.68 **or** 54 cos 35° × 0.68 **or** *W* × 0.34	C1
	54 sin 35° × 0.68 + 54 cos 35° × 0.68 = *W* × 0.34 so *W* = 150 (N)	A1
(b)(iv)	total vertical force = 150 – 31 = 120 N	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	$E = ½mv^2$	C1
	ratio = $(m \times 9.81 \times 4.8) / (½ \times m \times 9.2^2)$ **or** $(9.81 \times 4.8) / (½ \times 9.2^2)$	C1
	= 1.1	A1

79. 9702_s19_qp_23 Q: 2

	Answer	Mark
(a)(i)	**1.** $W = mas$	B1
	2. $s = (v^2 – u^2) / 2a$	B1
(a)(ii)	*W*/work equals energy transferred/gain or change in kinetic energy	B1
	$W (= mas) = ma(v^2 – u^2) / 2a$ leading to $W = m(v^2 – u^2) / 2$ (so KE = $½mv^2$)	B1
(b)(i)	**1.** solid curved line drawn from X to Y along path of ball and labelled D	B1
	2. solid straight line drawn from X to Y and labelled S	B1
(b)(ii)	$(\Delta)E = mg(\Delta)h$	C1
	$4.5 = (0.040 \times 9.81 \times h) + (½ \times 0.040 \times 9.5^2)$	C1
	h = 6.9 m	A1
(b)(iii)	line with a negative gradient starting from a non-zero value of kinetic energy when the vertical height is zero	M1
	straight line ends at a non-zero value of kinetic energy when the vertical height is *h*	A1

80. 9702_w19_qp_21 Q: 4

	Answer	Mark
(a)	$k = F / x$ **or** k = gradient	C1
	e.g. k = 4.0 / 0.050 k = 80 N m^{-1}	A1
(b)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	C1
	$(\Delta)E$ = (½ × 3.2 × 0.040) – (½ × 1.2 × 0.015) = 0.055 J **or** $(\Delta)E$ = (½ × 80 × 0.040^2) – (½ × 80 × 0.015^2) = 0.055 J **or** $(\Delta)E$ = ½ × (1.2 + 3.2) × 0.025 = 0.055 J	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	= 0.122 × 9.81 × (0.120 – 0.095) = 0.030 J	A1
	or	
	$(\Delta)E = W \times (\Delta)h$	(C1)
	= 1.2 × 0.025 = 0.030 J	(A1)

	Answer	Mark
(d)(i)	E = 0.055 – 0.030 = 0.025 J	A1
(d)(ii)	$E = ½mv^2$	C1
	v = [(2 × 0.025) / 0.122]$^{0.5}$ = 0.64 m s^{-1}	A1

81. 9702_w19_qp_22 Q: 3

	Answer	Mark
(a)	force on body A (by body B) is equal (in magnitude) to force on body B (by body A)	B1
	force on body A (by body B) is opposite (in direction) to force on body B (by body A)	B1
(b)(i)	$m_X \times 5v$ **or** $(m_X + m_Y) \times v$	C1
	$m_X \times 5v = (m_X + m_Y) \times v$ (so) $m_Y / m_X = 4$	A1
(b)(ii)	$(E =)$ $½mv^2$	C1
	ratio = [½ × $(m_X + m_Y) \times v^2$] / [½ × $m_X \times (5v)^2$]	C1
	= 0.2	A1
(b)(iii)	ratio = 1	A1
(c)(i)	**1.** (magnitude of resultant force is) zero	B1
	2. (magnitude of resultant force is) constant	B1
	(direction of resultant force is) opposite to the momentum	B1
(c)(ii)	horizontal line from (0 ms, 0 squares) ending at (20 ms, 0 squares)	B1
	straight line from (20 ms, 0 squares) ending at (40 ms, 4.0 squares [= 4.0 cm vertically])	B1
	horizontal line from (40 ms, 4.0 squares) ending at (60 ms, 4.0 squares)	B1

82. 9702_m18_qp_22 Q: 2

	Answer	Mark
(a)(i)	force × distance moved in the direction of the force	B1
(a)(ii)	energy (of a mass/body) due to motion / speed / velocity	B1
(b)(i)	1 $E = ½mv^2$	C1
	$(\Delta)E = ½ \times 580 \times (22^2 - 12^2) = 9.9 \times 10^4$ J	A1
	2 $(\Delta)E = mg(\Delta)h$ $\Delta E = 580 \times 9.81 \times 13$	C1
	$= 7.4 \times 10^4$ J	A1

	Answer	Mark
(b)(ii)	length = $(2\pi\times13) / 4$ or $(\pi\times26) / 4$ or $(\pi\times13) / 2$ = 20 m	A1
(b)(iii)	work done against resistive force = $9.9 \times 10^4 - 7.4 \times 10^4$ average resistive force = $(9.9 \times 10^4 - 7.4 \times 10^4) / 20$	C1
	= 1300 N	A1
(b)(iv)	from horizontal/right to vertical / up or 90°	A1
(b)(v)	$p = mv$ or (580×22) or (580×12)	C1
	$\Delta p = [(580\times12)^2 + (580\times22)^2]^{0.5}$	C1
	$= 1.5 \times 10^4$ N s	A1

83. 9702_s18_qp_22 Q: 2

	Answer	Mark
(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	M1
	for an isolated system **or** no (resultant) external force	A1
(b)(i)	$(p =) mv$ **or** $(3.0M \times 7.0)$ **or** $(2.0M \times 6.0)$ **or** $(1.5M \times 8.0)$	C1
	$3.0M \times 7.0 = 2.0M \times 6.0 \sin\theta + 1.5M \times 8.0 \sin\theta$	C1
	$\theta = 61°$	A1
	or (vector triangle method)	
	momentum vector triangle drawn	(C1)
	$\theta = 61°$ (*2 marks for* ±1°, *1 mark for* ±2°)	(A2)
	or (use of cosine rule)	
	$p = mv$ **or** $(3.0M \times 7.0)$ **or** $(2.0M \times 6.0)$ **or** $(1.5M \times 8.0)$	(C1)
	$(21M)^2 = (12M)^2 + (12M)^2 - (2 \times 12M \times 12M \times \cos 2\theta)$	(C1)
	$\theta = 61°$	(A1)
(b)(ii)	$(E =) ½mv^2$	C1
	ratio $= (½ \times 2.0M \times 6.0^2) / (½ \times 1.5M \times 8.0^2)$ $= 0.75$	A1

84. 9702_s18_qp_23 Q: 3

	Answer	Mark
(a)	$v = u + at$	A1
	$v = 9.6 - (9.81 \times 0.37) = 6.0\,\text{m}\,\text{s}^{-1}$	
(b)	$s = ½ \times (9.6 + 6.0) \times 0.37$ **or** $6.0^2 = 9.6^2 - (2 \times 9.81 \times s)$ **or** $s = (9.6 \times 0.37) - (½ \times 9.81 \times 0.37^2)$ **or** $s = (6.0 \times 0.37) + (½ \times 9.81 \times 0.37^2)$	C1
	$s = 2.9\,\text{m}$	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$\Delta E = 0.056 \times 9.81 \times 2.9$ $= 1.6\,\text{J}$	A1
(c)(ii)	$E = ½mv^2$	C1
	$\Delta E = ½ \times 0.056 \times (6.0^2 - 3.8^2)$ $= 0.60\,\text{J}$	A1
(d)	force on ball (by ceiling) equal to force on ceiling (by ball)	M1
	and opposite (in direction)	A1
(e)	$(p =)\ mv$ **or** 0.056×6.0 **or** 0.056×3.8	C1
	change in momentum $= 0.056 \times (6.0 + 3.8)$ $= 0.55\,\text{N}\,\text{s}$	A1
(f)	resultant force $= 0.55 / 0.085$ $(= 6.47\,\text{N})$	C1
	force by ceiling $= 6.47 - (0.056 \times 9.81)$ $= 5.9\,\text{N}$	A1

85. 9702_w18_qp_21 Q: 1

	Answer	Mark
(a)(i)	distance in a specified direction (from a point)	B1
(a)(ii)	change in velocity / time (taken)	B1
(b)(i)	vertical component of velocity = $(5.5^2 - 4.6^2)^{1/2} = 3.0$ (m s^{-1}) **or** $5.5\cos\theta = 4.6$ (so θ = 33.2°) **and** $5.5\sin 33.2° = 3.0$ (m s^{-1})	A1
(b)(ii)	$s = ut + \frac{1}{2}at^2$ $0 = (3.0 \times t) - (\frac{1}{2} \times 9.81 \times t^2)$ **or** $v = u + at$ $-3.0 = 3.0 - 9.81t$	C1
	$t = 0.61$ s	A1
(b)(iii)	$d = 4.6 \times 0.61$ $= 2.8$ m	A1
(b)(iv)	$E = \frac{1}{2}mv^2$	C1
	ratio = $(\frac{1}{2} \times m \times 4.6^2) / (\frac{1}{2} \times m \times 5.5^2)$ **or** ratio = $(\frac{1}{2} \times m \times 5.5^2 - m \times 9.81 \times 0.459) / (\frac{1}{2} \times m \times 5.5^2)$	C1
	ratio = 0.70	A1
(c)	straight line from positive value of v_y at $t = 0$ to negative value of v_y	M1
	straight line ends at $t = T$ and final magnitude of v_y greater than initial magnitude of v_y	A1

86. 9702_w18_qp_22 Q: 1

	Answer	Mark
(a)	$v_x = (6.0^2 - 4.8^2)^{1/2} = 3.6$ (m s^{-1}) **or** $6.0\sin\theta = 4.8$ (so θ = 53.1°) **and** $v_x = 6.0\cos 53.1° = 3.6$ (m s^{-1})	A1
(b)(i)	straight line from (0, 4.8) to (0.49, 0)	M1
	straight line continues with same slope to (0.98, –4.8) (labelled Y)	A1
(b)(ii)	a horizontal line	M1
	from (0, 3.6) to (0.98, 3.6) (labelled X)	A1
(c)	$s = ut + \frac{1}{2}at^2$ $= (4.8 \times 0.49) + (\frac{1}{2} \times -9.81 \times 0.49^2)$ **or** $s = \frac{1}{2}(u + v)t$ **or** area under graph $= \frac{1}{2} \times (4.8 + 0) \times 0.49$ **or** $s = vt - \frac{1}{2}at^2$ $= \frac{1}{2} \times 9.81 \times 0.49^2$ **or** $v^2 = u^2 + 2as$ $s = 4.8^2 / (2 \times 9.81)$	C1
	$s = 1.2$ m	A1

	Answer	Mark
(d)	(Δ)*E* = *mg*(Δ)*h*	C1
	$E = ½mv^2$	C1
	ratio = (½ × *m* × 3.6^2) / (*m* × 9.81 × 1.2) **or** ratio = [(½ × *m* × 6.0^2) – (*m* × 9.81 × 1.2)] / (*m* × 9.81 × 1.2) **or** ratio = (½ × *m* × 3.6^2) / (½ × *m* × 4.8^2)	C1
	ratio = 0.56	A1
(e)	(force due to) air resistance acts in opposite direction to the velocity **or** (with air resistance, average) resultant force is larger (than weight)	B1

87. 9702_w18_qp_23 Q: 2

	Answer	Mark
(a)	energy (of a mass/body/object) due to motion/speed/velocity	B1
(b)(i)	$E = ½mv^2$	C1
	480 = ½ × *m* × 80^2 so *m* = 0.15 kg	A1
(b)(ii)	**1.** *E* = *mgh* **or** Δ*E* = *mg*Δ*h*	C1
	= 0.15 × 9.81 × 210 = 310 J	A1
	2. work done = 480 – 310 = 170 J	A1
(b)(iii)	work done = *Fs*	C1
	force = 170 / 210 = 0.81 N	A1
(b)(iv)	curved line from positive value on *v*-axis to (*T*, 0)	M1
	magnitude of gradient decreases	A1
(b)(v)	as shell rises force decreases and as shell falls force increases	B1
	as shell rises force is downward and as shell falls force is upward	B1
	or	
	as shell rises the force decreases and is downward	(B1)
	as shell falls the force increases and is upward	(B1)

88. 9702_s17_qp_21 Q: 2

	Answer	Mark
(a)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(b)(i)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$	C1
	e.g. $a = (8.8 - 4.6) / (7.0 - 4.0) = 1.4\ \text{m s}^{-2}$	A1
(b)(ii)	$s = 4.6 \times 4 + [(8.8 + 4.6) / 2] \times 3$	C1
	$= 18.4 + 20.1$ $= 39\ (38.5)\ \text{m}$	A1
(b)(iii)	$\Delta E = ½ \times 95\ [(8.8)^2 - (4.6)^2]$	C1
	$= 3678 - 1005$ $= 2700\ (2673)\ \text{J}$	A1
(b)(iv)1.	weight = 95 × 9.81 (= 932 N)	C1
	vertical tension force = 280 sin 25° **or** 280 cos 65° (=118.3 N)	C1
	$F = 932 + 118$ $= 1100\ (1050)\ \text{N}$	A1
(b)(iv)2.	horizontal tension force = 280 cos 25° **or** 280 sin 65° (= 253.8 N)	C1
	resultant force = 95 × 1.4 (= 133 N)	C1
	$133 = 253.8 - R$ $R = 120\ (120.8)\ \text{N}$	A1

89. 9702_s17_qp_22 Q: 2

	Answer	Mark
(a)	rate of change of displacement **or** change in displacement/time taken	B1
(b)(i)	$s = ut + ½at^2$	C1
	$t = [(2 \times 1.25) / 9.81]^{1/2}\ (= 0.5048\ \text{s})$	C1
	or	
	$v^2 = u^2 + 2as$ $v_{vert} = (2 \times 9.81 \times 1.25)^{1/2}\ (= 4.95)$	**(C1)**
	$t = [2s / (u + v)] = 2 \times 1.25 / 4.95\ (= 0.5048\ \text{s})$	**(C1)**
	$v = d / t = 1.5 / 0.50(48)$ $= 3.0\ (2.97)\ \text{m s}^{-1}$	A1
(b)(ii)	vertical velocity $= at$ $= 9.81 \times 0.5048$ (= 4.95) [using t = 0.50 gives 4.9]	C1
	velocity $= [(v_h)^2 + (v_v)^2]^{1/2}$	C1
	$= [(2.97)^2 + (4.95)^2]^{1/2}$ $= 5.8$ (5.79) [using t = 0.50 leads to 5.7]	A1
	direction (= $\tan^{-1}$ 4.95/2.97) = 59°	A1
(b)(iii)	kinetic energy $= ½mv^2$	C1
	$= ½ \times 0.45 \times (5.8)^2$ $= 7.6$ (7.57) J [using t = 0.50 leads to 7.3 J]	A1

	Answer	Mark
(b)(iv)	potential energy = *mgh*	C1
	= (0.45 × 9.81 × 1.25) = 5.5 (5.52) J	A1
(c)	there is KE of the ball at the start/leaving table **or** the ball has an initial/constant horizontal velocity **or** the ball has velocity at start/leaving table	B1

90. 9702_m16_qp_22 Q: 2

(a) change in velocity / time (taken) **or** rate of change of velocity — B1

(b) **(i)** $v_X = (24 / 1.5) = 16\,(\text{m s}^{-1})$ — A1

(ii) $\tan 28° = v_Y / v_X$ *or* $v_X = v\cos 28°$ *and* $v_Y = v \sin 28°$ — C1
$v_Y = 16 \tan 28°$ *or* $v_Y = 16 \times (\sin 28° / \cos 28°)$ so $v_Y = 8.5\,(\text{m s}^{-1})$ — A1

(iii) $v = u + at$ — C1
$t = (0 - 8.5) / (-9.81)$
$= 0.87$ (s) — A1

(iv) straight line from positive v_Y at $t = 0$ to negative v_Y at $t = 1.5$ s — M1
line starts at (0, 8.5) and crosses t-axis at (0.87, 0) and does not go beyond $t = 1.5$ s. — A1

(c) **(i)** ($v^2 = u^2 + 2as$) $0 = 8.5^2 + 2(-9.81)s$
or ($s = ut + ½at^2$) $s = 8.5 \times 0.87 + ½ \times (-9.81) \times 0.87^2$
or ($s = vt - ½at^2$) $s = 0 - ½ \times (-9.81) \times 0.87^2$
or ($s = ½(u + v)t$ or area under graph) $s = 0.5 \times 8.5 \times 0.87$ — C1

$s = 3.7$ (m) — A1

(ii) $\Delta E_P = mg\Delta h$ (*allow* $E = mgh$) — C1
$m = 22 / (9.81 \times 3.7)$
$= 0.61$ (kg) — A1

(d) acceleration (of freefall) is unchanged / not dependent on mass, and so no effect (on maximum height)
or *explanation in terms of energy:*
(initial) KE ∝ mass, (Δ)KE = (Δ)PE, (max) PE ∝ mass, and so no effect (on maximum height) — B1

91. 9702_s16_qp_22 Q: 1

(a)	acceleration = change in velocity / time (taken) or rate of change of velocity	B1	[1]
(b) (i)	$v = 0 + at$ or $v = at$	C1	
	(a = 36 / 19 =) 1.9 (1.8947) m s^{-2}	A1	[2]
(ii)	$s = ½(u + v)t$ or $s = v^2 / 2a$ or $s = ½at^2$		
	= ½ × 36 × 19 = 36^2 / (2 × 1.89) = ½ × 1.89 × 19^2		
	= 340 m (342 m / 343 m / 341 m)	M1	[1]
(iii)	**1.** (ΔKE =) ½ × 95 × $(36)^2$	C1	
	= 62 000 (61 560) J	A1	[2]
	2. (ΔPE =) 95 × 9.81 × 340 sin 40° or 95 × 9.81 × 218.5	C1	
	= 200 000 J	A1	[2]
(iv)	work done (by frictional force) = ΔPE – ΔKE *or* work done = 200 000 – 62 000 (values from **1b(iii) 1.** and **2.**)	C1	
	(frictional force = 138 000 / 340 =) 410 (406) N [420 N if full figures used]	A1	[2]
(v)	$–ma = mg \sin 20° – f$ or $ma = –mg \sin 20° + f$	C1	
	–95 × 3.0 = 95 × 3.36 – f		
	f = 600 (604) N	A1	[2]

92. 9702_s16_qp_23 Q: 3

(a)	(gravitational potential energy is) the energy/ability to do work of a mass that it has or is stored due to its position/height in a gravitational field	B1	
	kinetic energy is energy/ability to do work a object/body/mass has due to its speed/velocity/motion/movement	B1	[2]
(b) (i)	$s = [(u + v)t] / 2$ or acceleration = 9.8/9.75 (using gradient)	C1	
	= [(7.8 + 3.9) × 0.4] / 2 or $s = 3.9 \times 0.4 + \frac{1}{2} \times 9.75 \times (0.4)^2$	C1	
	s = 2.3(4) m	A1	[3]
(ii)	$a = (v – u) / t$ or gradient of line	C1	
	= (7.8 – 3.9) / 0.4 = 9.8 (9.75) m s^{-2} (allow ± $\frac{1}{2}$ small square in readings)	A1	[2]

(iii) KE = $\frac{1}{2}mv^2$ C1

change in kinetic energy = $\frac{1}{2}mv^2 - \frac{1}{2}mu^2$

= $\frac{1}{2} \times 1.5 \times (7.8^2 - 3.9^2)$ C1

= 34 (34.22) J A1 [3]

(c) work done = force × distance (moved) or *Fd* or *Fx* or *mgh* or *mgd* or *mgx* M1

= 1.5 × 9.8 × 2.3 = 34 (33.8) J (equals the change in KE) A1 [2]

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93. 9702_w16_qp_22 Q: 2

(a) $\Delta E = mg\Delta h$ C1

= 0.030 × 9.81 × (–)0.31

= (–)0.091 J A1 [2]

(b) $E = ½mv^2$ C1

(initial) $E = ½ \times 0.030 \times 1.3^2$ (= 0.0254) C1

$0.5 \times 0.030 \times v^2 = (0.5 \times 0.030 \times 1.3^2) + (0.030 \times 9.81 \times 0.31)$ so $v = 2.8\,\text{m s}^{-1}$
or
$0.5 \times 0.030 \times v^2 = (0.0254) + (0.091)$ so $v = 2.8\,\text{m s}^{-1}$ A1 [3]

(c) (i) 0.096 = 0.030 (*v* + 2.8) C1

$v = 0.40\,\text{m s}^{-1}$ A1 [2]

(ii) $F = \Delta p / (\Delta)t$ *or* $F = ma$
$= 0.096 / 20 \times 10^{-3}$ *or* $0.030\,(0.40 + 2.8) / 20 \times 10^{-3}$ C1

= 4.8 N A1 [2]

(d) kinetic energy (of ball and wall) decreases/changes/not conserved, so inelastic
or
(relative) speed of approach (of ball and wall) not equal to/greater than (relative) speed of separation, so inelastic. B1 [1]

(e) force = work done / distance moved
= (0.091 – 0.076) / 0.60 C1

= 0.025 N A1 [2]

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94. 9702_s15_qp_23 Q: 2

(a)	constant rate of increase in velocity/acceleration from t = 0 to t = 8 s	B1	
	constant deceleration from t = 8 s to t = 16 s or constant rate of increase in velocity in the opposite direction from t = 10 s to t = 16 s	B1	[2]
(b) (i)	area under lines to 10 s	C1	
	(displacement =) (5.0 × 8.0) / 2 + (5.0 × 2.0) / 2 = 25 m or ½ (10.0 × 5.0) = 25 m	A1	[2]
(ii)	a = $(v - u)/t$ or gradient of line	C1	
	= (–15.0 –5.0) / 8.0		
	= (–) 2.5 m s^{-2}	A1	[2]
(iii)	KE = $\frac{1}{2}mv^2$	C1	
	= 0.5 × 0.4 × (15.0)^2 = 45 J	A1	[2]
(c)	(distance =) 25 (m) (= $ut + \frac{1}{2}at^2$) = 0 + ½ × 2.5 × t^2	C1	
	(t = 4.5 (4.47) s therefore) time to return = 14.5 s	A1	[2]

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95. 9702_w15_qp_21 Q: 3

(a)	work done is force × distance moved in direction of force **or** no work done along PQ as no displacement/distance moved in direction of force	B1	
	work done is same in vertical direction as same distance moved in direction of force	B1	[2]
(b) (i)	at maximum height t = 1.5 (s) **or** $s = \frac{1}{2}(u + v)t$, s = 11 m and t = 1.5 s	C1	
	V_v = 0 + 9.81 × 1.5 V_v = (11 × 2) / 1.5		
	= 15 (14.7) m s^{-1}	A1	[2]
(ii)	straight line from (0,0) to (3.00, 25.5)	B1	[1]
(iii)	at maximum height V_h = 25.5 / 3 (= 8.5 m s^{-1})	B1	
	ratio = $mgh / \frac{1}{2}mv^2$	C1	
	= (2 × 9.81 × 11.0) / (8.5)^2		
	= 3.0 (2.99)	A1	[3]
(iv)	deceleration is greater/resultant force (weight and friction force) is greater	M1	
	time is less	A1	[2]

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96. 9702_w15_qp_22 Q: 2

(a)	**(i)** $v = u + at$	C1	
	$0 = 3.6 - 3.0t$		
	$t\ (= 3.6/3.0) = 1.2\,\text{s}$	A1	[2]
	(ii) (distance to rest from P = (3.6 × 1.2)/2 =) 2.2 (2.16) m **or** $[0 - (3.6)^2]/[2 \times (-3.0)] = 2.2\ (2.16)\,\text{m}$ **or** $3.6 \times 1.2 - \frac{1}{2} \times 3.0 \times (1.2)^2 = 2.2\ (2.16)\,\text{m}$ **or** $0 + \frac{1}{2} \times 3.0 \times (1.2)^2 = 2.2\ (2.16)\,\text{m}$	A1	[1]
(b)	distance = 6.0 – 2.16 (= 3.84)	C1	
	$v^2 = u^2 + 2as = 2 \times 3.0 \times 3.84\ (= 23.04)$	M1	
	or		
	$x + 2 \times 2.16 = 6.0$ gives $x = 1.68\,(\text{m})$	(C1)	
	$v^2 = 3.6^2 + 2 \times 1.68 \times 3.0\ (= 23.04)$	(M1)	
	or correct method with intermediate time calculated (t = 1.6 s from Q to R)		
	$v = 4.8\,\text{m}\,\text{s}^{-1}$	A0	[2]
(c)	straight line from $v = 3.6\,\text{m}\,\text{s}^{-1}$ to $v = 0$ at $t = 1.2\,\text{s}$	B1	
	straight line continues with the same gradient as v changes sign	B1	
	straight line from $v = 0$ intercept to $v = -4.8\,\text{m}\,\text{s}^{-1}$	B1	[3]
(d)	difference in KE $= \frac{1}{2}m(v^2 - u^2)$ $= 0.5 \times 0.45\ (4.8^2 - 3.6^2)$ [= 5.184 – 2.916]	C1	
	$= 2.3\ (2.27)\,\text{J}$	A1	[2]

97. 9702_w15_qp_23 Q: 3

(a) (i) 1.	$s = ut + ½at^2$		
	$192 = ½ \times 9.81 \times t^2$	C1	
	$t = 6.3\ (6.26)$ s	A1	[2]
2.	max E_k (= mgh) = $0.27 \times 9.81 \times 192$	C1	
	or		
	calculation of v (= 61.4) and use of E_K (= $½ mv^2$) = $½ \times 0.27 \times (61.4)^2$	(C1)	
	max E_k = 510 (509) J	A1	[2]
(ii)	velocity is proportional to time **or** velocity increases at a constant rate		
	as acceleration is constant or resultant force is constant	B1	[1]
(iii)	use of $v = at$ or $v^2 = 2as$ or $E = ½mv^2$ to give $v = 61(.4)\ \text{m s}^{-1}$	B1	[1]
(b) (i)	R increases with velocity	B1	
	resultant force is $mg - R$ **or** resultant force decreases	B1	
	acceleration decreases	B1	[3]
(ii)	at $v = 40\ \text{m s}^{-1}$, $R = 0.6$ (N)	C1	
	$0.27 \times 9.8 - 0.6 = 0.27 \times a$		
	$a = 7.6\ (7.58)\ \text{m s}^{-2}$	A1	[2]
(iii)	R = weight for terminal velocity	B1	
	either weight requires velocity to be about $80\ \text{m s}^{-1}$ *or* at $60\ \text{m s}^{-1}$, R is less than weight		
	so does not reach terminal velocity	B1	[2]

98. 9702_s20_qp_22 Q: 1

	Answer	Mark
(a)	(velocity =) change in displacement / time (taken)	**B1**
(b)	units of F: kg m s^{-2}	**C1**
	units of k: $\text{kg m s}^{-2} / [\text{m}^2 \times (\text{m s}^{-1})^2]$ $= \text{kg m}^{-3}$	**A1**
(c)	$P = Fv$	**C1**
	$4.8 \times 10^4 = 0.24 \times 5.1 \times v^3$	**C1**
	$v = 34\ \text{m s}^{-1}$	**A1**

99. 9702_s19_qp_23 Q: 3

	Answer	Mark
(a)	$P = Fv$	C1
	$P = 8.9 \cos 30° \times 0.60$ $= 4.6$ W	A1
(b)	$p = F / A$	C1
	$F = 8.9 \sin 30° + (0.24 \times 9.81)$ $(= 6.80$ N$)$	C1
	$A = 6.80 / 3500$ $= 1.9 \times 10^{-3}$ m^2	A1
(c)(i)	upwards/up	B1
(c)(ii)	the Earth/planet	B1

100. 9702_w19_qp_23 Q: 2

	Answer	Mark
(a)	(work done =) force × distance moved in direction of force	B1
(b)(i)	**1.** acceleration = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / t$	C1
	e.g. $a = 2.4 / 3.0$ $= 0.80$ m s^{-2}	A1
	2. tension in cable = $(13.0 + 2.0) \times 10^3$	C1
	work done $= 15 \times 10^3 \times (3.0 \times 2.4)$ $= 1.1 \times 10^5$ J	A1
(b)(ii)	power = Fv	C1
	$v = 2.0$ (m s^{-1})	C1
	input power $= (1.6 \times 10^4 \times 2.0) / 0.67$ $= 4.8 \times 10^4$ W	A1
(b)(iii)	work is done against friction so (increase in) GPE is less (than work done by motor) **or** energy is lost or transferred or converted to heat/thermal energy due to friction or resistance force **or** work is done lifting the cable so GPE is less	A1

101. 9702_w18_qp_21 Q: 3

	Answer	Mark
(a)(i)	work (done) / time (taken)	B1
(a)(ii)	energy of a mass due to its position in a gravitational field	B1
(b)(i)	$P = Fv$	C1
	$= 2.0 \times 10^3 \times 45$ $= 9.0 \times 10^4$ W	A1
(b)(ii)	**1.** $W = (2.0 \times 10^3) \times (45 \times 3.0 \times 60)$ **or** $W = 9.0 \times 10^4 \times 3.0 \times 60$	C1
	$W = 1.6 \times 10^7$ J	A1
	2. $(\Delta)E_P = mg(\Delta)h$	C1
	$= 1200 \times 9.81 \times 3.3 \times 3.0 \times 60$ $= 7.0 \times 10^6$ J	A1
	3. $W = 1.6 \times 10^7 - 7.0 \times 10^6$ $= 9.0 \times 10^6$ J	A1
(b)(iii)	force $= (9.0 \times 10^6) / (45 \times 3.0 \times 60)$ $= 1.1 \times 10^3$ N	A1
(b)(iv)	constant velocity so no resultant force	B1
	no resultant force so in equilibrium	B1

102. 9702_m17_qp_22 Q: 3

	Answer	Mark
(a)	change of displacement / time (taken)	B1
(b)(i)	constant velocity, so resultant force is zero	M1
	(so car is) in (dynamic) equilibrium	A1
(b)(ii)	$F_D = 0.40$ (kN) or 0.40×10^3 (N)	C1
	component of weight $= 2.0 \times 10^3 - 0.40 \times 10^3$ $= 1.6 \times 10^3$ N	A1
(b)(iii)	$P = Fv$	C1
	$= 2.0 \times 10^3 \times 9.0 = 1.8 \times 10^4$ W	A1
(b)(iv)	(driving) force $= 1.8 \times 10^4 / 15$ $(= 1.2 \times 10^3)$	C1
	$F_D = 0.66$ (kN) or 0.66×10^3 (N)	C1
	acceleration $= (1.2 \times 10^3 - 0.66 \times 10^3) / 850$ $= 0.64$ (0.635) m s^{-2}	A1

103. 9702_s15_qp_23 Q: 3

(a)	(power =) work done / time (taken) or rate of work done	A1	[1]
(b) (i)	$F - R = ma$	C1	
	$F = 1500 \times 0.82 + 1200$	C1	
	= 2400 (2430) N	A1	[3]
(ii)	$P = Fv$	C1	
	= (2430 × 22) = 53 000 (53 500) W	A1	[2]
(c)	(there is maximum power from car and) resistive force = force produced by car hence no acceleration **or** suggestion in terms of power produced by car and power wasted to overcome resistive force	B1	[1]

104. 9702_m20_qp_22 Q: 3

	Answer	Mark
(a)	force × displacement in the direction of the force	B1
(b)(i)	displacement = 4.4 × 30	C1
	work done = 140 cos 30° × 4.4 × 30	C1
	= 1.6×10^4 J	A1
(b)(ii)	$p = F / A$	C1
	F = 860 – 140 sin 30° (= 790)	C1
	A = 790 / 2400 = 0.33 m^2	A1
(b)(iii)	$\sigma = F / A$ or $F / \pi r^2$ or $4F / \pi d^2$	C1
	$9.6 \times 10^6 = 4 \times 140 / \pi d^2$ $d = 4.3 \times 10^{-3}$ m	A1

	Answer	Mark
(c)	$E = ½Fx$ or $½kx^2$ or area under graph	C1
	$(\Delta)E = ½ \times (140 + 210) \times 0.20 \times 10^{-3}$ or $(\Delta)E = (½ \times 210 \times 0.60 \times 10^{-3}) - (½ \times 140 \times 0.40 \times 10^{-3})$ or $(\Delta)E = (140 \times 0.20 \times 10^{-3}) + (½ \times 0.20 \times 10^{-3} \times 70)$ or $(\Delta)E = [½ \times 3.5 \times 10^5 \times (0.60 \times 10^{-3})^2] - [½ \times 3.5 \times 10^5 \times (0.40 \times 10^{-3})^2]$	C1
	ΔE = 0.035 J	A1

105. 9702_w19_qp_23 Q: 4

	Answer	Mark
(a)(i)	$p = mv$	C1
	$= 0.2(00) \times 6.(00) \times \sin 60(.0)°$ **or** $0.2(00) \times 6.(00) \times \cos 30(.0)°$ $= 1.04\ \text{kg m s}^{-1}$	A1
(a)(ii)	$0.300 \times v_x \times \sin 60.0° = 1.04$ $v_x = 4.00\ \text{m s}^{-1}$	A1
(a)(iii)	$0.30 \times 4.0 \times \cos 60°$ **or** $0.20 \times 6.0 \times \cos 60°$ **or** $(0.30 + 0.20)v$ **or** $0.50v$	C1
	$0.30 \times 4.0 \times \cos 60° + 0.20 \times 6.0 \times \cos 60° = (0.30 + 0.20)v$ **or** $0.50v$ so $v = 2.4\ \text{m s}^{-1}$	A1
(b)(i)	$E = ½mv^2$	C1
	$½ \times 0.50 \times 2.4^2 = ½ \times 72 \times x^2$	C1
	$x = 0.20\ \text{m}$	A1
(b)(ii)	**1.** straight line from the origin sloping upwards	B1
	2. line drawn from a positive value of E_k at $x = 0$ to a positive value of x at $E_k = 0$	M1
	line has an increasing downwards slope	A1

106. 9702_m18_qp_22 Q: 3

	Answer	Mark
(a)(i)	force / (cross-sectional) area	B1
(a)(ii)	extension / original length	B1
(b)(i)	measure / determine / find diameter	B1
	using a micrometer / digital calipers	B1
	several measurements in different places / along the wire / around the circumference (and average them)	B1
(b)(ii)	$E = \sigma / \varepsilon$ or $E = FL / Ax$ or E = gradient × (L / A) $E = (4 \times 2.5) / (0.8 \times 10^{-3}) \times (9.4 \times 10^{-8})$	C1
	$= 1.3 \times 10^{11}\ \text{Pa}$	A1

	Answer	Mark
(b)(iii)	$E = ½Fx$ or $E = ½kx^2$ or E = area under graph $E = ½ \times (2+4) \times 0.4 \times 10^{-3}$ or $E = (½ \times 4 \times 0.8 \times 10^{-3}) - (½ \times 2 \times 0.4 \times 10^{-3})$ or $E = [\ ½ \times 5000 \times (0.8 \times 10^{-3})^2\ ] - [\ ½ \times 5000 \times (0.4 \times 10^{-3})^2\ ]$	C1
	$E = 1.2 \times 10^{-3}\ \text{J}$	A1
(c)	straight line from the origin and above the original line	M1
	straight line passes through (0.80, 8.0)	A1

107. 9702_s18_qp_21 Q: 2

	Answer	Mark
(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)1.	from 0–2 s, distance = ½ × 2 × 6.8 (= 6.8 m) **and** from 2–3 s, distance = ½ × 1 × 3.4 (= 1.7 m)	C1
	magnitude of displacement = 5.1 m	A1
	direction of displacement is down(wards)	B1
(b)(i)2.	$(\Delta E) = mg\Delta h$ **or** $(E) = mgh$ **or** $(E) = Wh$	C1
	$(\Delta)E = 15 \times 5.1$ $= (-)\ 77\,\text{J}$	A1
(b)(ii)	$a = (v - u) / t$ **or** a = gradient **or** $a = \text{d}v/\text{d}t$	C1
	$a = 3.4\,\text{m}\,\text{s}^{-2}$	A1
(b)(iii)	$T - W = ma$ **or** $T - mg = ma$	C1
	$T = 15 + (15 / 9.81) \times 3.4 = 20\,\text{N}$ or $20.2\,\text{N}$	A1
(b)(iv)	$E = F / A\varepsilon$ **or** $E = \sigma / \varepsilon$ and $\sigma = F / A$	C1
	$\varepsilon = 20 / (2.8 \times 10^{-5} \times 1.7 \times 10^{11})$	C1
	$= 4.2 \times 10^{-6}$	A1
(b)(v)	block is in equilibrium/has no resultant force	B1
	block could be stationary (**or** have constant velocity/speed) (so no, not possible to deduce)	B1

108. 9702_s18_qp_22 Q: 5

	Answer	Mark
(a)	$\rho = m / V$	C1
	$= (560 / 9.81) / (1.2 \times 0.018)$ $= 2600\,\text{kg}\,\text{m}^{-3}$	A1
(b)	$(\Delta)p = 940 \times 9.81 \times 1.2$	C1
	(upthrust =) $940 \times 9.81 \times 1.2 \times 0.018 = 200\,\text{N}$	A1
(c)(i)	tension $= 560 - 200$ $= 360\,\text{N}$	A1
(c)(ii)	$P = Fv$	C1
	$= 360 \times 0.020$ $= 7.2\,\text{W}$	A1
(d)(i)	upthrust decreases	B1
	tension (in wire) increases	M1
	power (output of motor) increases	A1
(d)(ii)	there is work done (on the cylinder) by the upthrust **or** GPE of oil decreases (as it fills the space left by cylinder and so total energy is conserved)	B1

109. 9702_w18_qp_23 Q: 1

	Answer	Mark
(a)	current temperature (**allow** amount of substance, luminous intensity) *any two correct answers, 1 mark each*	**B2**
(b)(i)	$W = 2 \times (150 \times \sin 17°)$ **or** $2 \times (150 \times \cos 73°)$	**C1**
	$W = 88$ N	**A1**
(b)(ii)	**1.** $\sigma = F / A$	**C1**
	$= 150 / (7.5 \times 10^{-6})$ $= 2.0 \times 10^{7}$ Pa	**A1**
	2. $\varepsilon = \sigma / E$	**C1**
	$= 2.0 \times 10^{7} / (2.1 \times 10^{11})$ $= 9.5 \times 10^{-5}$	**A1**

110. 9702_s17_qp_22 Q: 3

	Answer	Mark
(a)	E = stress / strain **or** $(F / A) / (e / l)$	**C1**
	$= [\text{gradient} \times 3.5] / [\pi \times (0.19 \times 10^{-3})^2]$ e.g. $E = [\{(40 - 5) / ([11.6 - 3.2] \times 10^{-3})\} \times 3.5] / [\pi \times (0.19 \times 10^{-3})^2]$ **or** $[4170 \times 3.5] / [\pi \times (0.19 \times 10^{-3})^2]$	**C1**
	E (= 1.3×10^{11}) = 0.13 TPa (*allow answers in range 0.120–0.136 TPa*)	**A1**
(b)	a larger <u>range</u> of F required **or** <u>range</u> greater than 35 N	**B1**

111. 9702_w17_qp_21 Q: 4

	Answer	Mark
(a)	(strain =) extension / <u>original</u> length	**B1**
(b)(i)	$E = \sigma / \varepsilon$	**C1**
	maximum stress $= 2.1 \times 10^{11} \times 4.0 \times 10^{-4}$ $= 8.4 \times 10^{7}$ Pa	**A1**
(b)(ii)	$\sigma = F / A$	**C1**
	minimum area $= 8.0 \times 10^{3} / 8.4 \times 10^{7}$ $= 9.5 \times 10^{-5}$ m^2	**A1**

112. 9702_w17_qp_22 Q: 3

	Answer	Mark
(a)	$p = 1000 \times 9.81 \times 7.0 \times 10^{-2}$ **or** $1000 \times 9.81 \times 1.9 \times 10^{-2}$	C1
	$\Delta p = 1000 \times 9.81 \times (7.0 \times 10^{-2} - 1.9 \times 10^{-2})$ **or** $686 - 186$ $= 500$ Pa	A1
(b)	$F = pA$ **or** $(\Delta)F = \Delta p \times A$	C1
	upthrust $= 500 \times (5.1 \times 10^{-2})^2 = 1.3$ N **or** upthrust $= (686 - 186) \times (5.1 \times 10^{-2})^2 = 1.3$ N **or** upthrust $= 1000 \times 9.81 \times 5.1 \times 10^{-2} \times (5.1 \times 10^{-2})^2 = 1.3$ N	A1
(c)	force $= 4.0 - 1.3$ $= 2.7$ N	A1

	Answer	Mark
(d)	extension/x/e $= 2.7/30$	C1
	$= 0.09$ (m) **or** 9 (cm)	C1
	height above surface $= 9 - 7$ $= 2$ cm	A1
(e)(i)	mass $= 4.0/9.81$	C1
	acceleration $= 2.7/(4.0/9.81)$ $= 6.6$ m s^{-2}	A1
(e)(ii)	viscous force <u>increases</u> (and then becomes constant)	M1
	(weight and upthrust constant so) acceleration decreases (to zero)	A1

113. 9702_s16_qp_22 Q: 3

(a) Young modulus = stress / strain B1 [1]

(b) **(i)** $E = (F \times l)/(A \times e)$ or $e = (F \times l)/(A \times E)$ B1

$e \propto 1/E$
or
ratio $e_C/e_S = E_S/E_C$ or $(1.9 \times 10^{11})/(1.2 \times 10^{11})$ or 19/12 C1

(ratio =) 1.6 (1.58) A1 [3]

(ii) two straight lines from (0,0) with **S** having the steepest gradient B1 [1]

114. 9702_w16_qp_22 Q: 3

(a) resultant force (in any direction) is zero B1
resultant moment/torque (about any point) is zero B1 [2]

(b) **(i)** force = 33 sin 52° *or* 33 cos 38°
= 26 N A1 [1]

(ii) 26×0.30 *or* $W \times 0.20$ *or* 12×0.40 C1

$26 \times 0.30 = (W \times 0.20) + (12 \times 0.40)$ C1

$W = 15\,\text{N}$ A1 [3]

(c) **(i)** $E = \Delta\sigma / \Delta\varepsilon$ *or* $E = \sigma / \varepsilon$ C1

$\Delta\sigma = 2.0 \times 10^{11} \times 7.5 \times 10^{-4}$
$= 1.5 \times 10^{8}\,\text{Pa}$ A1 [2]

(ii) $\Delta\sigma = \Delta F / A$ *or* $\sigma = F / A$ C1

$A = 78 / 1.5 \times 10^{8}$ $(= 5.2 \times 10^{-7}\,\text{m}^2)$ C1

$5.2 \times 10^{-7} = \pi d^2 / 4$

$d = 8.1 \times 10^{-4}\,\text{m}$ A1 [3]

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115. 9702_s20_qp_23 Q: 3

	Answer	Mark
(a)	for a body in (rotational) equilibrium	**B1**
	sum/total of clockwise moments about a point = sum/total of anticlockwise moments about the (same) point	**B1**
(b)(i)	$(W \times 0.45)$ **or** (19×1.3) **or** $(W \times 1.85)$ **or** (22×2.6)	**C1**
	$(W \times 0.45) + (19 \times 1.3) + (W \times 1.85) = (22 \times 2.6)$ so $W = 14\,\text{N}$	**A1**
(b)(ii)	magnitude = 19 + 14 + 14 – 22 = 25 N	**A1**
	direction: vertically upwards	**A1**
(c)(i)	the extension is zero when the force is zero	**B1**
	graph is a straight line and (so) Hooke's law obeyed	**B1**
(c)(ii)	$k = F / x$ **or** k = gradient	**C1**
	e.g. $k = 60 / (1.00 - 0.25)$ $k = 80\,\text{N m}^{-1}$	**A1**
(c)(iii)	area shaded below graph line between $L = 0.25\,\text{m}$ and $L = 0.75\,\text{m}$	**B1**

116. 9702_w20_qp_21 Q: 4

	Answer	Mark
(a)(i)	(stress =) force / cross-sectional area	B1
(a)(ii)	(strain =) extension / original length	B1
(b)(i)	$E = FL / Ax$	C1
	$= GL / A$	A1
(b)(ii)	straight line from origin above the original line	M1
	line ends at point (4 small squares, F_1).	A1
(b)(iii)	**1.** shaded area below the graph line and between the two vertical dashed lines	B1
	2. remove the force/F/F_2 and the wire goes back to original length/zero extension	B1
(b)(iv)	values have a large range	B1

117. 9702_w20_qp_22 Q: 3

	Answer	Mark
(a)(i)	$F = kx$	C1
	$F_1 = 800 \times 0.045$ $= 36$ N	A1
(a)(ii)	(E =) ½kx^2 **or** ½Fx **or** area under graph	C1
	$½ \times 800 \times (0.045)^2$ **or** $½ \times 36 \times 0.045 = 0.81$ (J)	A1
(b)(i)	efficiency = $(0.72 / 0.81) \times 100$ $= 89\%$	A1
(b)(ii)	$E = ½mv^2$	C1
	$p = mv$	C1
	$0.72 = ½ \times 0.020 \times v^2$ and $p = 0.020 \times v$ $p = 0.17$ N s	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$h = 0.60 / (0.020 \times 9.81) = 3.1$ m	A1
(c)(ii)	$F = (0.72 - 0.60) / 3.1$	C1
	$= 0.039$ N	A1
(c)(iii)	resultant force on ball is less (than that with air resistance) so time (taken) is more (than T)	B1

118. 9702_w20_qp_23 Q: 4

	Answer	Mark
(a)	compression/extension is proportional to force (provided limit of proportionality is not exceeded)	B1
(b)	$(E) = ½Fx$ **or** $½kx^2$ **or** area under graph	C1
	$= ½ \times 8 \times 16 \times 10^{-2} = 0.64$ (J) **or** $= ½ \times 50 \times (16 \times 10^{-2})^2 = 0.64$ (J)	A1
(c)(i)	$(E) = ½mv^2$	C1
	$0.64 = ½ \times 0.076 \times v^2$ $v = 4.1\ \text{m s}^{-1}$	A1
(c)(ii)	$(\Delta)(E) = mg(\Delta)h$	C1
	$= 0.076 \times 9.81 \times 0.24$ (= 0.18 (J))	C1
	kinetic energy = 0.64 – 0.18 = 0.46 J	A1
(c)(iii)	$v = 4.1\ \text{m s}^{-1}$	A1
(d)	$W = Fs$	C1
	$d = 0.30 + (2\pi \times 0.12) + 0.25$ (= 1.3 m)	C1
	$F = 0.23 / 1.3$ = 0.18 N	A1

119. 9702_s19_qp_21 Q: 3

	Answer	Mark
(a)(i)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	C1
	$E = ½ \times 4.0 \times 0.32 = 0.64$ J **or** $E = ½ \times 12.5 \times (0.32)^2 = 0.64$ J	A1
(a)(ii)	$E = mgh$ **or** $E = Wh$ $= 2.5 \times 0.32$	C1
	= 0.80 J	A1
(b)(i)	kinetic energy = 0.80 – 0.64 = 0.16 J	A1
(b)(ii)	$E = ½mv^2$ $0.16 = ½ \times (2.5 / 9.81) \times v^2$	C1
	$v = 1.1\ \text{m s}^{-1}$	A1

120. 9702_s18_qp_23 Q: 4

	Answer	Mark
(a)	(Young modulus =) stress / strain	B1
(b)(i)	$k = F / \Delta L$ **or** 1 / gradient	C1
	$= 90 \times 10^3 / (2 \times 10^{-3})$ (*or other point on line*) $= 4.5 \times 10^7$ N m^{-1}	A1
(b)(ii)	$E = ½F\Delta L$ **or** $E = ½k(\Delta L)^2$	C1
	$= ½ \times 90 \times 10^3 \times 2 \times 10^{-3}$ **or** $½ \times 4.5 \times 10^7 \times (2 \times 10^{-3})^2$	C1
	= 90 J	A1
(c)	straight line starting from (0, 150) and below original line	M1
	line ends at (90, 147)	A1

121. 9702_m17_qp_22 Q: 2

	Answer	Mark
(a)	sum / total momentum of bodies is constant *or* sum / total momentum of bodies before = sum / total momentum of bodies after	M1
	for an isolated / closed system / no (resultant) external force	A1
(b)(i)	EPE = area under graph or $½Fx$ or $½kx^2$ and $F = kx$	C1
	energy = $½ \times 12.0 \times 8.0 \times 10^{-2}$ = 0.48 J *or* energy = $½ \times 150 \times (8.0 \times 10^{-2})^2$ = 0.48 J	A1
(b)(ii)1	$4.0\ v_A = 6.0\ v_B$	C1
	$E_K = ½mv^2$	C1
	ratio $= \dfrac{0.50 \times 4.0}{0.50 \times 6.0}\left(\dfrac{6.0}{4.0}\right)^2 = 1.5$ *or* ratio $= \dfrac{1}{1.5} \times (1.5)^2 = 1.5$	A1
(b)(ii)2	$0.48 = E_K$ of A + E_K of B $= E_K$ of A + (E_K of A / 1.5) = 5/3 × E_K of A	C1
	E_K of A = 0.29 (0.288) J	A1
(b)(iii)	curve starts from origin and has decreasing gradient	M1
	final gradient of graph line is zero	A1

122. 9702_s17_qp_23 Q: 4

	Answer	Mark
(a)	the straight line does not go through the origin/the force is not proportional to extension (so does not obey Hooke's law)	A1
(b)	elastic potential energy	B1
(c)	remove the force/masses and the spring returns to its original length if elastic	B1
(d)	work done is represented by/linked to area under the line (× g)	C1
	work $= ½ (145 + 70) \times 10^{-3} \times 9.81 \times 120 \times 10^{-3}$	C1
	= 0.13 (0.127) J	A1

123. 9702_m16_qp_22 Q: 3

(a)	**(i)**	(work =) force × distance moved in the direction of the force.	B1
	(ii)	the energy stored (in an object) due to extension / compression / change of shape	B1
(b)	**(i)**	$E_K = ½mv^2$	C1
		$= 0.5 \times 0.40 \times 0.30^2$	
		$= 1.8 \times 10^{-2}$ (J)	A1
	(ii)	(change in) kinetic energy = work done on spring / (change in) elastic potential energy	C1
		$1.8 \times 10^{-2} = ½ \times F \times 0.080$	C1
		$F_{MAX} = 0.45$ (N)	A1
	(iii)	$a = F / m = 0.45 / 0.40$	
		$= 1.1$ (m s^{-2})	A1
	(iv)	**1.** constant velocity / resultant force is zero, so in equilibrium	B1
		2. decelerating / resultant force is not zero, so not in equilibrium	B1
(c)		curved line from the origin	M1
		with decreasing gradient	A1

124. 9702_s16_qp_21 Q: 4

(a)	the energy (stored) in a body due to its extension/compression/deformation/ change in shape/size	B1	[1]
(b) (i)	two values of *F*/*x* are calculated which are the same e.g. 10.4 / 40 = 0.26 and 6.5 / 25 = 0.26	B1	
	or		
	ratio of two forces and the ratio of the corresponding two extensions are calculated which are the same e.g. 5.2 / 10.4 = 0.5 and 20 / 40 = 0.5	(B1)	
	or		
	gradient of graph line calculated and coordinates of one point on the line used with straight line equation $y = mx + c$ to show $c = 0$	(B1)	
	(so) force is proportional to extension (and so Hooke's law obeyed)	B1	[2]
(b) (ii)	**1.** $k = F / x$ or k = gradient	C1	
	gradient or values from a single point used e.g. $k = 10.4 / (40 \times 10^{-2})$		
	$k = 26\,\text{N m}^{-1}$	A1	[2]
	2. work done = area under graph or $½Fx$ or $½(F_2 + F_1)(x_2 – x_1)$ or $½kx^2$ or $½k(x_2^2 – x_1^2)$	C1	
	= $½ \times 10.4 \times 0.4 – ½ \times 5.2 \times 0.2$ or $½ \times (5.2 + 10.4) \times 20 \times 10^{-2}$ or $½ \times 26 \times (0.4^2 – 0.2^2)$	C1	
	= 1.6 J	A1	[3]
(c)	remove the force and the spring goes back to its original length	B1	[1]

125. 9702_w16_qp_21 Q: 3

(a)	force/load is proportional to extension/compression (provided proportionality limit is not exceeded)	B1	[1]
(b) (i)	$k = F/x$ *or* k = gradient	C1	
	$k = 600\,\text{N m}^{-1}$	A1	[2]
(ii)	$(W =)\ \frac{1}{2}kx^2$ *or* $(W =)\ \frac{1}{2}Fx$ *or* $(W =)$ area under graph	C1	
	$(W =)\ 0.5 \times 600 \times (0.040)^2 = 0.48\,\text{J}$ *or* $(W =)\ 0.5 \times 24 \times 0.040 = 0.48\,\text{J}$	A1	[2]
(iii) 1.	$(E_K =)\ \frac{1}{2}mv^2$	C1	
	$= \frac{1}{2} \times 0.025 \times 6.0^2$		
	$= 0.45\,\text{J}$	A1	[2]
2.	(work done against resistive force =) 0.48 – 0.45 [= 0.03(0) J]	C1	
	average resistive force = 0.030 / 0.040	C1	
	= 0.75 N	A1	[3]
(iv)	efficiency = [useful energy out / total energy in] (×100)	C1	
	= [0.45 / 0.48] (×100)		
	= 0.94 *or* 94%	A1	[2]

126. 9702_w16_qp_23 Q: 3

(a)	force/load is proportional to extension/compression (provided proportionality limit is not exceeded)	B1	[1]
(b) (i)	$k = F/x$ *or* k = gradient	C1	
	$k = 600\,\text{N m}^{-1}$	A1	[2]
(ii)	(W =) $\frac{1}{2}kx^2$ *or* (W =) $\frac{1}{2}Fx$ *or* (W =) area under graph	C1	
	(W =) $0.5 \times 600 \times (0.040)^2 = 0.48\,\text{J}$ *or* (W =) $0.5 \times 24 \times 0.040 = 0.48\,\text{J}$	A1	[2]
(iii) 1.	(E_K =) $\frac{1}{2}mv^2$	C1	
	$= \frac{1}{2} \times 0.025 \times 6.0^2$		
	$= 0.45\,\text{J}$	A1	[2]
2.	(work done against resistive force =) 0.48 – 0.45 [= 0.03(0) J]	C1	
	average resistive force = 0.030 / 0.040	C1	
	= 0.75 N	A1	[3]
(iv)	efficiency = [useful energy out / total energy in] (×100)	C1	
	= [0.45 / 0.48] (×100)		
	= 0.94 *or* 94%	A1	[2]

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127. 9702_s15_qp_21 Q: 4

(a) (i)	two sets of co-ordinates taken to determine a constant value (F/x)	M1	
	F/x constant hence obeys Hooke's law	A1	[2]
	or gradient calculated and one point on line used	(M1)	
	to show no intercept hence obeys Hooke's law	(A1)	
(ii)	gradient or one point on line used e.g. $4.5 / 1.8 \times 10^{-2}$	C1	
	(k =) $250\,\text{N m}^{-1}$	A1	[2]
(iii)	work done or E_P = area under graph or $\frac{1}{2}Fx$ or $\frac{1}{2}kx^2$	C1	
	$= 0.5 \times 4.5 \times 1.8 \times 10^{-2}$ or $0.5 \times 250 \times (1.8 \times 10^{-2})^2$	C1	
	= 0.041 (0.0405) J	A1	[3]
(b)	KE = $\frac{1}{2}mv^2$		
	$\frac{1}{2}mv^2 = 0.0405$ or KE = 0.0405 (J)	C1	
	($v = [2 \times 0.0405 / 1.7]^{1/2}$ =) 0.22 (0.218) m s^{-1}	A1	[2]

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128. 9702_w15_qp_22 Q: 3

(a) **(i)** $k = F / x$ **or** 1 / gradient C1

($k = 4.4 / (5.4 \times 10^{-2})$ =) 81 (81.48) N m^{-1} A1 [2]

(ii) work done = area under line **or** ½Fx **or** ½kx^2 C1

(= $0.5 \times 4.4 \times 5.4 \times 10^{-2}$ =) 0.12 (0.119) J A1 [2]

(b) **(i)** kinetic energy/E_k of trolley/T (and block) changes to EPE/strain energy/elastic energy of spring B1

EPE changes to KE of trolley/T and KE of block **or** to give lower KE to trolley B1 [2]

(ii) change in momentum = $m(v + u)$ C1

= 0.25 (0.75 + 1.2) = 0.49 (0.488) N s A1 [2]

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129. 9702_w20_qp_21 Q: 5

	Answer	Mark
(a)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	**C1**
	$v = 8.0 \times 10^{-2} / 0.40$ $= 0.20$ m s^{-1}	**A1**
(b)	$I \propto A^2$	**C1**
	ratio $= 2^2 / 4^2$	**C1**
	= 0.25	**A1**

130. 9702_w15_qp_21 Q: 2

(a) ps = 10^{-12} (s) **or** $T = 4 \times 50 \times 10^{-12}$ (s) B1

$v = f\lambda$ **or** $v = \lambda / T$ C1

$\lambda = 3.0 \times 10^8 \times 4 \times 50 \times 10^{-12}$ C1

= 0.06(0) m A1 [4]

(b) $1500 = 3.0 \times 10^8 \times 4 \times$ time-base setting **or** $T = 5 \times 10^{-6}$ s C1

time-base setting = 1.3 (1.25) μs cm^{-1} A1 [2]

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131. 9702_w18_qp_22 Q: 4

	Answer	Mark
(a)	vibration(s)/oscillation(s) (of particles) parallel to direction of propagation of energy	B1
(b)(i)	phase difference = 180°	A1
(b)(ii)	$v = f\lambda$	C1
	$\lambda/2$ = 25 (cm) or 0.25 (m)	C1
	f = 330/0.50 = 660 Hz	A1
(b)(iii)	(readings from graph =) 2.6 and 4.0	C1
	ratio = $(2.6/4.0)^{1/2}$ = 0.81	A1

132. 9702_s19_qp_23 Q: 5

	Answer	Mark
(a)	(incident) wave reflects at end/top of tube	B1
	(incident) wave and reflected wave interfere/superpose	B1
(b)	line has maximum value of amplitude at h = 0 and h = 0.60 m only	B1
	line has minimum/zero value of amplitude at h = 0.30 m only	B1
(c)(i)	vertical/along length of tube/along axis of tube	B1
(c)(ii)	phase difference = 0	A1
(d)	$v = f\lambda$	C1
	v = 340 / (2 × 0.60) = 280 Hz	A1
(e)	f = 340 / 0.60 = 570 Hz	A1

133. 9702_w19_qp_22 Q: 5

	Answer	Mark
(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(b)	(T =) 2.0 × 2.5 (= 5.0 ms) **or** 2.0 × 2.5 × 10^{-3} (= 5.0 × 10^{-3} s)	C1
	f = 1 / (5.0 × 10^{-3}) = 200 Hz	A1
(c)(i)	(path difference =) 8.0 + $(20.8^2 - 8.0^2)^{0.5}$ – 20.8 = 6.4 (m)	A1
(c)(ii)	• path difference = 4λ • waves (meet at C) in phase • constructive interference (of waves) *any two points, one mark each*	B2
(c)(iii)	v = 200 × 1.6 = 320 (m s^{-1})	C1
	Δt = 6.4 / 320 **or** 27.2 / 320 – 20.8 / 320 = 0.020 s	A1
(c)(iv)	3λ = 6.4 λ = 2.1 m	A1

134. 9702_s17_qp_22 Q: 5

	Answer	Mark
(a)	frequency is the number of vibrations/oscillations per unit time or the number of wavefronts passing a point per unit time	B1
(b)	vibrations/oscillation of the air particles are parallel to the direction of it (the direction of travel of the sound wave)	B1
(c)(i)	T = 2(.0) (ms)	C1
	f = 500 Hz	A1
(c)(ii)	**1.** amplitude increases (time) period decreases **2.** amplitude decreases (time) period increases *any 3 points*	B3

135. 9702_m20_qp_22 Q: 2

	Answer	Mark
(a)	$f_0 = f_S\, v / (v - v_S)$ 9560 = f × 1510 / (1510 – 4.50)	C1
	f = 9530 Hz	A1
(b)(i)	$v^2 = u^2 + 2as$ height = 5.6^2 / (2 × 9.81)	C1
	= 1.6 m	A1
(b)(ii)	downward sloping straight line starting from a point on the speed axis and ending at point (T, 0)	B1

	Answer	Mark
(b)(iii)	$(\Delta)E = mg(\Delta)h$ $= 0.45 \times 9.81 \times 1.6$	C1
	$= 7.1$ J	A1
(b)(iv)	air resistance increases (and weight constant)	B1
	(resultant force decreases so) acceleration decreases	B1

136. 9702_s19_qp_22 Q: 2

	Answer	Mark
(a)	(resultant) force proportional/equal to/is rate of change of momentum	B1
(b)(i)	distance = area under graph **or** $s = ½ (u + v) t$ $= ½ \times (9 + 13) \times 10$ **or** $s = ut + ½at^2$ $= (9 \times 10) + (½ \times 0.40 \times 10^2)$ **or** $s = vt - ½at^2$ $= (13 \times 10) - (½ \times 0.40 \times 10^2)$ **or** $v^2 = u^2 + 2as$ $13^2 = 9^2 + (2 \times 0.40 \times s)$	C1
	distance = 110 m	A1

	Answer	Mark
(b)(ii)	**1.** a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 - 9) / 12.5$ **or** $(13 - 9) / 10$	C1
	$a = 0.40$ m s^{-2}	A1
	2. resultant force = 850×0.40 = 340 N	A1
	3. (F =) 510 + 440 + 340 = 1300 (N)	A1
	4. $P = Fv$	C1
	$= 1300 \times 13$ $= 1.7 \times 10^4$ W	A1
(c)	$E = \sigma / \varepsilon$	C1
	$E = (F / A) / (\Delta L / L)$ **or** $E = FL / A\Delta L$	C1
	$\Delta L = (480 \times 0.48) / (3.0 \times 10^{-4} \times 2.2 \times 10^{11})$ $= 3.5 \times 10^{-6}$ m	A1
(d)	$f_o = f_s v / (v - v_s)$ $480 = f_s \times 340 / (340 - 14)$	C1
	$f_s = 460$ Hz	A1

137. 9702_w19_qp_21 Q: 3

	Answer	Mark
(a)	$\rho = m / V$	C1
	$V = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0$ (= 0.458 m^3)	C1
	$m = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0 \times 1.2 = 0.55$ kg	A1
(b)(i)	$\Delta p = 0.55 \times 7.6$ = 4.2 N s	A1
(b)(ii)	F = 4.2 / 3.0 **or** 0.55 × 7.6 / 3.0 = 1.4 N	A1
(c)(i)	F = 1.4 N	A1
(c)(ii)	Newton's third law (of motion)	B1
(d)	2 × 1.4 = m × 9.81 m = 0.29 kg	A1
(e)	the density of air is less at high altitude	B1
(f)	$f_o = f_s v / (v - v_s)$ = 3000 × 340 / (340 – 22)	C1
	= 3200 Hz	A1

138. 9702_s18_qp_22 Q: 3

	Answer	Mark
(a)	time = 12s	A1
(b)	distance (up slope) = ½ × 12 × 18 (= 108)	C1
	distance (down slope) = ½ × 12 × 6 (= 36)	C1
	displacement from A = 108 – 36 = 72m	A1
(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta)t$	C1
	a = 6 / 12 = 0.50 (ms^{-2}) *(other points from the line may be used)*	A1
	or	
	$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$	(C1)
	$a = 6.0^2 / (2 \times 36) = 0.50$ (ms^{-2})	(A1)
	or	
	$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$	(C1)
	$a = 2 \times 36 / 12^2 = 0.50$ (ms^{-2})	(A1)
	or	
	$s = vt – ½at^2$	(C1)
	$a = 2 \times (6 \times 12 – 36)/12^2 = 0.50$ (ms^{-2})	(A1)

	Answer	Mark
(d)(i)	$F = 70 \times 0.50$ (= 35)	C1
	frictional force = 80 – 35 = 45 N	A1
(d)(ii)	$\sin\theta = 80/(70 \times 9.81)$	C1
	$\theta = 6.7°$	A1
(e)(i)	$f_0 = (900 \times 340)/(340 + 12)$	C1
	= 870 Hz	A1
(e)(ii)	speed/velocity (of sledge) decreases and (so) frequency increases	B1

139. 9702_s18_qp_23 Q: 2

	Answer	Mark
(a)(i)	(work =) force × distance moved in the direction of the force	B1
(b)(i)	$\rho = m/V$	C1
	$= (20/9.81)/(4/3 \times \pi \times 0.16^3)$ $= 120\,\text{kg}\,\text{m}^{-3}$	A1
(b)(ii)	the pressure on the lower surface (of sphere) is greater than the pressure on the upper surface (of sphere)	B1
(b)(iii)	$a = (170 - 20)/(20/9.81)$	C1
	$= 74\,\text{m}\,\text{s}^{-2}$	A1
(b)(iv)	$D = 170 - 20$ (= 150)	C1
	$810 \times (0.16^2) \times v^2 = 150$	C1
	$v = 2.7\,\text{m}\,\text{s}^{-1}$	A1
(b)(v)	$4870 = (4850 \times v)/(v - 6.30)$	C1
	$v = 1530\,\text{m}\,\text{s}^{-1}$	A1

140. 9702_m17_qp_22 Q: 4

	Answer	Mark
(a)	change in frequency when source moves relative to observer	M1
	refers to 'change in observed / apparent frequency'	A1
(b)(i)	$f = (950 \times 330)/(330 - 7.5)$	C1
	= 970 (972) Hz	A1
(b)(ii)	frequency decreases	M1
	from greater than 950 Hz / from 970 (972) Hz / to less than 950 Hz / to 930 (929) Hz / by 40 (43) Hz	A1

141. 9702_s17_qp_21 Q: 5

	Answer	Mark
(a)	observed frequency is different to source frequency when source moves relative to observer	B1
(b)	$360 = (400 \times 340) / (340 \pm v)$	C1
	$v = 38$ (37.8) $\text{m}\,\text{s}^{-1}$	A1
	away (from the observer)	B1

142. 9702_w17_qp_23 Q: 4

	Answer	Mark
(a)	displacement of particles/vibration(s)/oscillation(s) is parallel to/along the direction of energy/propagation	B1
(b)	period = 1 / 800 (= 1.25×10^{-3} s)	C1
	time-base setting = 1.25×10^{-3} / 2.5	C1
	= 5.0×10^{-4} s cm^{-1}	A1
(c)(i)	$I \propto A^2$	C1
	$(I_X / I_Y =)\ [r_Y / r_X]^2 = [A_X / A_Y]^2$	C1
	ratio A_Y / A_X = 120 / 30 = 4.0	A1

	Answer	Mark
(c)(ii)	**1.** $v = f\lambda$	C1
	minimum λ = 330 / (800 + 16) = 0.40 m	A1
	2. $f_o / f_s = v / (v - v_s)$ 816 / 800 = 330 / (330 – v_s)	C1
	v_s = 6.5 m s^{-1}	A1

143. 9702_s16_qp_22 Q: 4

(a) longitudinal: vibrations/oscillations (of the particles/wave) are parallel to the direction **or** in the same direction (of the propagation of energy) B1

transverse: vibrations/oscillations (of the particles/wave) are perpendicular to the direction (of the propagation of energy) B1 [2]

(b) LHS: intensity = power / area units: kg m s^{-2} × m × s^{-1} × m^{-2} or kg m^2 s^{-3} × m^{-2} B1

RHS: units: m s^{-1} × kg m^{-3} × s^{-2} × m^2 M1

LHS and RHS both kg s^{-3} A1 [3]

(c) **(i)** change/difference in the <u>observed</u>/<u>apparent</u> frequency when the source is moving (relative to the observer) B1 [1]

(ii) wavelength increases/frequency decreases/red shift B1 [1]

(d) observed frequency = $vf_S / (v - v_S)$ C1

550 = (340 × 510) / (340 – v_S) C1

v_S = 25 (24.7) m s^{-1} A1 [3]

144. 9702_w16_qp_21 Q: 4

(a)	the number of oscillations per unit time of the source/of a point on the wave/of a particle (in the medium) *or* the number of wavelengths/wavefronts per unit time passing a (fixed) point	M1 A1 (M1) (A1)	 [2]
(b)	*T* or period = 2.5 × 250 (μs) (= 625 μs) frequency = 1 / (6.25 × 10^{-4}) or 1 / (2.5 × 250 × 10^{-6}) = 1600 Hz	M1 A1	 [2]
(c) (i)	for maximum frequency: $f_o = f_s v / (v - v_s)$ 1640 = (1600 × 330) / (330 – v_s) v_s = 8(.0) m s^{-1} (8.049 m s^{-1})	 C1 A1	 [2]
(ii)	loudspeaker moving towards observer causes rise in/high<u>er</u> frequency loudspeaker moving away from observer causes fall in/low<u>er</u> frequency *or* <u>repeated</u> rise and fall/higher and then lower frequency caused by loudspeaker moving towards and away from observer	B1 B1 (M1) (A1)	 [2]

145. 9702_w16_qp_23 Q: 4

(a)	the number of oscillations per unit time of the source/of a point on the wave/of a particle (in the medium) *or* the number of wavelengths/wavefronts per unit time passing a (fixed) point	M1 A1 (M1) (A1)	 [2]
(b)	*T* or period = 2.5 × 250 (μs) (= 625 μs) frequency = 1 / (6.25 × 10^{-4}) or 1 / (2.5 × 250 × 10^{-6}) = 1600 Hz	M1 A1	 [2]
(c) (i)	for maximum frequency: $f_o = f_s v / (v - v_s)$ 1640 = (1600 × 330) / (330 – v_s) v_s = 8(.0) m s^{-1} (8.049 m s^{-1})	 C1 A1	 [2]
(ii)	loudspeaker moving towards observer causes rise in/high<u>er</u> frequency loudspeaker moving away from observer causes fall in/low<u>er</u> frequency *or* <u>repeated</u> rise and fall/higher and then lower frequency caused by loudspeaker moving towards and away from observer	B1 B1 (M1) (A1)	 [2]

146. 9702_w20_qp_23 Q: 1

	Answer	Mark
(a)(i)	wavelength = 8.5×10^{-5} m	A1
(a)(ii)	$f = v / \lambda$ **or** c / λ	C1
	$= 3.0 \times 10^{8} / 8.5 \times 10^{-5}$ ($= 3.5 \times 10^{12}$) = 3.5 THz	A1
(a)(iii)	infrared	B1
(b)	(implied) percentage uncertainty in I = 4% **or** (implied) fractional uncertainty in I = 0.04	C1
	percentage uncertainty in E = 5% + (4% × 2) = 13%	A1

147. 9702_s20_qp_22 Q: 4

	Answer	Mark
(a)	progressive waves transfer energy **or** stationary waves do not transfer energy	B1
(b)(i)	0.32 m	A1
(b)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	v = 0.32 / 0.020 **or** 50 × 0.32 = 16 m s^{-1}	A1
(b)(iii)	450° **or** 90°	A1
(b)(iv)	(P has) maximum downward displacement at 0.005 s	B1
	returns to original position/point (at 0.010 s)	B1
(c)(i)	(position where) zero amplitude	B1
(c)(ii)	2	A1
(c)(iii)	180°	A1
(c)(iv)	string drawn between X and Y with one antinode midway along the string	B1

148. 9702_w20_qp_21 Q: 6

	Answer	Mark
(a)	the waves (of the same type) move in opposite directions and overlap	B1
	the waves have the same (speed and) frequency/wavelength	B1
(b)(i)	zero amplitude	B1
(b)(ii)	distance = 6.0 × 4 = 24 cm	A1
(b)(iii)	180°	A1

149. 9702_m18_qp_22 Q: 4

	Answer	Mark
(a)	(two) waves (travelling at same speed) in opposite directions overlap	B1
	(waves are same type and) have same frequency / wavelength	B1
(b)(i)	$v = f\lambda$ $f = 330 / 0.18$	C1
	$= 1800$ Hz (1830 Hz)	A1
(b)(ii)	$T = 1 / 1800$ ($= 5.5 \times 10^{-4}$) time-base setting $= (1.5 \times 5.5 \times 10^{-4}) / 8.0$ or $1 / (1800 \times 5.3)$	C1
	$= 1.0 \times 10^{-4}$ s cm^{-1}	A1
(b)(iii)	waveform drawn with same period as original waveform	B1
	waveform drawn with amplitude of 1.7 cm	B1
(c)(i)	distance $= \lambda / 2 = 0.18 / 2$ $= 0.090$ m	A1
(c)(ii)	letter N shown at level B and at level A and not anywhere else.	B1
(c)(iii)	$m = \rho Ax$ $= 0.79 \times 13 \times 9.0$ ($=92.4$) or $790 \times 13 \times 10^{-4} \times 0.090$ ($=0.0924$) $t = 92.4 / 6.7$ or $0.0924 / 0.0067$	C1
	$= 14$ s	A1

150. 9702_s18_qp_22 Q: 4

	Answer	Mark
(a)(i)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(a)(ii)	(position where) maximum amplitude	B1
(b)(i)	$\lambda = 4 \times 0.045$ ($= 0.18$ (m) or 18 (cm))	C1
	$v = f\lambda$	C1
	$f = 340/0.18$ $= 1900$ Hz	A1
(b)(ii)	distance $= \lambda/2$ ($= 0.09$ (m) or 9 (cm))	C1
	time $= 0.09 / 0.0075$ $= 12$ s	A1
	or	
	$t = 4.5/0.75$ **and** $t = 13.5/0.75$	(C1)
	time $= 18 - 6$ $= 12$ s	(A1)

151. 9702_w18_qp_23 Q: 4

	Answer	Mark
(a)	graph with *x*-axis labelled 'distance' and wavelength/λ correctly shown	B1
	graph with *x*-axis labelled 'time' and period/*T* correctly shown	B1
	graph with *y*-axis labelled 'displacement' and amplitude/*A* correctly shown	B1
(b)(i)	wave (moves along string and) reflects at fixed point/Y/X/end/wall/boundary	B1
	the incident and reflected waves interfere/superpose	B1
(b)(ii)	100/40 **or** 2.5 (cycles/periods/*T*)	C1
	1. displacement = 0	B1
	2. distance = 130 mm	A1
(b)(iii)	**1.** $f = 1/40 \times 10^{-3}$ $= 25\,\text{Hz}$	A1
	2. $v = f\lambda$ **or** $\lambda = vT$	C1
	$\lambda = 30/25$ **or** $30 \times 40 \times 10^{-3}$ (= 1.2 m)	C1
	distance $= 1.2 \times 1.5$ $= 1.8\,\text{m}$	A1

152. 9702_s17_qp_21 Q: 4

	Answer	Mark
(a)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (are same type and) have same frequency/wavelength	B1
(b)(i)	$\lambda = 12/250$ (= 0.048 m)	C1
	distance $= 1.5 \times 0.048$ $= 0.072\,\text{m}$	A1
(b)(ii)	$T = 1/250$ $= 0.004$ (s) or 4 (ms)	C1
	1. curve drawn is mirror image of that in Fig. 4.2 and labelled P	A1
	2. horizontal line drawn between A and B and labelled Q	A1

153. 9702_w17_qp_21 Q: 3

	Answer	Mark
(a)(i)	in a stationary wave energy is not transferred **or** in a progressive wave energy is transferred	B1
(a)(ii)	in a stationary wave (adjacent) particles are in phase **or** in a progressive wave (adjacent) particles are out of phase/have a phase difference/not in phase	B1
(b)(i)	(position where) maximum amplitude	B1
(b)(ii)	distance = 0.10 m	B1
(b)(iii)	**1.** λ = 0.60/1.5 = 0.40 m	A1
	2. $v = f\lambda$	C1
	f = 340/0.40 = 850 Hz	A1
(b)(iv)	$\lambda = 2 \times 0.60$ **or** $\lambda = 3 \times 0.40$ **or** $f = 850/3$	C1
	f = 280 (283) Hz	A1

154. 9702_w17_qp_22 Q: 4

	Answer	Mark
(a)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (are same type and) have same frequency/wavelength	B1
(b)(i)	5	A1
(b)(ii)	$T = 1/40$ (= 2.5×10^{-2})	C1
	time taken = $2.5 \times 10^{-2}/2$ = 1.3×10^{-2} s (1.25×10^{-2} s)	A1
(b)(iii)	180°	A1
(b)(iv)	$v = f\lambda$	C1
	λ = 2.0/2.5 (= 0.80 m) $v = 0.80 \times 40$ = 32 m s^{-1}	A1

155. 9702_s16_qp_23 Q: 7

(a)	**(i)**	alter distance from vibrator to pulley alter frequency of generator (change tension in string by) changing value of the masses		
		any two	B2	[2]
	(ii)	points on string have <u>amplitudes</u> varying from maximum to zero/minimum	B1	[1]
(b)	**(i)**	60° or $\pi/3$ rad	A1	[1]
	(ii)	ratio = $[3.4/2.2]^2$	C1	
		= 2.4 (2.39)	A1	[2]

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156. 9702_s15_qp_22 Q: 6

(a)		progressive waves transfer/propagate energy **and** stationary waves do not	B1	
		<u>amplitude</u> constant for progressive wave **and** varies (from max/antinode to min/zero/node) for stationary wave	B1	
		adjacent particles in phase for stationary wave **and** out of phase for progressive wave	(B1)	[2]
(b)	**(i)**	wave / microwave <u>from source/S</u> reflects <u>at reflector/R</u>	B1	
		reflected and (further) incident waves overlap/meet/superpose	B1	
		waves have same <u>frequency/wavelength/period</u> **and** <u>speed</u> (so stationary waves formed)	B1	[3]
	(ii)	detector/D is moved between reflector/R and source/S (or v.v.)	B1	
		maximum, minimum/zero, (maximum… etc.) observed on meter/deflections/readings/measurements/recordings	B1	[2]
	(iii)	<u>determine/measure</u> the distance between adjacent minima/nodes or maxima/antinodes **or** across <u>specific number</u> of nodes/antinodes	B1	
		wavelength is twice distance between <u>adjacent</u> nodes/minima or maxima/antinodes (or other correct method of calculation of wavelength from measurement)	B1	[2]
(c)		$v = f\lambda$	C1	
		$f = 3.0 \times 10^8 / (2.8 \times 10^{-2})$ [= 1.07×10^{10} Hz]	C1	
		11 (10.7) GHz	A1	[3]

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157. 9702_w15_qp_21 Q: 5

(a)	progressive: all particles have same amplitude stationary: no nodes or antinodes or maximum to minimum/zero amplitude	B1	
	progressive: adjacent particles are not in phase stationary: waves particles are in phase (between adjacent nodes)	B1	[2]
(b) (i)	wavelength 1.2 m (zero displacement at 0.0, 0.60 m, 1.2 m, 1.8 m, 2.4 m)		
	either peaks at 0.30 m and 1.5 m and troughs at 0.90 m and 2.1 m or vice versa (but not both)	B1	
	maximum amplitude 5.0 mm	B1	[2]
(ii)	180° or π rad	A1	[1]
(iii)	at t = 0 particle has kinetic energy as particle is moving	B1	
	at t = 5.0 ms no kinetic energy as particle is stationary so decrease in kinetic energy (between t = 0 and t = 5.0 ms)	B1	[2]

158. 9702_w15_qp_23 Q: 6

(a)	waves from loudspeaker (travel down tube and) are reflected at closed end	B1	
	two waves (travelling) in opposite directions with same frequency/wavelength overlap	B1	[2]
(b) (i)	0.51 m 0.85 m	A1 A1	[2]
(ii)	A at open end, N at closed end, with an N and A in between, equally spaced (by eye)	B1	[1]

159. 9702_s20_qp_21 Q: 4

	Answer	Mark
(a)(i)	vibrations (of particles) are parallel to direction of energy propagation	B1
(a)(ii)	waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of individual displacements	B1
(b)(i)	$\lambda = ax / D$	C1
	$= (3.7 \times 10^{-4} \times 4.3 \times 10^{-3}) / 2.3$	C1
	$= 6.9 \times 10^{-7}$ (m) = 690 nm	A1
(b)(ii)	• no change to fringe separation/fringe width/number of fringes • bright fringes are darker • dark fringes are brighter *Any two marking points, 1 mark each*	B2

160. 9702_s20_qp_23 Q: 4

	Answer	Mark
(a)(i)	frequency **or** period	B1
(a)(ii)	amplitude	B1
(b)	constant phase difference so coherent	B1
(c)	120°	B1
(d)	resultant displacement = 4.0 μm – 1.0 μm = 3.0 μm	B1
(e)	$I \propto A^2$	C1
	intensity of Z = $(2^2 / 4^2)\ I$ = 0.25 I	A1
(f)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$330 = \lambda / 3.0 \times 10^{-3}$	C1
	λ = 0.99 m	A1

161. 9702_w20_qp_22 Q: 5

	Answer	Mark
(a)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.0 \times 10^8 / 0.040$	C1
	$= 7.5 \times 10^9$ (Hz) = 7.5 GHz	A1
(b)(i)	path difference = 0.020 m	A1
(b)(ii)	phase difference = 180°	A1
(c)	(intensity) increases	C1
	(intensity) increases by a factor of 4	A1
(d)(i)	minimum moves closer to the maximum **or** decrease in separation of maximum and minimum	B1
(d)(ii)	the maximum and minimum exchange places **or** the maximum becomes a minimum **and** the minimum becomes a maximum	B1

162. 9702_m19_qp_22 Q: 5

	Answer	Mark
(a)(i)	(two) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the displacement of each wave	B1
(a)(ii)	constant phase difference (between the waves)	B1
(b)	$I \propto A^2$ $3I / I = (A + 1.5)^2 / 1.5^2$	C1
	A = 1.1 cm	A1
(c)(i)	$\lambda = ax / D$	C1
	e.g. $a = 680 \times 10^{-9} \times 2.0 / 4.0 \times 10^{-3}$	C1
	$a = 3.4 \times 10^{-4}$ m	A1
(c)(ii)	straight line from positive value on x-axis and always below 'old' line	B1
	straight line with a smaller positive gradient than 'old' line	B1

163. 9702_s19_qp_21 Q: 5

	Answer	Mark
(a)(i)	**1.** $N\lambda$	B1
	2. N / f	B1
(a)(ii)	v (= distance / time) = $N\lambda / (N / f)$ so $v = f\lambda$	B1
(b)	$T = 4.0 \times 0.20 = 0.80$ (ms) **or** 8.0×10^{-4} (s)	C1
	$f = 1 / 8.0 \times 10^{-4}$ = 1300 Hz	A1
(c)(i)	constant phase difference (between the waves)	B1
(c)(ii)	180°	A1
(c)(iii)	path difference = 2λ **or** $S_1Y - S_2Y = 2\lambda$	C1
	distance = 7.40 + (0.85 × 2) = 9.1 m	A1

164. 9702_w19_qp_21 Q: 5

	Answer	Mark
(a)(i)	the dippers are connected to the same vibrator/motor	B1
(a)(ii)	(the overlapping waves have) similar/same amplitude	B1
(b)	any means of 'freezing' the pattern e.g. use a stroboscope/strobe	B1
(c)	$vT = \lambda$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	T = 0.060 / 0.40 = 0.15 s	A1
(d)(i)	path difference = 3.0 cm	A1
(d)(ii)	phase difference = 180°	A1
(e)	line drawn joining points where only maxima are observed (i.e. through points where wavefronts intersect) of length at least 4 cm	B1

165. 9702_s18_qp_21 Q: 4

	Answer	Mark
(a)(i)	time for one oscillation/one vibration/one cycle **or** time between adjacent wavefronts/points in phase **or** shortest time between two wavefronts/points in phase	**B1**
(a)(ii)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts **or** minimum distance between two points having the same displacement and moving in the same direction	**B1**
(b)(i)	$v = \lambda / T$ **or** $v = f\lambda$ <u>and</u> $f = 1/T$	**C1**
	$\lambda = 20 \times 0.60$ $= 12\,\text{cm}$	**A1**
(b)(ii)	phase difference $= 360° \times (0.20/0.60)$ **or** $360° \times (0.40/0.60)$ $= 120°$ **or** $240°$	**A1**
(b)(iii)	$I \propto A^2$	**C1**
	$I_Q/I_P = A_Q^2/A_P^2$ $= 2.0^2/3.0^2$ $= 0.44$	**A1**
(b)(iv)	displacement $= 1.00 - 3.00$ $= -2.00\,\text{mm}$	**A1**

166. 9702_s18_qp_23 Q: 5

	Answer	Mark
(a)	intensity $\propto$ (amplitude)^2	**B1**
(b)(i)	$v = f\lambda$ **or** $c = f\lambda$	**C1**
	$f = 3.00 \times 10^8 / 0.060$ $= 5.0 \times 10^9\,\text{Hz}$	**A1**
(b)(ii)	(at X path) difference $= 3\lambda$	**M1**
	(at X phase) difference = 0 or 1080°	**M1**
	so intensity is at a maximum/it is an intensity maximum	**A1**
(b)(iii)	**1.** decrease in the distance between (adjacent intensity) maxima/minima	**B1**
	2. (intensity) maxima and minima exchange places	**B1**

167. 9702_w18_qp_21 Q: 4

	Answer	Mark
(a)	when (two or more) waves meet (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
(b)(i)	constant phase difference (between the waves)	B1
(b)(ii)	**1.** phase difference = 360° **or** 0	B1
	2. path difference = 1.5λ = 1.5×610 = 920 nm	A1
(b)(iii)	$\lambda = ax / D$	C1
	$x = 22/4$ (= 5.5 mm) **or** $22 \times 10^{-3}/4$ (= 5.5×10^{-3} m)	C1
	$a = (610 \times 10^{-9} \times 2.7)/(5.5 \times 10^{-3})$ $= 3.0 \times 10^{-4}$ m	A1
(b)(iv)	shorter wavelength **and** (so) separation decreases	B1
(b)(v)	• no change to fringe separation/fringe width/number of fringes • bright fringes are brighter • dark fringes are unchanged *Any two of the above three points, 1 mark each.*	B2

168. 9702_s17_qp_22 Q: 6

	Answer	Mark
(a)(i)	waves at (each) slit/aperture spread	B1
	(into the geometric shadow) wave(s) overlap/superpose/sum/meet/intersect	B1
(a)(ii)	there is not a constant phase difference/coherence (for two separate light source(s)) **or** waves/light from the double slit are coherent/have a constant phase difference	B1
(b)	$x = \lambda D / a$	C1
	$\lambda = (36 \times 10^{-3} \times 0.48 \times 10^{-3}) / (16 \times 2.4)$	C1
	$= 4.5 \times 10^{-7}$ m	A1
(c)(i)	no movement of the water/water is flat/no ripples/disturbance	B1
	the path difference is 2.5λ **or** the phase difference is 900° **or** 5π rad	B1
(c)(ii)	**1.** surface/water/P vibrates/ripples **and** as (waves from the two dippers) arrive in phase	B1
	2. surface/water/P vibrates/ripples **and** as amplitudes/displacements are no longer equal/do not cancel	B1

169. 9702_m16_qp_22 Q: 4

(a)	**(i)**	Displacement of particles perpendicular to direction of energy propagation	B1
	(ii)	waves meet / overlap (at a point) (resultant) displacement is sum of the individual displacements	B1 B1
(b)	**(i)**	$\lambda = vT$ **or** $\lambda = v / f$ and $f = 1 / T$ $\lambda = 4.0 \times 1.5$ $\lambda = 6.0$ (cm)	C1 A1
	(ii)	path difference [= (44 cm – 29 cm) / 6 cm] = 2.5λ	M1
		either waves have path difference = $(n + ½)\lambda$ **or** waves have phase difference = 180°	 M1
		so destructive interference	A1
(c)	**(i)**	intensity $\propto$ (amplitude)^2 ratio = $(0.60^2 / 0.90^2) = 0.44$	C1 A1
	(ii)	phase difference = 90°	A1

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170. 9702_s16_qp_21 Q: 5

(a)		$T = 4$ (ms) or 4×10^{-3} (s)	C1	
		$f = 1 / T = 1 / 0.004$		
		= 250 Hz	A1	[2]
(b)		intensity $\propto$ (amplitude)^2 and amplitude = 2.8 (2.83) (cm)	B1	
		curve with same period and with amplitude 2.8 cm	B1	
		curve shifted 1.0 ms to left or to right of wave X	B1	[3]
(c)	**(i)**	gradient = $(4.5 - 2.4) \times 10^{-3} / (3.25 - 1.75)$ [= 1.4×10^{-3}]	B1	
		wavelength = $0.45 \times 10^{-3} \times 1.4 \times 10^{-3}$	C1	
		= 6.30×10^{-7} (m)	C1	
		= 630 nm	A1	[4]
	(ii)	(gradient is equal to λ / a therefore) gradient of line is reduced	B1	
		value of x will be reduced for all values of D *or* new line is completely below old line *or* intercept is less	 B1	 [2]

171. 9702_w16_qp_22 Q: 4

(a)		wave incident on/passes by or through an aperture/edge	B1	
		wave spreads (into geometrical shadow)	B1	[2]
(b)	**(i)**	waves (from slits) overlap (at point X)	B1	
		path difference (from slits to X) is zero/ phase difference (between the two waves) is zero (so constructive interference gives bright fringe)	B1	[2]
	(ii)	difference in distances = $\lambda / 2 = 580 / 2$ $= 290$ nm	A1	[1]
	(iii)	$\lambda = ax / D$	C1	
		$D = [0.41 \times 10^{-3} \times (2 \times 2.0 \times 10^{-3})] / 580 \times 10^{-9}$	C1	
		$= 2.8$ m	A1	[3]
	(iv)	same separation/fringe width/number of fringes bright fringe(s)/central bright fringe/(fringe at) X less bright dark fringe(s)/(fringe at) Y/(fringe at) Z brighter contrast between fringes decreases		
		Any two of the above four points, 1 mark each	B2	[2]

172. 9702_s15_qp_23 Q: 6

(a)	**(i)**	coherent: constant phase difference	B1	
		interference is the (overlapping of waves and the) sum of/addition of displacement of two waves	B1	[2]
	(ii)	wavelength = 3.2 m (allow ± 0.05 m)	M1	
		f (= v / λ = 240 / 3.2) = 75 Hz	A1	[2]
	(iii)	90° (allow ± 2°) or $\pi/2$ rad	A1	[1]
	(iv)	sketch has amplitude 3.0 ± 0.1 cm	M1	
		correct displacement values at previous peaks to produce correct shape	A1	[2]
(b)	**(i)**	$\lambda = ax / D$	C1	
		$x = (546 \times 10^{-9} \times 0.85) / 0.13 \times 10^{-3}$ (= 3.57×10^{-3} m)	C1	
		AB = 8.9 (8.93) × 10^{-3} m	A1	[3]
	(ii)	shorter wavelength for blue light so separation is less	B1	[1]

173. 9702_w15_qp_22 Q: 7

(a)	**(i)** 3.2 mm	A1	[1]
	(ii) 20 mm	A1	[1]
(b)	**(i)** energy is transferred/propagated (through the water) or wave profile/wavefronts move (outwards from dipper) so progressive	B1	[1]
	(ii) to produce waves with constant/zero phase difference/coherent waves	B1	[1]
(c)	**(i)** path difference is λ	B1	
	water vibrates/oscillates with amplitude about 2×3.2 mm	B1	[2]
	(ii) path difference is $\lambda/2$ so little/no motion/displacement/amplitude	B1	[1]

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174. 9702_w15_qp_23 Q: 2

(a)	**(i)** (the loudspeakers) are connected to the same signal generator	B1	[1]
	(ii) **1.** the waves (that overlap) have phase difference of zero or path difference of zero and so *either* constructive interference *or* displacement larger	B1	[1]
	2. the waves (that overlap) have phase difference of $(n + ½) \times 360°$ or $(n + ½) \times 2\pi$ rad or path difference of $(n + ½)\lambda$ and so *either* destructive interference *or* displacements cancel/smaller	B1	[1]
	3. the waves (that overlap) are in phase or have phase difference of $n360°$ or $2\pi n$ rad or path difference of $n\lambda$ and so *either* constructive interference *or* displacement larger	B1	[1]
(b)	time period = 0.002 s or 2 ms	C1	
	wave drawn is half time period	B1	
	amplitude 1.0 cm (same as Fig. 2.2)	B1	[3]

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175. 9702_m20_qp_22 Q: 4

	Answer	Mark
(a)(i)	distance moved by wavefront / energy during one cycle / vibration / oscillation / period (of source) or minimum distance between two wavefronts or distance between two adjacent wavefronts	B1
(a)(ii)	maximum displacement (of particle / point on wave)	B1
(b)(i)	1 light / waves spread (at each slit)	B1
	2 constant phase difference (between light / waves)	B1
(b)(ii)	$n\lambda = d \sin\theta$	C1
	$d = 3 \times 650 \times 10^{-9} / \sin34°$	C1
	$d = 3.5 \times 10^{-6}$ m	A1
(b)(iii)	wavelength of blue light is shorter (than 650 nm / red light)	M1
	so angle (between third order diffraction maxima) decreases	A1

176. 9702_w20_qp_23 Q: 5

	Answer	Mark
(a)(i)	$T = 2.0 \times 10^{-5} \times 6.0$ (= 1.2×10^{-4} s)	C1
	$f = 1 / (2.0 \times 10^{-5} \times 6.0)$ = 8300 Hz	A1
(a)(ii)	new trace shows the same period	B1
	new trace shows amplitude of 10 small squares	B1
(a)(iii)	(trace is a) vertical line	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = (3.4 \times 10^{-6} \times \sin 16°) / 2$ $= 4.7 \times 10^{-7}$ m	A1
(b)(ii)	$n = 3.4 \times 10^{-6}$ (× sin 90°) / 4.7×10^{-7} or 2 (× sin 90°) / sin 16° (= 7.2 or 7.3)	C1
	highest order = 7	A1

177. 9702_s19_qp_22 Q: 4

	Answer	Mark
(a)(i)	distance (in a specified direction of particle/point on wave) from the equilibrium position	B1
(a)(ii)	the maximum distance (of particle/point on wave) from the equilibrium position **or** the maximum displacement (of particle/point on wave)	B1
(b)	$I \propto A^2$	C1
	$I_R / I = (3.6 - 1.2)^2 / (1.2)^2$ resultant intensity = $4.0I$	A1
(c)(i)	as wave(s) pass through the slit(s)	B1
	wave(s) spread (into geometric shadow)	B1
(c)(ii)	$n\lambda = d \sin\theta$	C1
	$3\lambda = d \sin 90°$ **or** $3\lambda = d$	C1
	$d = 3 \times 630 \times 10^{-9}$ $= 1.9 \times 10^{-6}$ m	A1
(c)(iii)	wavelength of blue light is shorter (than 540 nm/630 nm/wavelengths of original light)	M1
	(so) third order diffraction maximum is produced	A1

178. 9702_w19_qp_23 Q: 5

	Answer	Mark
(a)(i)	(coherence means) constant phase difference (between waves)	B1
(a)(ii)	(interference is) the sum/addition/combination of the displacements of overlapping/meeting waves	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = \sin 51° / (2 \times 6.7 \times 10^5)$ $= 5.8 \times 10^{-7}$ m	A1
(b)(ii)	smaller angle (corresponding to second order maxima and so) shorter distance (between second order maxima spots)	B1

179. 9702_s18_qp_21 Q: 5

	Answer	Mark
(a)(i)	waves spread at (each) slit/gap	B1
(a)(ii)	constant phase difference (between (each of) the waves)	B1
(b)(i)	$n\lambda = d \sin\theta$	B1
	$d \sin\theta$ is the same **and** $3\lambda_1 = 4\lambda_2$ so $\lambda_2 / \lambda_1 = 0.75$	A1
(b)(ii)	$\lambda_2 / \lambda_1 = 0.75$ and $\lambda_1 - \lambda_2 = 170$ $\lambda_1 = 680$ nm	A1

180. 9702_w18_qp_22 Q: 5

	Answer	Mark
(a)	$n\lambda = d\sin\theta$	C1
	$\lambda = 640 \times 10^{-9}$ (m)	C1
	$2 \times 640 \times 10^{-9} = 1.7 \times 10^{-6} \times \sin\theta$ so $\theta = 49(°)$	A1
(b)	$2 \times 640 \times 10^{-9} = 3 \times \lambda$ **or** $1.7 \times 10^{-6} \times \sin 49° = 3 \times \lambda$	C1
	$\lambda = 4.3 \times 10^{-7}$ m	A1

181. 9702_s17_qp_23 Q: 5

	Answer	Mark
(a)(i)	waves at the elements/slits	B1
	waves spread (into the geometric shadow)	B1
(a)(ii)	**1.** waves (from each element/slit) overlap/meet/superpose	B1
	with a phase difference/path difference of zero	B1
	2. phase difference is 360°/path difference of λ	B1
(b)(i)	e.g. gradient = $(0.40 - 0.32) / [(500 - 400) \times 10^{-9}]$	C1
	$= 8(.0) \times 10^{5}$	A1
(b)(ii)	$d \sin\theta = n\lambda$	C1
	$d = n$ / gradient	
	$= 2 / 8.0 \times 10^{5} = 2.5 \times 10^{-6}$ m	A1
(b)(iii)	straight line drawn with lower gradient (about ½) and all points lower	B1

182. 9702_s16_qp_22 Q: 5

(a) diffraction: spreading/diverging of waves/light (takes place) at (each) slit/element/gap/aperture B1

interference: overlapping of waves (from coherent sources at each element) B1

path difference λ/phase difference of 360(°)/2π (produces the first order) B1 [3]

(b) $d \sin\theta = n\lambda$ or $\sin\theta = Nn\lambda$ C1

$d = (2 \times 486 \times 10^{-9}) / \sin 29.7°$ (= 1.962×10^{-6}) C1

number of lines = 510 (509.7) mm^{-1} A1 [3]

183. 9702_w16_qp_21 Q: 5

(a)	wave incident on/passes by or through an aperture/edge wave spreads (into geometrical shadow)	B1 B1	[2]
(b)	$n\lambda = d \sin\theta$	C1	
	substitution of $\theta = 90°$ *or* $\sin\theta = 1$	C1	
	$4 \times 500 \times 10^{-9} = d \times \sin 90°$		
	line spacing = 2.0×10^{-6} m	A1	[3]
(c)	wavelength of red light is long<u>er</u> (than 500 nm)	M1	
	(each order/fourth order is now at a greater angle so) the fifth-order maximum cannot be formed/not formed	A1	[2]

184. 9702_w16_qp_23 Q: 5

(a)	wave incident on/passes by or through an aperture/edge wave spreads (into geometrical shadow)	B1 B1	[2]
(b)	$n\lambda = d \sin\theta$	C1	
	substitution of $\theta = 90°$ *or* $\sin\theta = 1$	C1	
	$4 \times 500 \times 10^{-9} = d \times \sin 90°$		
	line spacing = 2.0×10^{-6} m	A1	[3]
(c)	wavelength of red light is long<u>er</u> (than 500 nm)	M1	
	(each order/fourth order is now at a greater angle so) the fifth-order maximum cannot be formed/not formed	A1	[2]

185. 9702_s15_qp_21 Q: 6

(a) diffraction is the spreading of a wave as it passes through a slit or past an edge B1

when two (or more) waves superpose/meet/overlap M1
resultant displacement is the sum of the displacement of each wave A1 [3]

(b) $n\lambda = d \sin\theta$ and $v = f\lambda$ C1

max order number for $\theta = 90°$
hence n (= f / vN) = $7.06 \times 10^{14} / (3 \times 10^{8} \times 650 \times 10^{3})$ M1

n = 3.6
hence number of orders = 3 A1 [3]

(c) greater wavelength so fewer orders seen A1 [1]

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186. 9702_m17_qp_22 Q: 5

	Answer	Mark
(a)	to the right / from the left / from A to B / in the same direction as electron velocity	B1
(b)	$v^2 = u^2 + 2as$ $a = (1.5 \times 10^7)^2 / (2 \times 2.0 \times 10^{-2})$ Other alternative calculations for the C1 mark: e.g. $a = 1.5\times10^7 / 2.67\times10^{-9}$ e.g. $a = [(1.5\times10^7 \times 2.67\times10^{-9}) - 2.0\times10^{-2}] \times [2 / (2.67\times10^{-9})^2]$ e.g. $a = (2.0\times10^{-2} \times 2) / (2.67\times10^{-9})^2$	C1
	$= 5.6 \times 10^{15}$ m s^{-2}	A1
(c)	$E = F / Q$	C1
	$= (9.1 \times 10^{-31} \times 5.6 \times 10^{15}) / 1.6 \times 10^{-19}$	C1
	$= 3.2 \times 10^4$ V m^{-1}	A1
(d)	straight line with negative gradient starting at an intercept on the v-axis and ending at an intercept on the t-axis.	B1

187. 9702_s17_qp_23 Q: 3

	Answer	Mark
(a)	force per unit (positive) charge	B1
(b)(i)	$a = (v^2 - u^2) / 2s$ $= [(18 \times 10^6)^2 - (2.5 \times 10^3)^2] / (2 \times 12 \times 10^{-3})$	B1
	$= 1.3\ (1.35) \times 10^{16}$ m s^{-2}	A1
(b)(ii)	KE = ½ mv^2 **or** ½ $m(v^2 - u^2)$	C1
	change in KE $= 0.5 \times 9.11 \times 10^{-31} \times [(18 \times 10^6)^2 - (2.5 \times 10^3)^2]$	B1
	$= 1.5\ (1.48) \times 10^{-16}$ J	A1
(b)(iii)	$E = F / e = ma / e$ **or** $eV = \Delta$KE so $E = \Delta$KE $/ (e \times d)$	C1
	$E = (9.11 \times 10^{-31} \times 1.35 \times 10^{16}) / 1.60 \times 10^{-19}$ **or** $E = (1.48 \times 10^{-16}) / (12 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 7.7\ (7.69) \times 10^4$ V m^{-1}	A1
(c)	charge on α opposite to electron/charge on α is positive	B1
	ΔKE is negative/KE reduced	B1
	charge of α greater/twice that of electron causes larger/twice ΔKE (in magnitude)	B1

188. 9702_m19_qp_22 Q: 4

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	1 $E = V / d$ or $E = \Delta V / \Delta d$ $d = 4.0 \times 10^3 / 5.0 \times 10^4$	C1
	$= 8.0 \times 10^{-2}$ m	A1
	2 plates are (in) horizontal (plane) (above and below the rod)	B1
	top (plate) negative and bottom (plate) positive	B1
(b)(ii)	magnitude $= 5.0 \times 10^4 \times 3 \times 1.6 \times 10^{-19}$ $= 2.4 \times 10^{-14}$ N	A1
	direction is (vertically) downwards / down	B1
(b)(iii)	$6.2 \times 10^{-16} = 2.4 \times 10^{-14} \times 72 \times 10^{-3} \times \cos\theta$	C1
	$\theta = 69°$	A1

189. 9702_s19_qp_21 Q: 4

	Answer	Mark
(a)(i)	$m = \rho \times V$	C1
	$= (4 / 3) \times \pi \times (1.2 \times 10^{-6})^3 \times 940 = 6.8 \times 10^{-15}$ (kg)	A1
(a)(ii)	minimum charge (on drop) is 1.6×10^{-19} C	B1
(b)(i)	$V = Ed$	C1
	$V = 2.1 \times 10^5 \times 8.0 \times 10^{-3}$ $= 1.7 \times 10^3$ V	A1
(b)(ii)	constant velocity so no resultant force (so in equilibrium)	B1
(b)(iii)	$mg = Eq$ **or** $mg = (V / d)q$ **or** $F = mg$ **and** $F = Eq$	C1
	$q = (6.8 \times 10^{-15} \times 9.81) / 2.1 \times 10^5$ $= 3.2 \times 10^{-19}$ C	A1
	sign of charge is negative	A1
(c)(i)	electric force decreases	B1
	weight > electric force **or** resultant force acts downwards	B1
(c)(ii)	(field line) separation increases	B1
(d)(i)	upthrust (force)	B1
(d)(ii)	air resistance/drag/viscous (force)	B1

190. 9702_s19_qp_23 Q: 4

	Answer	Mark
(a)	straight (horizontal) lines **and** from the +0.90 kV plate/to the 0 V plate	B1
	(lines are) equally spaced	B1
(b)	weight/gravitational force **and** electric force	B1
(c)	$s = \frac{1}{2}at^2$ **or** $s = ut + \frac{1}{2}at^2$ **and** $u = 0$	C1
	$2.0 = \frac{1}{2} \times 9.81 \times t^2$ so $t = 0.64$ s	A1
(d)	$0.080 = \frac{1}{2} \times a \times 0.64^2$	C1
	$a = 0.39$ m s^{-2}	A1
(e)(i)	$E = (\Delta)V / (\Delta)d$	C1
	$E = 0.90 \times 10^3 / 0.12$ $= 7.5 \times 10^3$ N C^{-1}	A1
(e)(ii)	$ma = Eq$ **or** $F = ma$ **and** $F = Eq$	C1
	$q / m = 0.39 / 7.5 \times 10^3$ $= 5.2 \times 10^{-5}$ C kg^{-1}	A1
(f)(i)	no effect	B1
(f)(ii)	decreases/smaller	B1

191. 9702_w19_qp_21 Q: 2

	Answer	Mark
(a)	the (two) plates are <u>vertical</u> (and separated)	B1
	left plate positively charged **and** right plate negatively charged/earthed **or** right plate negatively charged **and** left plate positively charged/earthed	B1
(b)	$F = Eq$	C1
	$= 1.3 \times 10^4 \times 3.7 \times 10^{-9}$ $= 4.8 \times 10^{-5}$ N	A1
(c)	$F^2 = (4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2$ so $F = 7.2 \times 10^{-5}$ N **or** $F = [(4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2]^{0.5}$ so $F = 7.2 \times 10^{-5}$ N	A1
(d)	electric force is constant (because field strength/E is constant)	B1
	weight is constant (and so resultant force constant)	B1
(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ ($= 5.5 \times 10^{-6}$)	C1
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $= 13$ m s^{-2}	A1
(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	C1
	$v = 3.9$ m s^{-1}	A1

192. 9702_w19_qp_23 Q: 3

	Answer	Mark
(a)(i)	mass	B1
(a)(ii)	charge	B1
(b)(i)	$E = V / d$ **or** $E = F / q$	C1
	$F = (1.2 \times 10^3 \times 4.2 \times 10^{-9}) / 3.6 \times 10^{-2}$	C1
	$= 1.4 \times 10^{-4}$ N	A1
(b)(ii)	$W = mg$	C1
	$= 5.9 \times 10^{-6} \times 9.81$ resultant force $= 1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)$	C1
	$a = F / m$	C1
	$a = [1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)] / [5.9 \times 10^{-6}] = 14$ m s^{-2}	A1
(b)(iii)	**1.** $s = ut + ½at^2$ $1.8 \times 10^{-2} = ½ \times 14 \times t^2$	C1
	$t = 0.051$ s	A1
	2. $p = 0.75 \times 0.051$ $= 0.038$ m	A1

193. 9702_w17_qp_21 Q: 6

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	$E_K = ½mv^2$	C1
	$2.4 \times 10^{-16} = ½ \times 1.7 \times 10^{-27} \times v^2$ $v = 5.3 \times 10^5\,\text{m s}^{-1}$	A1
(b)(ii)	work done = 2.4×10^{-16} J	A1
(b)(iii)	$W = Fs$	C1
	$F = 2.4 \times 10^{-16} / 15 \times 10^{-3}$ $= 1.6 \times 10^{-14}$ N	A1
(b)(iv)	$V = Fd / Q$ **or** $V = W / Q$ **or** $E = V / d$ **and** $E = F / Q$	C1
	$V = (1.6 \times 10^{-14} \times 15 \times 10^{-3}) / 1.6 \times 10^{-19}$ **or** $2.4 \times 10^{-16} / 1.6 \times 10^{-19}$	C1
	= 1500 V	A1
(b)(v)	straight line with positive gradient starting at the origin and going as far as x = 15 mm	B1

194. 9702_w17_qp_23 Q: 5

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	$s = ½at^2$	C1
	$a = (2 \times 0.045) / (1.5 \times 10^{-7})^2 = 4(.0) \times 10^{12}\,\text{m s}^{-2}$	A1
(b)(ii)	$F = 1.67 \times 10^{-27} \times 4.0 \times 10^{12} = 6.7\ (6.68) \times 10^{-15}$ N	A1
(b)(iii)	**1.** $E = F / Q$	C1
	$= 6.68 \times 10^{-15} / 1.6 \times 10^{-19}$ $= 4.2\ (4.18) \times 10^4\,\text{N C}^{-1}$	A1
	2. $E = V / d$	C1
	$V = 4.18 \times 10^4 \times 0.045$ $= 1.9 \times 10^3$ V	A1

	Answer	Mark
(c)	$a = Eq / m$ **or** $F = ma$ **and** $F = Eq$	C1
	ratio $= \dfrac{(2 \times 1.6 \times 10^{-19}) \times (1.67 \times 10^{-27})}{(1.6 \times 10^{-19}) \times (4 \times 1.66 \times 10^{-27})}$ **or** $\dfrac{2 \times 1}{1 \times 4}$ = 0.50	A1

195. 9702_s16_qp_22 Q: 6

(a)	at least six horizontal lines equally spaced and arrow to the right	B1	[1]
(b)	charge used 2*e*	C1	
	gain in KE = $15 \times 1.6 \times 10^{-19} \times 10^3 = 2 \times 1.6 \times 10^{-19} \times V$ (p.d.across plates) *or* F (= W/d) = $15 \times 1.6 \times 10^{-19} \times 10^3 / 16 \times 10^{-3}$	C1	
	(hence $V = 7500$ V or $F = 1.5 \times 10^{-13}$ N)		
	$E = V/d$ or $E = F/Q$	C1	
	$E = (7500/16 \times 10^{-3})$ or $E = (1.5 \times 10^{-13}/3.2 \times 10^{-19})$		
	$E = 4.7 \times 10^5$ (468 750) V m^{-1}	A1	[4]
	or		
	KE (= $\frac{1}{2}mv^2$) = $15 \times 10^3 \times 1.6 \times 10^{-19}$		
	$v = [(2 \times 15 \times 10^3 \times 1.6 \times 10^{-19})/(6.68 \times 10^{-27})]^{1/2} = 8.5 \times 10^5$ m s^{-1}	(C1)	
	a (= $v^2/2s$) = $(8.5 \times 10^5)^2/2 \times 16 \times 10^{-3} = 2.25 \times 10^{13}$ m s^{-2}		
	F (= $6.68 \times 10^{-27} \times 2.25 \times 10^{-13}$) = 1.5×10^{-13} N		
	$E = F/Q$	(C1)	
	$Q = 2e$	(C1)	
	$E = 4.7 \times 10^5$ V m^{-1}	(A1)	

196. 9702_w16_qp_21 Q: 2

(a)	force per unit positive charge	B1	[1]
(b) (i)	time $= 5.9 \times 10^{-2} / 3.7 \times 10^{7}$ $= 1.6 \times 10^{-9}$ s (1.59×10^{-9} s)	A1	[1]
(ii)	$E = V / d$	C1	
	$= 2500 / 4.0 \times 10^{-2}$		
	$= 6.3 \times 10^{4}$ N C^{-1} (6.25×10^{4} or 62500 N C^{-1})	A1	[2]
(iii)	$a = Eq / m$ *or* $F = ma$ <u>*and*</u> $F = Eq$	C1	
	$= (6.3 \times 10^{4} \times 1.60 \times 10^{-19}) / 9.11 \times 10^{-31} = 1.1 \times 10^{16}$ m s^{-2}	A1	[2]
(iv)	$s = ut + ½at^2$		
	$= ½ \times 1.1 \times 10^{16} \times (1.6 \times 10^{-9})^2$	C1	
	$= 1.4 \times 10^{-2}$ (m)	C1	
	distance from plate $= 2.0 - 1.4$ $= 0.6$ cm (*allow 1 or more s.f.*)	A1	[3]
(v)	electric force $\gg$ gravitational force (on electron)/weight *or* acceleration due to electric field $\gg$ acceleration due to gravitational field	B1	[1]
(vi)	v_X–t graph: horizontal line at a non-zero value of v_X	B1	
	v_Y–t graph: straight line through the origin with positive gradient	B1	[2]

197. 9702_w16_qp_23 Q: 2

(a)	force per unit positive charge	B1	[1]
(b) (i)	time $= 5.9 \times 10^{-2} / 3.7 \times 10^{7}$ $= 1.6 \times 10^{-9}$ s (1.59×10^{-9} s)	A1	[1]
(ii)	$E = V/d$	C1	
	$= 2500 / 4.0 \times 10^{-2}$		
	$= 6.3 \times 10^{4}$ N C^{-1} (6.25×10^{4} or 62500 N C^{-1})	A1	[2]
(iii)	$a = Eq/m$ *or* $F = ma$ <u>and</u> $F = Eq$	C1	
	$= (6.3 \times 10^{4} \times 1.60 \times 10^{-19}) / 9.11 \times 10^{-31} = 1.1 \times 10^{16}$ m s^{-2}	A1	[2]
(iv)	$s = ut + ½at^{2}$		
	$= ½ \times 1.1 \times 10^{16} \times (1.6 \times 10^{-9})^{2}$	C1	
	$= 1.4 \times 10^{-2}$ (m)	C1	
	distance from plate $= 2.0 - 1.4$ $= 0.6$ cm (*allow 1 or more s.f.*)	A1	[3]
(v)	electric force ≫ gravitational force (on electron)/weight *or* acceleration due to electric field ≫ acceleration due to gravitational field	B1	[1]
(vi)	v_X–t graph: horizontal line at a non-zero value of v_X	B1	
	v_Y–t graph: straight line through the origin with positive gradient	B1	[2]

198. 9702_s15_qp_21 Q: 7

(a)	a region/space/area where a (stationary) charge experiences an (electric) force	B1	[1]
(b) (i)	at least four parallel equally spaced straight lines perpendicular to plates	B1	
	consistent direction of an arrow on line(s) from left to right	B1	[2]
(ii)	electric field strength $E = V / d$	C1	
	$E = (450 / 16 \times 10^{-3})$ $= 28 \times 10^{3}$ (28125) V m^{-1}	A1	[2]
(iii)	$W = Eqd$ or Vq	C1	
	$q = 3.2 \times 10^{-19}$ (C)	C1	
	$W = 28125 \times 3.2 \times 10^{-19} \times 16 \times 10^{-3}$ or $450 \times 3.2 \times 10^{-19}$		
	$= 1.4(4) \times 10^{-16}$ J	A1	[3]
(iv)	ratio $= \dfrac{450 \times 3.2 \times 10^{-19}}{450 \times -1.6 \times 10^{-19}}$ *(evidence of working required)*		
	= (–) 2	A1	[1]

199. 9702_s20_qp_23 Q: 6

	Answer	Mark
(a)	A: cross-sectional area	**B1**
	n: number density of free electrons	**B1**
(b)	units of I: A **and** units of A: m^2 **and** units of v: m s^{-1}	**B1**
	units of e: A / (m^2 m^{-3} m s^{-1}) = A s	**A1**
(c)	ratio $= A_Q / A_P$	**C1**
	$= [\pi r^2] / [\pi(2r^2)]$ = 0.25	**A1**

200. 9702_w18_qp_22 Q: 7

	Answer	Mark
(a)	A: (cross-sectional) area (of wire)	**B1**
	n: number of free electrons per unit volume **or** number density of free electrons	**B1**
(b)	line drawn between (X, v_x) and (Y, $4v_x$)	**M1**
	line has increasing gradient	**A1**

201. 9702_w18_qp_23 Q: 6

	Answer	Mark
(a)	(coulomb is an) ampere second	B1
(b)	8.0×10^{-19} C and 1.6×10^{-19} C both underlined (and no others underlined)	B1
(c)	line drawn between (S, $1.00v_s$) and (T, $0.25v_s$)	M1
	line with decreasing magnitude of gradient	A1

202. 9702_w17_qp_22 Q: 5

	Answer	Mark
(a)	(coulomb is) ampere second	B1
(b)(i)	$E = V/d$ **or** $E = F/Q$	C1
	$F = VQ/d$ $F = (2.0 \times 10^2 \times 8.0 \times 10^{-19})/4.0 \times 10^{-2} = 4.0 \times 10^{-15}$ N	A1
(b)(ii)	arrow pointing to the left labelled 'electric force' **and** arrow pointing downwards labelled 'weight'	B1
(b)(iii)	**1.** resultant force $= \sqrt{[(3.9 \times 10^{-15})^2 + (4.0 \times 10^{-15})^2]}$	C1
	$= 5.6 \times 10^{-15}$ N	A1
	2. angle $= \tan^{-1}(3.9 \times 10^{-15}/4.0 \times 10^{-15})$ $= 44°$	A1
(c)	downward sloping line from (0, 2.0)	M1
	magnitude of gradient of line increases with time and line ends at (T, 0)	A1

203. 9702_s15_qp_22 Q: 1

(a) (work =) force × distance or force × displacement or (W =) $F \times d$ M1

units of work: kg m s^{-2} × m = kg m^2 s^{-2} A1 [2]

(b) (p.d. =) $\dfrac{\text{work (done) or energy (transformed) (from electrical to other forms)}}{\text{charge}}$ B1 [1]

(c) $R = V/I$ B1
units of V: kg m^2 s^{-2} / A s **and** units of I: A C1

or
$R = P/I^2$ [or $P = VI$ **and** $V = IR$] (B1)
units of P: kg m^2 s^{-3} **and** units of I: A (C1)

or
$R = V^2/P$ (B1)
units of V: kg m^2 s^{-2} / A s **and** units of P: kg m^2 s^{-3} (C1)

units of R: (kg m^2 s^{-2} / A^2 s =) kg m^2 s^{-3} A^{-2} A1 [3]

204. 9702_s20_qp_22 Q: 5

	Answer	Mark
(a)	Hooke's (law)	B1
(b)(i)	$\sigma = F / A$	C1
	$= 36 / (4.1 \times 10^{-7})$ $= 8.8 \times 10^{7}$ Pa	A1
(b)(ii)	Young modulus = σ / ε **or** $F / A\varepsilon$	C1
	$\varepsilon = 8.8 \times 10^{7} / (1.7 \times 10^{11})$ $= 5.2 \times 10^{-4}$	A1
(c)	$R = \rho L / A$	C1
	$\Delta R = \rho \Delta x / A$ $= 3.7 \times 10^{-7} \times 0.12 \times 10^{-3} / (4.1 \times 10^{-7})$	C1
	$= 1.1 \times 10^{-4}\ \Omega$	A1
(d)	remove the force/*F* and wire returns to original length	B1

205. 9702_s19_qp_23 Q: 1

	Answer	Mark
(a)(i)	potential difference / current	B1
(a)(ii)	$R = 4.0 \times 10^{9}$ (Ω)	C1
	$I = 0.60 / 4.0 \times 10^{9} = 1.5 \times 10^{-10}$ (A) $I = 150$ pA	A1
(b)	units of energy: kg m^{2} s^{-2}	C1
	units of charge: A s	C1
	units of potential difference: (kg m^{2} s^{-2} / A s =) kg m^{2} A^{-1} s^{-3}	A1

206. 9702_w18_qp_22 Q: 6

	Answer	Mark
(a)	joule / coulomb	B1
(b)(i)	$7.0 = (I \times 5.2) + (I \times 6.0) + 1.4$	C1
	$I = 0.50$ A	A1
(b)(ii)	$R = 1.4 / 0.50$ $= 2.8\ \Omega$	A1
(b)(iii)	$P = EI$ **or** $P = VI$ **or** $P = I^{2}R$ **or** $P = V^{2}/R$	C1
	efficiency = $[(0.50^{2} \times 6.0)/(7.0 \times 0.50)]$ ($\times 100$) **or** efficiency = $[(0.50 \times 3.0)/(7.0 \times 0.50)]$ ($\times 100$) **or** efficiency = $[(3.0^{2}/6.0)/(7.0 \times 0.50)]$ ($\times 100$)	C1
	efficiency = 43%	A1
(b)(iv)	$R = \rho l / A$	C1
	$\alpha = \rho / R$ $= 3.7 \times 10^{-7} / 6.0$ $= 6.2 \times 10^{-8}$ m	A1

207. 9702_w17_qp_21 Q: 7

	Answer	Mark
(a)	(the ohm is) volt / ampere	B1
(b)(i)	$R = \rho L / A$	C1
	ratio = $[\rho L / (\pi d^2 / 4)] / [0.028\rho \times 7.0L / \{\pi(14d)^2 / 4\}] = 1000$ **or** ratio = $14^2 / (0.028 \times 7) = 1000$	A1
(b)(ii)	same current (in connecting and filament wires) **and** the lamp/filament (wire) has greater resistance	B1
(b)(iii)	$P = V^2 / R$ **or** $P = VI$ **or** $P = I^2R$	C1
	(for filament wire) $R = 12^2 / 6.0$ **or** $R = 6.0 / 0.50^2$ **or** $R = 12 / 0.50$	C1
	(for filament wire) $R = 24\,\Omega$ (for connecting wire) $R = 24 / 1000$ $= 2.4 \times 10^{-2}\,\Omega$	A1
(b)(iv)	resistance of connecting wire increases	B1
	current in circuit/lamp/filament (wire) decreases **or** potential difference across lamp/filament (wire) decreases	M1
	(so) resistance of lamp/filament (wire) decreases	A1

208. 9702_w17_qp_22 Q: 6

	Answer	Mark
(a)	flow of charge carriers	B1
(b)(i)	$nALe$	B1
(b)(ii)	(t is time taken for electrons to move length L) $I = Q / t$	B1
	$I = nALe / t$ **or** $I = nALe / (L / v)$ **or** $I = nAvte / t$ **and** $I = nAve$	B1
(c)(i)	ratio = area at X / area at Y $= [\pi d^2 / 4] / [\pi(0.69d)^2 / 4]$ **or** $d^2 / (0.69d)^2$ **or** $1 / 0.69^2$	C1
	$= 2.1$	A1
(c)(ii)	**1.** $R = \rho L / A$ **or** $R / L \propto 1 / A$	C1
	resistance per unit length $= 1.7 \times 10^{-2} \times$ (area at X / area at Y) $= 1.7 \times 10^{-2} \times 2.1$ $= 3.6 \times 10^{-2}\,\Omega\,m^{-1}$	A1
	2. $P = I^2R$ **or** $P = V^2 / R$	C1
	$R = 3.6 \times 10^{-2} \times 3.0 \times 10^{-3}$ ($= 1.08 \times 10^{-4}\,\Omega$) $P = 0.50^2 \times 1.08 \times 10^{-4}$ **or** $P = (5.4 \times 10^{-5})^2 / 1.08 \times 10^{-4}$ $= 2.7 \times 10^{-5}\,W$	A1

	Answer	Mark
(c)(iii)	(cross-sectional area decreases so) resistance increases	M1
	($P = I^2R$, so) power increases	A1

209. 9702_w17_qp_23 Q: 6

	Answer	Mark
(a)(i)	$P = VI$	C1
	$I = 30 / 120$ $= 0.25$ A	A1
(a)(ii)	$Q = 0.25 \times 3.0 \times 3600$ (= 2700)	C1
	number $= (0.25 \times 3.0 \times 3600) / 1.60 \times 10^{-19}$ $= 1.7 \times 10^{22}$	A1
(b)	$R = V / I$ **or** $R = P / I^2$ **or** $R = V^2 / P$	C1
	$= 120 / 0.25$ **or** $= 30 / 0.25^2$ **or** $= 120^2 / 30$ $= 480\,\Omega$	A1
(c)	$R = \rho l / A$	C1
	$A = (6.1 \times 10^{-7} \times 580 \times 10^{-3}) / 480$ (= 7.37×10^{-10})	C1
	$d = [(4 \times 7.37 \times 10^{-10}) / \pi]^{1/2}$ $= 3.1 \times 10^{-5}$ m	A1
(d)	temperature decreases and so resistance decreases	B1

210. 9702_s16_qp_21 Q: 6

(a) (coulomb is) ampere second B1 [1]

(b) (total) charge or $Q = nAle$ M1

$I = Q / t$ and $l / t = v$ M1

$I = nAle / t = nAve$ therefore $v = I / nAe$ A1 [3]

(c) **(i)** ratio $= (I / nA_Ye) / (I / nA_Ze)$ C1

$= A_Z / A_Y$ or $4A / A$ or $\pi d^2 / (\pi d^2 / 4)$ C1

$= 4$ A1 [3]

(ii) $R = \rho l / A$ or $R = 4\rho l / \pi d^2$ B1

$R_Y = \rho l / A$ and $R_Z = \rho(2l) / 4A$ so $R_Y / R_Z = 2$

or

$R_Y = 4\rho l / \pi d^2$ and $R_Z = 4\rho(2l) / \pi 4d^2$ or $2\rho l / \pi d^2$ so $R_Y / R_Z = 2$ A1 [2]

(iii) $V = 12R_Y / (R_Y + R_Z)$ or $I = 12 / (R_Y + R_Z)$ and $V = IR_Y$ C1

$V = 12 \times 2/3$

$= 8(.0)$ V A1 [2]

(iv) ratio $= I^2R_Y / I^2R_Z$ or $(V_Y^2 / R_Y) / (V_Z^2 / R_Z)$ or $(V_YI) / (V_ZI)$

$= 2$ A1 [1]

211. 9702_s16_qp_23 Q: 6

(a) ohm is volt per ampere or volt / ampere B1 [1]

(b) **(i)** $R = \rho l / A$ B1

$R_P = 4\rho(2l) / \pi d^2$ or $8\rho l / \pi d^2$ or $R_Q = \rho l / \pi d^2$
or
ratio idea e.g. length is halved hence R halved and diameter is halved hence R is 1/4 C1

R_Q (= $4\rho l / \pi 4d^2$) = $\rho l / \pi d^2$
= $R_P / 8$
(= 12 / 8) = 1.5 Ω A1 [3]

(ii) power = I^2R or V^2/R or VI C1

= $(1.25)^2 \times 12 + (10)^2 \times 1.5$ or $(15)^2/12 + (15)^2/1.5$ or 15×11.25 C1

= (18.75 + 150 =) 170 (168.75) W A1 [3]

(iii) I_P = (15 / 12 =) 1.25 (A) and I_Q = (15 / 1.5 =) 10 (A) C1

$v_P / v_Q = I_P n A_Q e / I_Q n A_P e$ or $(1.25 \times \pi d^2) / (10 \times \pi d^2/4)$ C1

= 0.5 A1 [3]

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212. 9702_m20_qp_22 Q: 6

	Answer	Mark
(a)	$E = V / d$ $d = 350 / 1.4 \times 10^4$	C1
	= 0.025 m	A1
(b)(i)	$E = F / Q$	C1
	$Q = 6.7 \times 10^{-15} / 1.4 \times 10^4$ (= 4.8×10^{-19} C) = $(4.8 \times 10^{-19} / 1.6 \times 10^{-19})$ e	C1
	= 3.0 e	A1
(b)(ii)	mass = $8.3 \times 10^{-27} / 1.66 \times 10^{-27}$ = 5.0 u	A1
(b)(iii)	number = 5 – 3 = 2	A1

213. 9702_s15_qp_21 Q: 5

(a)	very high/infinite resistance for negative voltages up to about 0.4 V	B1	
	resistance decreases from 0.4 V	B1	[2]
(b)	initial straight line from (0,0) into curve with decreasing gradient but not to horizontal	M1	
	repeated in negative quadrant	A1	[2]
(c) (i)	$R = 12^2 / 36 = 4.0\,\Omega$	A1	
	or $I = P / V = 36 / 12 = 3.0$ A and $R = 12 / 3.0 = 4.0\,\Omega$	(A1)	[1]
(ii)	lost volts = $0.5 \times 2.8 = 1.4$ (V) or $E = 12 = 2.8 \times (R + r)$	C1	
	$R = V / I = (12 - 1.4) / 2.8$ or $(R + r) = 4.29\,\Omega$	C1	
	$= 3.8\ (3.79)\,\Omega$ or $R = 3.8\,\Omega$	A1	[3]
(d)	resistance of the lamp increases with increase of V or I	B1	[1]

214. 9702_m20_qp_22 Q: 5

	Answer	Mark
(a)	volt / ampere	**B1**
(b)	$R = \rho L / A$	**C1**
	$L = (1.8 \times 0.38 \times 10^{-6}) / 9.6 \times 10^{-7}$	**C1**
	$= 0.71$ m	**A1**
(c)(i)	thermal energy is dissipated in resistor Y	**B1**
(c)(ii)	$V / 1.2 = 1.8 / (1.8 + 0.6)$	**C1**
	$V = 0.90$ V	**A1**
	or	
	$I = 1.2 / (1.8 + 0.6)\ (= 0.50)$	**(C1)**
	$V = 0.50 \times 1.8$ $= 0.90$ V	**(A1)**
(d)(i)	remain the same	**B1**
(d)(ii)	decrease	**B1**
(e)(i)	$1 / R = 1 / 1.8 + 1 / 3.6$ $R = 1.2\,\Omega$	**A1**

	Answer	Mark
(e)(ii)	I = 1.2 / (1.2 + 0.60)	C1
	= 0.67 A	A1
	or	
	V_Y = 1.2 × 0.60 / (1.2 + 0.60) (= 0.40)	(C1)
	I = 0.40 / 0.60 = 0.67 A	(A1)

215. 9702_s20_qp_22 Q: 6

	Answer	Mark
(a)(i)	energy is dissipated in the internal resistance/r	B1
(a)(ii)	**1.** I = Q / t	C1
	= 750 / 1500 = 0.50 A	A1
	2. V = W / Q **or** V = W / It	C1
	= 5700 / 750 **or** 5700 / (0.50 × 1500) = 7.6 V	A1
	or	
	V = P / I **and** P = W / t	(C1)
	V = 3.8 / 0.50 = 7.6 V	(A1)
	3. r = (7.8 – 7.6) / 0.50	C1
	= 0.40 Ω	A1
(b)(i)	90 Ω and 45 Ω resistors shown connected in parallel	B1
(b)(ii)	the resistors connected in parallel labelled as 90 Ω and 45 Ω with the other resistor labelled as 20 Ω	M1
	V_{OUT} or 3.6 V labelled across the 20 Ω resistor	A1

216. 9702_s20_qp_23 Q: 5

	Answer	Mark
(a)	joule per coulomb	B1
(b)(i)	$1/R = 1/R_1 + 1/R_2$ $= 1/300 + 1/200$ $R = 75\ \Omega$	A1
(b)(ii)	$R = 75 + 55$ $= 130\ \Omega$	A1
(c)(i)	**1.** $P = I^2R$ **or** $P = VI$ **and** $V = IR$	C1
	$I = (0.20/55)^{0.5}$ $= 0.060$ A	A1
	2. $I = 0.060/4$ $= 0.015$ A	A1
(c)(ii)	potential difference $= 130 \times 0.060$ $= 7.8$ V	A1
	or	
	potential difference $= (300 \times 0.015) + (55 \times 0.060)$ $= 7.8$ V (*other valid methods are also possible*)	(A1)

217. 9702_w20_qp_21 Q: 7

	Answer	Mark
(a)	volt / ampere	B1
(b)	$R = \rho L/A$	C1
	$A = 460 \times 10^{-9} \times 2.5/3.2$	C1
	$= 3.6 \times 10^{-7}$ m^2	A1
(c)(i)	energy is dissipated in the internal resistance/*r*	B1
(c)(ii)	$E = IR + Ir$ **or** $E = I(R + r)$	B1
(c)(iii)	$P = I^2R$ **or** $P = I^2r$	C1
	$I = E/2r$ (so) $P = E^2/4r$	A1

218. 9702_w20_qp_22 Q: 6

	Answer	Mark
(a)	$I = I_1 + I_2 + I_3$	B1
	$(V / R) = (V / R_1) + (V / R_2) + (V / R_3)$ **or** $(I / V) = (I_1 / V) + (I_2 / V) + (I_3 / V)$ **and** $1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3$	B1
(b)(i)	current = 0.49 + 0.45 = 0.94 A	A1
(b)(ii)	$8.0 = (0.94 \times r) + (0.45 \times 16)$	C1
	$r = 0.85\ \Omega$	A1
(c)	$I = Anvq$ $v = (0.45 / 0.49) \times 2.1 \times 10^{-4}$	C1
	$= 1.9 \times 10^{-4}\ \text{m s}^{-1}$	A1
(d)	total/combined resistance decreases	B1
	(current in battery increases so terminal) potential difference decreases	B1

219. 9702_w20_qp_23 Q: 6

	Answer	Mark
(a)	$\frac{\text{work (done) / energy (transferred from electrical to other forms)}}{\text{charge}}$	B1
(b)	$R = \rho L / A$	B1
	$V = LA$ **and** (so) $R = \rho V / A^2$ (with ρ and V constant)	B1
(c)	$E = IR + Ir$ **or** $E = I(R + r)$ **or** $E - Ir = IR$ **and** $R = (E / I) - r$	A1
(d)(i)	$P = I^2R$ **or** $P = IV$ **or** $P = V^2 / R$	C1
	$R = 5.4\ (\Omega)$ **or** $V = 10.8\ (\text{V})$	C1
	$P = 2.0^2 \times 5.4$ = 22 W	A1
(d)(ii)	**1.** $r = 0.60\ \Omega$	A1
	2. E = gradient	C1
	= e.g. 5.4 / 0.45 = 12 V	A1

220. 9702_m19_qp_22 Q: 6

	Answer	Mark
(a)	e.m.f.: energy transferred from chemical to electrical (per unit charge)	B1
	p.d.: energy transferred from electrical to thermal (per unit charge)	B1

	Answer	Mark
(b)(i)	1 I = 4.8 / 32 = 0.15 A	A1
	2 P = EI or $P = VI$ or $P = I^2R$ or $P = V^2/R$ = 6.0 × 0.15 or $0.15^2 \times 40$ or $6.0^2 / 40$	C1
	= 0.90 W	A1
	3 number = It / e = [0.15 × 25] / 1.6 × 10^{-19}	C1
	= 2.3 × 10^{19}	A1
	or Q = 0.15 × 25 (= 3.75) number = 3.75 / 1.6 × 10^{-19}	(C1)
	= 2.3 × 10^{19}	(A1)
	4 4.8 / 6.0 = 32 / (R_{XY} + 32) or 1.2 / 6.0 = R_{XY} / (R_{XY} + 32) or 4.8 / 1.2 = 32 / R_{XY}	C1
	R_{XY} = 8.0 Ω	A1
	Alternative methods:	
	R_{XY} = (6.0 – 4.8) / 0.15 or	(C1)
	= 8.0 Ω	(A1)
	or 6.0 = 0.15 (32 + R_{XY})	(C1)
	R_{XY} = 40 – 32 = 8.0 Ω	(A1)

	Answer	Mark
(b)(i)	5 1 / 8.0 = 1 / R_X + 1 / 24	C1
	R_X = 12 Ω	A1
	Alternative method:	
	I_Z = 4.8 / 32 = 0.15 and I_Y = 1.2 / 24 = 0.05 I_X = 0.15 – 0.05 (= 0.10)	(C1)
	R_X = 1.2 / 0.10 = 12 Ω	(A1)
(b)(ii)	total resistance decreases	M1
	(so voltmeter) reading increases	A1

221. 9702_s19_qp_21 Q: 6

	Answer	Mark
(a)	energy is dissipated in the internal resistance	B1
(b)	$E = V + Ir$	B1
(c)(i)	(graph shows) maximum value of potential difference is 2.8 (V) **or** (graph shows) when current/I (from battery) is zero, V is 2.8 (V) / E	B1
(c)(ii)	r = (–)gradient **or** $r = (E – V) / I$ **or** substituted values from the graph for E, V and I	C1
	$r = 1.4\,\Omega$	A1
(d)(i)	$R = 2.1 / 0.50$ $= 4.2\,\Omega$	A1
(d)(ii)	number $= 0.50 / 1.60 \times 10^{-19}$ $= 3.1 \times 10^{18}$	A1
(d)(iii)	energy $= EIt$ **or** $P = EI$ **and** $P = W / t$	C1
	$(9.2 – 1.6) \times 10^3 = 2.8 \times 0.50 \times t$	C1
	$t = 5.4 \times 10^3$ s	A1

222. 9702_s19_qp_22 Q: 5

	Answer	Mark
(a)	<u>sum of</u> e.m.f.(s) = <u>sum of</u> p.d.(s)	M1
	around a loop/around a closed circuit	A1
(b)(i)	**1.** $1 / R = 1 / R_1 + 1 / R_2$ $1 / R = 1 / 90 + 1 / 18$	C1
	$R = 15\,\Omega$	A1
	2. $I = V / R$	C1
	$I = 4.8 / 15$ **or** $I = 4.8 / 90 + 4.8 / 18$ $I = 0.32$ A	A1
(b)(ii)	$E = V + Ir$ **or** $E = I(R + r)$	C1
	$5.6 = 4.8 + 0.32\,r$ so $r = 2.5\,(\Omega)$ **or** $5.6 = 0.32 \times (15 + r)$ so $r = 2.5\,(\Omega)$	A1
(b)(iii)	$P = EI$ **or** $P = VI$ **or** $P = I^2R$ **or** $P = V^2 / R$	C1
	ratio $= (0.32^2 \times 2.5) / (5.6 \times 0.32)$ **or** $0.256 / 1.792$	C1
	$= 0.14$	A1
(c)	$7.2 – 5.6 – 2.5I – 3.5I = 0$	C1
	$I = 0.27$ A	A1

223. 9702_s19_qp_23 Q: 6

	Answer	Mark
(a)	volt / ampere	B1
(b)(i)	**1.** I = 1.8 + 0.60 = 2.4 A	A1
	2. (8.0 × 0.60) = 1.8 × (2.0 + R_Z)	C1
	R_Z = 0.67 Ω	A1
	3. E – (2.4 × 1.5) = (0.60 × 8.0) **or** E – (2.4 × 1.5) = 1.8 × (2.0 + 0.67) **or** E = 2.4 × [1.5 + (8.0 × 2.67) / (8.0 + 2.67)]	C1
	E = 8.4 V	A1
(b)(ii)	**1.** $R = \rho L / A$ **or** $R \propto 1 / A$	C1
	ratio = R_Y / R_X = 2.0 / 8.0 = 0.25	A1
	2. $I \propto Av$ **or** $I_X / I_Y = A_X v_X / A_Y v_Y$	C1
	ratio = (0.60 / 1.8) × (1 / 0.25) = 1.3	A1

224. 9702_w19_qp_21 Q: 6

	Answer	Mark
(a)	work done / charge **or** energy (transferred from electrical to other forms) / charge	B1
(b)	for V < 0.25 V resistance is infinite/very high (as current is zero)	B1
	for V > 0.25 V resistance decreases (as V increases)	B1
(c)(i)	$R = V / I$	C1
	= 0.75 / (15 × 10^{-3})	C1
	= 50 Ω	A1

	Answer	Mark
(c)(ii)	**1.** $V_Y = 15 \times 10^{-3} \times 60$ (= 0.90 V)	C1
	$V_X = 2.0 - 0.90 - 0.75$ (= 0.35 V)	C1
	$R_X = 0.35 / (15 \times 10^{-3})$ $= 23\ \Omega$	A1
	or	
	total $R = 60 + 50 + R_X$	(C1)
	$60 + 50 + R_X = 2.0 / (15 \times 10^{-3})$	(C1)
	$R_X = 23\ \Omega$	(A1)
	2. $P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2 / R$	C1
	ratio $= \dfrac{(15\times10^{-3})^2\times60}{2.0\times15\times10^{-3}}$ **or** $\dfrac{0.90\times15\times10^{-3}}{2.0\times15\times10^{-3}}$ **or** $\dfrac{(0.90^2/60)}{2.0\times15\times10^{-3}}$ $= 0.45$	A1

225. 9702_w19_qp_22 Q: 6

	Answer	Mark
(a)	<u>sum of</u> current(s) into junction = <u>sum of</u> current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	B1
(b)(i)	$R = V / I$	C1
	$= 0.60 / 7.5 \times 10^{-3}$	C1
	$= 80\ \Omega$	A1
(b)(ii)	resistance decreases	B1
(c)(i)	$E = 0.60 + 0.30$ $= 0.90$ V	A1
(c)(ii)	$(I =)\ 9.3 - 7.5$	C1
	$I = 1.8$ (mA) **or** 1.8×10^{-3} (A) $R = 0.90 / 1.8 \times 10^{-3}$ $= 500\ \Omega$	A1
	or	
	total resistance $= 0.90 / 9.3 \times 10^{-3} = 96.8\ (\Omega)$ total resistance of diode and X $= 0.90 / 7.5 \times 10^{-3} = 120\ (\Omega)$ $1 / 96.8 = 1 / R + 1 / 120$	(C1)
	$R = 500\ \Omega$	(A1)

	Answer	Mark
(c)(iii)	$P = VI$ **or** I^2R **or** V^2 / R	C1
	$= 0.60 \times 7.5 \times 10^{-3}$ **or** $(7.5 \times 10^{-3})^2 \times 80$ **or** $0.60^2 / 80$ $= 4.5 \times 10^{-3}$ W	A1
(c)(iv)	current = 2.5 mA	A1

226. 9702_w19_qp_23 Q: 6

	Answer	Mark
(a)(i)	$R = V / I$	C1
	resistance = (12 / 0.20) / 2 **or** 6 / 0.20 = 30 Ω	A1
(a)(ii)	I = 0.50 – 0.20 (= 0.30 A)	C1
	R + 28 = 12 / 0.30 (= 40 Ω) R = 12 Ω	A1

	Answer	Mark
(b)	p.d. across lamp = 0.20 × 30 (= 6.0 V)	C1
	p.d. across R = 0.30 × 12 (= 3.6 V)	C1
	V_{XY} = 6.0 – 3.6 = 2.4 V	A1
	or	
	p.d. across lamp = 0.20 × 30 (= 6.0 V)	(C1)
	p.d. across 28 Ω resistor = 0.30 × 28 (= 8.4 V)	(C1)
	V_{XY} = 8.4 – 6.0 = 2.4 V	(A1)
(c)	$P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2/R$	C1
	ratio = (6.0 × 0.20) × 2 / (12 × 0.50) **or** 0.20 / 0.50 = 0.40	A1
(d)	no change to V across lamps, so power in lamps unchanged **or** current in battery/total current increases (and e.m.f. the same) so power produced by battery increases	B1
	both the above statements and so the ratio decreases	B1

227. 9702_m18_qp_22 Q: 5

	Answer	Mark
(a)	sum of e.m.f.(s) = sum of p.d.(s)	M1
	around a loop / around a closed circuit	A1
(b)(i)	1 6.0 – 4.0I = 0 I = 1.5 A	A1
	2 6.0 + 6.0 = I (4.0 + R + 1.5) 12 = 1.5 (4.0 + R + 1.5)	C1
	R = 2.5 Ω	A1
	or 6.0 = I (R + 1.5) 6.0 = 1.5 (R + 1.5)	(C1)
	R = 2.5 Ω	(A1)
	or combines 6 = 4I and 6 = I(R + 1.5) to give 4 = R + 1.5	(C1)
	R = 2.5 Ω	(A1)

	Answer	Mark
(b)(ii)	$I = Anvq$ ratio = $1^2 / 2^2$	C1
	= 0.25	A1
(b)(iii)	total (circuit) resistance increases	B1
	current / I decreases or $P \propto I$ or $P \propto 1$ / (total resistance)	M1
	power (transformed) decreases	A1

228. 9702_s18_qp_21 Q: 6

	Answer	Mark
(a)	joule / coulomb	B1
(b)(i)	lamps have same p.d./lamps have p.d. of 2.7 V	B1
	current = 0.15 + 0.090 = 0.24 A	A1
(b)(ii)	$R = (4.5 - 2.7) / 0.24$ **or** $R_P = 18\,(\Omega)$ and $R_Q = 30\,(\Omega)$ $I / R_T = 1/18 + 1/30$ and so $R_T = 11.25$ $4.5 = 0.24 \times (R + 11.25)$	C1
	$R = 7.5\,\Omega$	A1

	Answer	Mark
(b)(iii)	$R = \rho l / A$	C1
	$R_P / R_Q = [(2.7/0.15)/(2.7/0.09)]$ (= 0.60)	C1
	ratio = 0.60×2^2 = 2.4	A1
(b)(iv)	less p.d. across resistor/greater p.d. across P	B1
	greater current through P and so resistance (of P) increases	B1

229. 9702_s18_qp_22 Q: 6

	Answer	Mark
(a)(i)	sum of current(s) into junction = sum of current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	B1
(a)(ii)	charge	B1
(b)(i)1.	$E = I^2Rt$ **or** $E = VIt$ **or** $E = (V^2/R)t$	C1
	$E = 2.5^2 \times 2.0 \times 5.0 \times 60$ **or** $5.0 \times 2.5 \times 5.0 \times 60$ **or** $(5.0^2/2.0) \times 5.0 \times 60$ = 3800 J	A1
(b)(i)2.	p.d. = 8.0 – (2.0 × 2.5) = 3.0 V	A1
(b)(ii)	$I_X = 3.0/15 = 0.20$ (A)	C1
	$I_Y = 2.5 - 0.20 = 2.3$ (A)	C1
	$R_Y = 3.0/2.3 = 1.3\,\Omega$	A1
	or	
	$R_T = 3.0/2.5 = 1.2(\Omega)$ **or** $(8.0/2.5) - 2.0 = 1.2(\Omega)$	(C1)
	$1/1.2 = 1/15 + 1/R_Y$	(C1)
	$R_Y = 1.3\Omega$	(A1)

	Answer	Mark
(b)(iii)1.	Z has larger radius/diameter/(cross-sectional) area	B1
	Z has (material of) smaller resistivity/greater conductivity	B1
(b)(iii)2.	current/I (in battery) increases	M1
	($P = EI$ so) power/P (produced by battery) increases	A1

230. 9702_s18_qp_23 Q: 6

	Answer	Mark
(a)	$R = \rho L/A$	C1
	$3.0 = \rho/[\pi \times (0.48 \times 10^{-3}/2)^2]$	C1
	$\rho = 5.4 \times 10^{-7}\,\Omega$m	A1
(b)(i)	p.d. = 5.0 – (2.0 × 1.6) = 1.8 V	A1
(b)(ii)1.	current in resistor = 1.8/4.5 (= 0.40 A)	C1
	current in wire = 1.6 – 0.40 (= 1.2 A)	C1
	$R_X = 1.8/1.2 = 1.5\Omega$	A1
	or	
	$R_T = 1.8/1.6$ **or** $(5.0/1.6) - 2.0$ (= 1.125Ω)	(C1)
	$(1/1.125) = (1/4.5) + (1/R_X)$	(C1)
	$R_X = 1.5\Omega$	(A1)
(b)(ii)2.	length = 1.5/3.0 **or** $1.5 \times 1.8 \times 10^{-7}/(5.4 \times 10^{-7})$ = 0.50 m	A1

231. 9702_w18_qp_21 Q: 6

	Answer	Mark
(a)	<u>sum of</u> e.m.f.(s) equal to <u>sum of</u> p.d.(s)	M1
	around a loop/around a closed circuit	A1
(b)(i)	current in variable resistor = (6.0 / 2.4) + (6.0 / 1.2) (= 7.5 A)	C1
	p.d. across variable resistor = 9.0 – 6.0 (= 3.0 V)	C1
	R = 3.0 / 7.5 = 0.40 Ω	A1
	or	
	$\frac{1}{R_T} = \frac{1}{2.4} + \frac{1}{1.2}$ R_T = 0.80 (Ω)	(C1)
	$\frac{3}{9} = \frac{R}{(R+0.80)}$ **or** $\frac{3}{R} = \frac{6}{0.8}$	(C1)
	R = 0.40 Ω	(A1)
(b)(ii)	$P = V^2/R$ **or** $P = I^2R$ **or** $P = IV$	C1
	$P = 6.0^2/24$ **or** $2.5^2 \times 2.4$ **or** 6.0×2.5 = 15 W	A1

	Answer	Mark
(b)(iii)	**1.** $R = \frac{\rho L}{A}$	C1
	ratio = (2.4 / 1.2) × (3 / 1) = 6.0	A1
	2. ($I = nAvq$) I_X / I_Y = 2.5 / 5.0 **or** 1.2 / 2.4 **or** 0.5	C1
	ratio = (2.5 / 5.0) × (1 / 3) **or** (1.2 / 2.4) × (1 / 3) = 0.17	A1

232. 9702_w18_qp_23 Q: 7

	Answer	Mark
(a)	<u>sum of</u> current(s) in(to) junction = <u>sum of</u> current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	B1
(b)(i)	**1.** potential difference = 0	A1
	2. potential difference = 9.6 V	A1
(b)(ii)	for resistance in parallel: (1 / R_T) = (1 / 400) + (1 / 400) R_T = 200 (Ω)	C1
	V / 9.6 = 200 / 600	C1
	V = 3.2 V	A1

233. 9702_m17_qp_22 Q: 6

	Answer	Mark
(a)	$I = I_1 + I_2 + I_3$	B1
	$(V / R) = (V / R_1) + (V / R_2) + (V / R_3)$ *or* $(I / V) = (I_1 / V) + (I_2 / V) + (I_3 / V)$ <u>and</u> (so) $1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3$	A1
(b)(i)	e.m.f. is total energy available per unit charge	B1
	energy is dissipated in the internal resistance / resistor / *r*	B1
(b)(ii)1	Energy $= EQ$	C1
	$= 6.0 \times 2.5 \times 10^3$ $= 1.5 \times 10^4$ J	A1
(b)(ii)2	number $= 2.5 \times 10^3 / 1.6 \times 10^{-19}$ $= 1.6 \times 10^{22}$ (1.56×10^{22})	A1
(b)(iii)	$1 / 4.8 = 1 / 12 + 1 / R_X$ $R_X = 8.0\,\Omega$	A1
(b)(iv)	$P = V^2 / R$ *or* $P = VI$ <u>and</u> $V = IR$	C1
	ratio $= (V^2 / 8) / (V^2 / 12) = 12 / 8$ $= 1.5$	A1
(b)(v)	(total) current, *or* I, increases <u>and</u> $P = EI$ *or* $P = 6I$ *or* $P \propto I$ *or* total (circuit) resistance decreases <u>and</u> $P = E^2 / R$ *or* $P = 36 / R$ or $P \propto 1 / R$	B1

234. 9702_s17_qp_21 Q: 6

	Answer	Mark
(a)	volt / ampere	B1
(b)(i)	$R_T = [1/3.0 + 1/6.0]^{-1} + 4.0$ $(= 6.0\,\Omega)$	C1
	$I = 1.5 / 6.0$	C1
	$= 0.25$ A	A1
(b)(ii)	$V_B = 0.5$ V $I = 0.5 / 3.0$ $= 0.17$ (0.167) A	A1
(b)(iii)	$P = I^2R$ **or** VI **or** V^2/R	C1
	ratio $= (0.167^2 \times 3.0) / (0.25^2 \times 4.0)$ $= 0.33$	A1
(c)(i)	vary/change/different radius/diameter/<u>cross-sectional</u> area (of wire)	B1
(c)(ii)	$v = I / Ane$ ratio $= \dfrac{(I_B / A_B)}{(I_C / A_C)}$ **or** $\dfrac{I_B}{I_C} \times \dfrac{A_C}{A_B}$	C1
	($R \propto 1/A$ so) ratio $= \dfrac{I_B}{I_C} \times \dfrac{R_B}{R_C} = \dfrac{0.167}{0.25} \times \dfrac{3.0}{4.0}$ $= 0.50$	A1
(d)(i)	0.25 A to 0.13 (0.125) A **or** halved	A1
(d)(ii)	no change	A1

235. 9702_s17_qp_22 Q: 7

	Answer	Mark
(a)	energy transformed from chemical to electrical / unit charge (driven around a complete circuit)	B1
(b)(i)	the current decreases (as resistance of Y increases)	M1
	lost volts go down (as resistance of Y increases)	M1
	p.d. AB increases (as resistance of Y increases)	A1
(b)(ii)1.	1.50 = 0.180 × (6.00 + 0.200 + R_X)	C1
	R_X = 2.1(3) Ω	A1
(b)(ii)2.	p.d. AB = 1.5 – (0.180 × 0.200) **or** 0.18 × (2.13 + 6.00)	C1
	= 1.46(4) V	A1
(b)(ii)3.	efficiency = (useful) power output / (total) power input **or** IV / IE	C1
	(= 1.46 / 1.5) = 0.97 [0.98 if full figures used]	A1

236. 9702_s17_qp_23 Q: 6

	Answer	Mark
(a)(i)	straight line through the origin	B1
(a)(ii)	zero current for one direction (–ve V) up to zero or a few tenths of volt (+ve V)	B1
	straight line positive gradient/increasing gradient (+ve V)	B1
(b)(i)	**1.** current = 2.8 A	A1
	2. 4(.0) A for each lamp	C1
	current in circuit = 8(.0) A	A1
(b)(ii)	use of $R = V / I$ with correct values of V from graph for each arrangement	C1
	1. series resistance (= 2.1 + 2.1) = 4.2 or 4.3 Ω **or** (12 / 2.8) = 4.3 Ω	A1
	2. parallel resistance 1.5 Ω (each lamp 3.0 Ω) **or** (12 / 8.0) = 1.5 Ω	A1
(b)(iii)	power = IV **or** V^2 / R **or** I^2R	C1
	ratio = (2.8 × 6.0) / (4.0 × 12) = 0.35	A1

237. 9702_w17_qp_21 Q: 5

	Answer	Mark
(a)	$I_1 + I_2 = I_3$ [any subject]	B1
(b)	$E_1 + E_3 = I_1R_1 + I_3R_3 + I_3R_4$ [any subject]	B1
(c)	$E_1 - E_2 = I_1R_1 - I_2R_2$ [any subject]	B1

238. 9702_m16_qp_22 Q: 5

(a) (i)	movement/flow of charge carriers	B1
(ii)	$\frac{\text{work (done) or energy (transformed)(from electrical to other forms)}}{\text{charge}}$	B1
(b) (i)	p.d. across one lamp = 2.5 V resistance = [(8.7 – 7.5)/0.3]/2 = 2.0 (Ω)	C1 A1
(ii)	straight line through the origin with gradient of 0.5	M1 A1
(iii)	$P = I^2R$ **or** $P = VI$ and $V = IR$ **or** $P = V^2/R$ and $V = IR$ $= 0.30^2 \times 2.0$ $= 0.60 \times 0.30$ $= 0.60^2 / 2.0$ $= 0.18$ (W)	C1 A1
(iv) 1	$R = \rho l/A$ $l = (2.0 \times 0.40 \times 10^{-6}) / 1.7 \times 10^{-8}$ $= 47$ (m)	C1 A1
2	$I = Anvq$ $v = 0.30 / (0.40 \times 10^{-6} \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19})$ $= 5.5 \times 10^{-5}$ (m s^{-1})	 C1 A1

239. 9702_s16_qp_22 Q: 7

(a)	charge exists only in discrete amounts	B1	[1]
(b) (i)	$E = I(R + r)$ or $V = IR$	C1	
	(total resistance =) 2.7 + 0.30 + 0.25 (= 3.25 Ω)	M1	
	I = 9.0 / (2.7 + 0.30 + 0.25) or 9.0 / 3.25 = 2.8 A	A1	[3]
(ii)	$V = IR_{ext}$ = 2.77 × 3.0 or 2.8 × 3.0	C1	
	or		
	$V = E - Ir$ = 9.0 – 2.77 × 0.25 or 9.0 – 2.8 × 0.25	(C1)	
	V = 8.3 (8.31) V or 8.4 V	A1	[2]
(c) (i)	$I = nevA$		
	$v = 2.77 / (8.5 \times 10^{29} \times 1.6 \times 10^{-19} \times 2.5 \times 10^{-6})$	M1	
	$= 8.1\ (8.147) \times 10^{-6}\ \text{m s}^{-1}$ or $8.2 \times 10^{-6}\ \text{m s}^{-1}$	A1	[2]
(ii)	A reduces by a factor 4 (1/4 less) or resistance of Z goes up by 4×	M1	
	current goes down but by less than a factor of 4 (as total resistance does not go up by a factor of 4) so drift speed goes up	A1	[2]

240. 9702_w16_qp_21 Q: 6

(a)	$\dfrac{\text{work done or energy (transformed) (from electrical to other forms)}}{\text{charge}}$	B1	[1]
(b) (i) 1.	$V = IR$ *or* $E = IR$	C1	
	$I = 14/6.0$ $= 2.3\ (2.33)$ A	A1	[2]
2.	total resistance of parallel resistors = 8.0 Ω	C1	
	current = 14 / (6.0 + 8.0) = 1.0 A	A1	[2]
(ii)	$P = EI$ (*allow* $P = VI$) *or* $P = V^2/R$ *or* $P = I^2R$	C1	
	change in power = (14 × 2.33) – (14 × 1.0) *or* $(14^2 / 6.0) - (14^2 / 14)$ *or* $(2.33^2 \times 6.0) - (1.0^2 \times 14)$		
	= 19 W (18 W if 2.3 A used)	A1	[2]
(c)	$I = Anvq$		
	ratio = $(0.50n/n) \times (1.8A/A)$ or ratio = 0.50 × 1.8	C1	
	= 0.90	A1	[2]

241. 9702_w16_qp_22 Q: 5

(a) total/sum of electromotive forces or e.m.f.s = total/sum of potential differences or p.d.s — M1
around a loop/(closed) circuit — A1 [2]

(b) (i) (current in battery =) current in A + current in B *or* $I_A + I_B$ — C1

$(I =)$ 0.14 + 0.26 = 0.40 A — A1 [2]

(ii) $E = V + Ir$

6.8 = 6.0 + 0.40r *or* 6.8 = 0.40(15 + r) — C1

r = 2.0 Ω — A1 [2]

(iii) $R = V / I$ — C1

ratio (= R_A / R_B) = (6.0 / 0.14) / (6.0 / 0.26)
= 42.9 / 23.1 *or* 0.26 / 0.14

= 1.9 (1.86) — A1 [2]

(iv) 1. $P = EI$ or VI *or* $P = I^2R$ *or* $P = V^2/R$ — C1

= 6.8 × 0.40   = $0.40^2 \times 17$ = $6.8^2 / 17$

= 2.7 W (2.72 W) — A1 [2]

2. output power = VI
= 6.0 × 0.40 (= 2.40 W) — C1

efficiency = (6.0 × 0.40) / (6.8 × 0.40) = 2.40 / 2.72
= 0.88 or 88% (*allow 0.89 or 89%*) — A1 [2]

242. 9702_w16_qp_23 Q: 6

(a)	$\dfrac{\text{work done or energy (transformed) (from electrical to other forms)}}{\text{charge}}$	B1	[1]
(b) (i) 1.	$V = IR$ *or* $E = IR$	C1	
	$I = 14 / 6.0$ $= 2.3\ (2.33)$ A	A1	[2]
2.	total resistance of parallel resistors = 8.0 Ω	C1	
	current = 14 / (6.0 + 8.0) = 1.0 A	A1	[2]
(ii)	$P = EI$ (allow $P = VI$) *or* $P = V^2 / R$ *or* $P = I^2R$	C1	
	change in power = $(14 \times 2.33) - (14 \times 1.0)$ *or* $(14^2 / 6.0) - (14^2 / 14)$ *or* $(2.33^2 \times 6.0) - (1.0^2 \times 14)$		
	= 19 W (18 W if 2.3 A used)	A1	[2]
(c)	$I = Anvq$		
	ratio = $(0.50n / n) \times (1.8A / A)$ or ratio = 0.50×1.8	C1	
	= 0.90	A1	[2]

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243. 9702_s15_qp_22 Q: 5

(a)	curved line showing decreasing gradient with temperature rise	M1	
	smooth line not touching temperature axis, not horizontal or vertical anywhere	A1	[2]
(b) (i)	(no energy lost in battery because) no/negligible internal resistance	B1	[1]

(ii) $I = V / R$

$= 8 / 15 \times 10^3$ or $1.6 / 3.0 \times 10^3$ or $2.4 / 4.5 \times 10^3$ or $12 / 22.5 \times 10^3$ C1

$= 0.53 \times 10^{-3}$ A A1 [2]

(iii) p.d. across X = $12 - 8.0 - 3.0 \times 10^3 \times 0.53 \times 10^{-3}$ (= 2.4 V) C1

$R_X = 2.4 / (0.53 \times 10^{-3})$ C1

or
$R_{tot} = 12 / 0.53 \times 10^{-3}$ (= $22.5 \times 10^3\ \Omega$) (C1)
$R_X = (22.5 - 15.0 - 3.0) \times 10^3$ (C1)

$4.5(2) \times 10^3\ \Omega$ A1 [3]

(iv) resistance decreases hence current (in circuit) is greater M1

p.d. across X and Y is greater hence p.d across Z decreases A1

or explanation in terms of potential divider:
R_Z decreases so $R_Z / (R_X + R_Y + R_Z)$ is less (M1)
therefore p.d. across Z decreases (A1) [2]

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244. 9702_w15_qp_21 Q: 6

(a) energy converted from chemical to electrical per unit charge B1 [1]

(b) (i) current $= E / (R + r)$ C1

$= 6.0 / (16 + 0.5)$
$= 0.36\ (0.364)$ A A1 [2]

(ii) terminal p.d. = (0.36×16) = 5.8 V **or** $(6 - 0.36 \times 0.5)$
= 5.8 V A1 [1]

(c) (i) use of $R = \rho l / A$ or proportionality with length and inverse proportionality with area or d^2 C1

$d/2$ and $l/2$ gives resistance of Z = $2R_Y$ = 24 (Ω) C1

R = resistance of parallel combination = $[1/24 + 1/12]^{-1}$
= 8(.0) (Ω) A1 [3]

(ii) resistance of circuit less therefore current larger B1

lost volts greater therefore terminal p.d. less B1 [2]

(d) power = $I^2 R$ **or** VI **or** V^2 / R C1

current in second circuit (= 6.0 / 12.5) = 0.48 (A) B1

ratio = $[(0.36)^2 \times 16] / [(0.48)^2 \times 12]$ = 0.75 [0.77 if full s.f. used] B1 [3]

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245. 9702_w15_qp_22 Q: 6

(a)	internal resistance causes lost volts	B1	
	p.d. across lamp is less than 12 V, power is less than 48 W	B1	[2]
(b) (i)	greater lost volts or p.d. across cell/lamp reduced, less current in lamp	B1	[1]
(ii)	p.d. across lamp/current <u>in lamp</u> decreases, hence resistance decreases	B1	[1]

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246. 9702_w15_qp_23 Q: 5

(a) (i)	resistance = V / I	B1	
	very high/infinite resistance at low voltages	B1	
	resistance decreases as V increases	B1	[3]
(ii)	p.d. from graph 0.50 (V)	C1	
	resistance = $0.5 / (4.4 \times 10^{-3})$		
	= 110 (114) Ω	A1	[2]
(b) (i)	current (= 1.2 / 375) = 3.2×10^{-3} A	A1	[1]
(ii)	current in diode = 4.4×10^{-3} (A) total resistance = $1.2 / 4.4 \times 10^{-3}$ = 272.7 (Ω)	C1	
	resistance of R_1 = 272.7 – 113.6 = 160 (159) Ω	A1	
	or		
	p.d. across diode = 0.5 V and p.d. across R_1 = 0.7 V	(C1)	
	resistance of R_1 = $0.7 / 4.4 \times 10^{-3}$ = 160 (159) Ω	(A1)	[2]
(iii)	power = IV **or** I^2R **or** V^2/R	C1	
	ratio = $(4.4 \times 0.5)/(3.2 \times 1.2)$ **or** $[(4.4)^2 \times 114]/[(3.2)^2 \times 375]$ **or** $[(0.5)^2 \times 375]/[114 \times (1.2)^2]$ = 0.57	A1	[2]

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247. 9702_s20_qp_21 Q: 5

	Answer	Mark
(a)(i)	$R = \rho L / A$	C1
	$A = (2.6 \times 10^{-8} \times 59) / 3.4 = 4.5 \times 10^{-7}$ m^2	A1
(a)(ii)	I = 1.8 / 3.4	A1
	= 0.53 A	
(a)(iii)	$I = Anvq$	C1
	$v = 0.53 / (4.5 \times 10^{-7} \times 6.1 \times 10^{28} \times 1.60 \times 10^{-19})$	
	$= 1.2 \times 10^{-4}$ m s^{-1}	A1
(b)(i)	(cross-sectional) area/A is less	M1
	(I, n, e the same so) average drift speed is greater	A1
(b)(ii)	(area is less so) more resistance/R	M1
	(I is the same, so) more power/P	A1
	or	
	($P = I^2 \rho L / A$ so) $P \propto 1 / A$	(M1)
	(A is less so) more P	(A1)
(c)(i)	180 Ω and 90 Ω resistors shown connected in parallel	B1
(c)(ii)	resistors connected in parallel labelled as 180 Ω and 90 Ω **and** the other resistor labelled as 30 Ω	M1
	V_{OUT} or 8.0 V labelled across the two resistors in parallel	A1

248. 9702_s15_qp_23 Q: 5

(a) $R = \rho l / A$ C1

$= (5.1 \times 10^{-7} \times 0.50) / \pi(0.18 \times 10^{-3})^2 = 2.5\ (2.51)\,\Omega$ M1 [2]

(b) (i) resistance of CD = 8 × resistance of AB = 20 (Ω) C1

circuit resistance = $[1/5.0 + 1/20]^{-1}$ = 4.0 (Ω) C1

current = V / R = 6.0 / 4.0 C1

= 1.5 A A1 [4]

(ii) power in AB = I^2R or power = V^2/R C1

$= (1.2)^2 \times 2.5 = 3.6$ W $= (3.0)^2/2.5 = 3.6$ W A1 [2]

(iii) potential drop A to M = 1.25 × 1.2 = 1.5 V M1

potential drop C to N = 3.0 V
p.d. MN = 1.5 V A1 [2]

249. 9702_w15_qp_22 Q: 5

(a)	**(i)**	$I = V/R$	C1	
		(= 240 / 1500 =) 0.16 A	A1	[2]
	(ii)	I_2 = 0.40 – 0.16 (= 0.24)	C1	
		0.24 (350 + R) = 240		
		R = 650 Ω	A1	[2]
	(iii)	power = IV **or** I^2R **or** V^2/R	C1	
		ratio = (84 × 0.24) / (88 × 0.16) **or** [(0.24)^2 × 350] / [(0.16)^2 × 550] **or** (84^2/350) / (88^2 / 550) **or** 20.16 / 14.08		
		= 1.4(3)	A1	[2]
(b)	**(i)**	p.d. across 350 Ω resistor = 0.24 × 350 **or** p.d. across 550 Ω resistor = 0.16 × 550	C1	
		V_{350} = 84 (V) and V_{550} = 88 (V) gives V_{AB} = 4.0 V **or** V_{950} = 152 (V) and V_R = 156 V gives V_{AB} = 4.0 V	A1	[2]
	(ii)	p.d. across R increases **or** potential at B increases **or** V_{350} decreases hence V_{AB} increases	B1	[1]

250. 9702_s20_qp_21 Q: 6

	Answer	Mark
(a)(i)	$E = \Delta V / \Delta d$	C1
	E = (180 + 120) / (2.0 × 10^{-2}) = 1.5 × 10^4 N C^{-1}	A1
(a)(ii)	vertically downwards	B1
(b)(i)	number of protons = 92	A1
	number of neutrons = 146	A1
	number of electrons = 90	A1
(b)(ii)	$F = EQ$	C1
	= 1.5 × 10^4 × 2 × 1.60 × 10^{-19} = 4.8 × 10^{-15} N	A1
(b)(iii)	number of α-particles = 2	A1
	number of β$^-$ particles = 2	A1

251. 9702_w20_qp_23 Q: 7

	Answer	Mark
(a)(i)	electric field strength = *V* / *d*	**B1**
(a)(ii)	force = *Vq* / *d*	**B1**
(a)(iii)	kinetic energy = *Vq*	**B1**
(b)(i)	no change	**B1**
(b)(ii)	no change	**B1**
(c)(i)	nucleon number = 14 **and** proton number = 7	**A1**
(c)(ii)	(electron) antineutrino	**B1**

252. 9702_w19_qp_22 Q: 7

	Answer	Mark
(a)	number of protons = 92	**A1**
	number of neutrons = 142	**A1**
(b)	5.6 MeV = $5.6 \times 1.60 \times 10^{-19} \times 10^6$ (= 8.96×10^{-13} J)	**C1**
	number = 0.15 / ($5.6 \times 1.60 \times 10^{-13}$) = 1.7×10^{11}	**A1**
	or	
	0.15 W = 0.15 / ($1.60 \times 10^{-19} \times 10^6$) (= 9.38×10^{11} MeV s^{-1})	**(C1)**
	number = 9.38×10^{11} / 5.6 = 1.7×10^{11}	**(A1)**

253. 9702_w19_qp_23 Q: 7

	Answer	Mark
(a)	number of protons = 95	**A1**
	number of neutrons = 146	**A1**
(b)	Np/neptunium (nucleus) has kinetic energy **or** gamma/γ-radiation produced	**B1**
(c)(i)	*I* = *NQ* / *t*	**C1**
	I = ($6.9 \times 10^{11} \times 2 \times 1.60 \times 10^{-19}$) / 30 = 7.4×10^{-9} A	**A1**
(c)(ii)	*P* = ($6.9 \times 10^{11} \times 5.5 \times 10^6 \times 1.60 \times 10^{-19}$) / 30	**C1**
	= 0.020 W	**A1**

254. 9702_m18_qp_22 Q: 6

	Answer	Mark
(a)	–1 / decreases by 1	A1
(b)	$I = Q/t$ or Ne/t	C1
	$= (9.8\times10^{10} \times 1.6\times10^{-19}) / (2.0 \times 60)$ $= 1.3 \times 10^{-10}$ (A)	C1
	= 130 pA	A1
(c)	antineutrino(s) (emitted) / other particle(s) (emitted)	C1
	energy / momentum shared with antineutrino(s)	A1

255. 9702_w18_qp_21 Q: 5

	Answer	Mark
(a)	region (of space) where a force acts on a (stationary) charge	B1
(b)	$E = F/Q$	B1
	$F = ma$ **and** (so) $a = \frac{Eq}{m}$	A1
(c)(i)	protons = 96	A1
	neutrons = 148	A1
(c)(ii)	mass-energy is conserved/mass change is 'seen' as energy	B1
	energy released as gamma (radiation)/KE of α/KE of Pu	B1
(c)(iii)	ratio $= \frac{2}{4}\times\frac{240}{94}$ **or** ratio $= \frac{2\times1.60\times10^{-19}}{4\times1.66\times10^{-27}}\times\frac{240\times1.66\times10^{-27}}{94\times1.60\times10^{-19}}$	C1
	ratio = 1.3	A1

256. 9702_w18_qp_23 Q: 5

	Answer	Mark
(a)	$E = F/Q$	M1
	$F = ma$ **and** (so) $q/m = a/E$	A1
(b)	$m = (4 \times 1.60 \times 10^{-19} \times 3.5 \times 10^{4}) / 1.5 \times 10^{12}$ ($= 1.49 \times 10^{-26}$ kg)	B1
	$= 1.49 \times 10^{-26} / 1.66 \times 10^{-27} = 9.0$ (u)	A1
(c)	protons: 4 **and** neutrons: 5	A1
(d)(i)	nuclei have the same charge and so same (magnitudes of) force	B1
(d)(ii)	nuclei have different masses and same force and so different (magnitudes of) acceleration	B1

257. 9702_m17_qp_22 Q: 7

	Answer	Mark
(a)	number of protons = 83 and number of neutrons = 129	A1
(b)	$\lambda = 3.8 \times 10^{-12}$	C1
	$f = 3.0 \times 10^{8} / 3.8 \times 10^{-12}$	C1
	$f = 7.9 \times 10^{19}$ (7.89×10^{19}) Hz	A1
(c)	use an electric field (at an angle to the beam)	M1
	α is deflected <u>and</u> γ is undeflected	A1
(d)	*either*	
	energy $= 9.3 \times 10^{-13} / 1.8 \times 10^{5}$ ($= 5.17 \times 10^{-18}$ J)	C1
	$= 5.17 \times 10^{-18} / 1.6 \times 10^{-19}$ = 32 (32.3) eV	A1
	or	
	energy $= 9.3 \times 10^{-13} / 1.6 \times 10^{-19}$ ($= 5.81 \times 10^{6}$ eV)	(C1)
	$= 5.81 \times 10^{6} / 1.8 \times 10^{5}$ = 32 (32.3) eV	(A1)

258. 9702_w17_qp_23 Q: 7

	Answer	Mark
(a)	nucleons = 23	B1
	neutrons = 11	B1
(b)	similarity: same (rest) mass **or** equal (magnitude of) charge	B1
	difference: opposite (sign of) charge **or** one is matter and one is antimatter **or** one is an electron and one is an antielectron	B1

259. 9702_s15_qp_22 Q: 7

(a) 92 protons and 143 neutrons B1 [1]

(b)

	value
a	1
b	0
c	141
d	55

(a and b both required) B1

B1

B1 [3]

(c) kinetic energy (of products) or gamma/γ (radiation or photon) B1 [1]

(d) (total) mass on left-hand side/reactants is <u>greater</u> than (total) mass on right-hand side/products M1

difference in mass is (converted to) energy A1 [2]

260. 9702_s15_qp_23 Q: 7

(a) **(i)** (rate of decay) not affected by any external factors **or** changes in temperature and pressure etc. B1 [1]

(ii) two protons and two neutrons B1 [1]

(b) **(i)** (total) mass before decay/on left-hand side is greater than (total) mass on right-hand side/after the decay M1

the difference in mass is released as kinetic energy of the products A1 [2]

(may also be some γ radiation) (to conserve mass-energy)

(ii) ($6.2 \times 10^6 \times 1.6 \times 10^{-19}$ =) $9.9(2) \times 10^{-13}$ J A1 [1]

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261. 9702_w15_qp_21 Q: 7

(a) **(i)** curved path towards negative (–) plate (right-hand side) B1 [1]

(ii) range of α-particle is only few cm in air/loss of energy of the α-particles due to collision with air molecules/ionisation of the air molecules B1 [1]

(iii) $V = E \times d$ C1

$= 140 \times 10^6 \times 12 \times 10^{-3} = 1.7\ (1.68)$ MV A1 [2]

(b) β have opposite charge to α therefore deflection in opposite direction B1

β has a range of velocities/energies hence number of different deflections B1

β have less mass or q/m is larger hence deflection is greater
or
β with (very) high speed (may) have less deflection B1 [3]

(c)

emitted particle	change in Z	change in A
α-particle	–2	–4
β-particle	+1	0

A1 [1]

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262. 9702_w15_qp_22 Q: 8

(a) result: majority / most (of the α-particles) went straight through/were deviated by small angles — M1

conclusion: most of the atom is (empty) space **or** size/volume of nucleus very small compared with atom — A1

result: a small proportion were deflected through large angles or >90° or came straight back — M1

conclusion: the mass or majority of mass is in a (very) small charged volume/region/nucleus — A1 [4]

(b) $\rho = m / V$ — C1

mass of atom and mass of nucleus (approx.) equal stated **or** cancelled **or** values given e.g. 63 u or $63 \times 1.66 \times 10^{-27}$ — C1

ratio $= (r_A)^3 / (r_N)^3 = (1.15 \times 10^{-10})^3 / (1.4 \times 10^{-14})^3$

or

ratio $= (d_A)^3 / (d_N)^3 = (2.3 \times 10^{-10})^3 / (2.8 \times 10^{-14})^3$

$= 5.5 \times 10^{11}$ — A1 [3]

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263. 9702_w15_qp_23 Q: 8

(a) mass-energy
proton number or charge
nucleon number — B2 [2]

(b) (i) $E_k = ½ mv^2$ and $p = mv$ with working leading to

[via $E_k = ½m^2v^2 / m$ or $½m(p/m)^2$]

to $E_k = \dfrac{p^2}{2m}$ — B1 [1]

(ii) $p = (2E_k m)^{½}$ hence $(2[E_k m]_\alpha)^{½} = (2[E_k m]_{Th})^{½}$ — C1

$2 \times [E_k]_{Th} \times 234 = 2 \times 6.69 \times 10^{-13} \times 4$ — C1

$[E_k]_{Th} = 1.14 \times 10^{-14}$ J
$= 71(.5)$ keV — A1

or

calculation of speed of α-particle $= 1.42 \times 10^7$ m s^{-1}
calculation of momentum of α-particle/nucleus $= 9.43 \times 10^{-20}$ N s — (C1)

$[E_k]_{Th} = 1.14 \times 10^{-14}$ J — (C1)
$= 71(.5)$ keV — (A1) [3]

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264. 9702_m20_qp_22 Q: 7

	Answer	Mark
(a)	made up of quarks (so) not a fundamental particle	B1
(b)(i)	beta plus / β^+ (particle)	B1
	(electron) neutrino / $\nu_{(e)}$	B1
(b)(ii)	kinetic energy of nucleus	B1
	gamma / γ radiation	B1

265. 9702_s20_qp_22 Q: 7

	Answer	Mark
(a)(i)	P = 0 **and** Q = 39	A1
	R = (+)1 **and** S = 20	A1
(a)(ii)	weak (nuclear force/interaction)	B1
(b)	charge of quark(s) = (+) 2*e* / 3	B1
	up/u (quarks)	B1

266. 9702_s20_qp_23 Q: 7

	Answer	Mark
(a)(i)	$E = V / d$ **or** $E = F / Q$	C1
	$F = (450 \times 1.60 \times 10^{-19}) / 6.0 \times 10^{-3}$	C1
	$= 1.2 \times 10^{-14}$ N	A1
	direction: vertically downwards	B1

	Answer	Mark
(a)(ii)	work done = *Fs* **or** *Fd* **or** *EQd*	C1
	$= (-)1.2 \times 10^{-14} \times 6.0 \times 10^{-3}$ $= (-)7.2 \times 10^{-17}$ J	A1
	or	
	work done = *VQ*	(C1)
	$= (-)450 \times 1.60 \times 10^{-19}$ $= (-)7.2 \times 10^{-17}$ J	(A1)
(b)	$E = ½mv^2$	C1
	$3.4 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v = 2.7 \times 10^7$ m s^{-1}	A1
(c)(i)	$^{1}_{1}p$	A1
	$^{0}_{0}\bar{\nu}_{(e)}$	A1
(c)(ii)	**1.** hadrons	B1
	2. leptons	B1

267. 9702_w20_qp_21 Q: 8

	Answer	Mark
(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	**B1**
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	**B1**
(b)(i)	number of protons = 13 **and** number of neutrons = 12	**A1**
(b)(ii)	(charge =) $13 \times 1.60 \times 10^{-19}$ (C) = 2.1×10^{-18} (C)	**A1**
(c)	force = $11 \times 10^3 \times 2.1 \times 10^{-18}$	**C1**
	work done = $11 \times 10^3 \times 2.1 \times 10^{-18} \times 0.04$	**C1**
	= 9.2×10^{-16} J	**A1**

268. 9702_w20_qp_22 Q: 7

	Answer	Mark
(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	**B1**
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	**B1**
(b)(i)	arrow points to the right	**B1**
(b)(ii)	(electric) field strength increases **or** (electric) force increases	**B1**
	acceleration increases	**B1**
(b)(iii)	force (on α-particle) has twice the magnitude (of force on electron)	**B1**
	force (on α-particle) is in opposite direction (to force on electron)	**B1**

269. 9702_m19_qp_22 Q: 7

	Answer	Mark
(a)(i)	alpha, neutron and proton	**B1**
(a)(ii)	neutron	**B1**
(a)(iii)	beta plus or β^+	**B1**
(b)	$\bar{d}$ has charge (+)⅓ e	**C1**
	(so) other quark has charge = e – ⅓ e = (+)⅔ e	**M1**
	other quark is an up / u	**A1**

270. 9702_s19_qp_21 Q: 7

	Answer	Mark
(a)	nucleus is charged	B1
	the mass is <u>concentrated</u> in (very small) nucleus **or** the <u>majority</u> of the mass is in (very small) nucleus	B1
(b)(i)	–(1 / 3)*e*	B1
(b)(ii)	2*q* – (1 / 3)*e* = *e* so *q* = (2 / 3)*e*	M1
	up / u (quarks) (*allow charm or top quarks*)	A1

271. 9702_s19_qp_22 Q: 6

	Answer	Mark
(a)	path/direction in which a (free) <u>positive</u> charge will move	B1
(b)	(lines) closer together in Y/further apart in X	B1
(c)(i)	*a* = *Eq* / *m* **or** *F* = *Eq* **and** *F* = *ma*	C1
	ratio = (1*e* / 0.15 u) × (4 u / 2*e*) **or** 1 / 0.15 × 4 / 2	C1
	ratio = 13	A1
(c)(ii)	down quark charge is –(1 / 3)*e*	C1
	– (1 / 3)*e* + *q* = –1*e* so *q* = –(2 / 3)*e*	A1
	(–(2 / 3)*e* is) anti-up / $\bar{u}$ (quark) (*allow charm or top antiquark*)	B1

272. 9702_s19_qp_23 Q: 7

	Answer	Mark
(a)	beta/β	B1
(b)	alpha/α	B1
(c)	gamma/γ	B1
(d)	beta/β	B1

273. 9702_w19_qp_21 Q: 7

	Answer	Mark
(a)(i)	proton number = 17 **and** nucleon number = 35	A1
(a)(ii)	(electron) neutrino	B1
(b)	d/down (quark charge) is –⅓(*e*) **or** <u>two</u> d/down (quark charges) is –⅔(*e*) **or** s/strange (quark charge) is –⅓(*e*)	C1
	charge = –⅓(*e*) –⅓(*e*) –⅓(*e*) = –1(*e*)	A1

274. 9702_s18_qp_21 Q: 7

	Answer	Mark
(a)	arrow pointing vertically down the page	B1
(b)	$E = ½mv^2$	C1
	$E = 460 \times 1.60 \times 10^{-19}$ (= 7.36×10^{-17} (J))	C1
	$v = [(2 \times 460 \times 1.60 \times 10^{-19}) / (9.11 \times 10^{-31})]^{½}$ $= 1.3 \times 10^7 \text{ m s}^{-1}$	A1
(c)	β^- particles have range of/different/various speeds/velocities/momenta/energies	M1
	so they follow different paths	A1

275. 9702_s18_qp_22 Q: 7

	Answer	Mark
(a)	circle(s) drawn only around β^- and $\bar{\nu}$ symbols	B1
(b)	(electron) antineutrino	B1
(c)	kinetic (energy)	B1
(d)	Y has one more proton (and one less neutron)/X has one less proton (and one more neutron) **or** Y has more protons (and fewer neutrons)/X has fewer protons (and more neutrons) **or** a neutron changes to a proton **or** the number of protons increases	M1
	(so) not isotopes	A1
(e)	up down down changes to up up down **or** udd → uud **or** down changes to up **or** d → u	B1

276. 9702_s18_qp_23 Q: 7

	Answer	Mark
(a)(i)	Q plotted at (82, 210)	A1
(a)(ii)	R plotted at (83, 210)	A1
(b)	lepton(s)	B1
(c)	up down down changes to up up down **or** udd → uud **or** down changes to up **or** d → u	B1

277. 9702_w18_qp_22 Q: 8

	Answer	Mark
(a)	antineutrino **and** positron both underlined (and no other particles)	B1
(b)(i)	nucleon number = 27	A1
	proton number = 13	A1
(b)(ii)	weak (nuclear force/interaction)	B1
(b)(iii)	an (electron) antineutrino / $\bar{\nu}_{(e)}$ is produced (and this has energy)	B1
	X has kinetic energy	B1

278. 9702_s17_qp_21 Q: 7

	Answer	Mark
(a)(i)	(proton is uud so) (2 / 3)*e* + (2 / 3)*e* – (1 / 3)*e* = *e*	B1
(a)(ii)	(neutron is udd so) (2 / 3)*e* – (1 / 3)*e* –(1 / 3)*e* = 0	B1
(b)(i)	<table><tr><td></td><td>β⁻</td><td>β⁺</td></tr><tr><td>nucleon number</td><td>90</td><td>64</td></tr><tr><td>proton number</td><td>39</td><td>28</td></tr></table> *all correct*	B1
(b)(ii)	weak (nuclear force/interaction)	B1
(b)(iii)	β^- decay: electron and (electron) antineutrino β^+ decay: positron and (electron) neutrino *all correct*	B1

279. 9702_s17_qp_22 Q: 8

	Answer	Mark
(a)	β^- emission: neutron changes to proton (+ beta$^-$/electron) **and** β^+ emission: proton changes to neutron (+ beta$^+$/positron)	B1
	β^- emission: (electron) antineutrino also emitted **and** β^+ emission: (electron) neutrino also emitted	B1
(b)	proton: up up down (and zero strange) neutron: up down down (and zero strange)	B1

280. 9702_s17_qp_23 Q: 7

	Answer	Mark
(a)	electron **and** quark both underlined/clearly indicated and no others	B1
(b)(i)	<table><tr><td></td><td>value</td></tr><tr><td>A</td><td>60</td></tr><tr><td>B</td><td>28</td></tr></table> *both correct*	B1
(b)(ii)	(electron) antineutrino	B1

281. 9702_w17_qp_21 Q: 8

	Answer	Mark
(a)	(quark structure is) up, down, down/udd	B1
	up/u has charge +⅔(*e*), down/d has charge –⅓(*e*)	C1
	+⅔*e* –⅓*e* –⅓*e* = 0	A1
(b)	charge: p +1.6(0) × 10^{-19} (C) **or** +*e* β^- –1.6(0) × 10^{-19} (C) **or** –*e* $\bar{\nu}$ zero/0	B1
	mass: p 1.67 × 10^{-27} (kg)/1.7 × 10^{-27} (kg) β^- 9.1(1) × 10^{-31} (kg) $\bar{\nu}$ very small/zero/0	B1

282. 9702_w17_qp_22 Q: 7

	Answer	Mark
(a)	lepton(s)	B1
(b)	protons: 7 **and** neutrons: 6	A1
(c)	$E = ½mv^2$	C1
	$= 0.80 \times 10^6 \times 1.60 \times 10^{-19}$	C1
	$= 1.28 \times 10^{-13}$ (J) $v^2 = 2 \times 1.28 \times 10^{-13} / 2.2 \times 10^{-26}$ $v = 3.4 \times 10^6 \text{ m s}^{-1}$	A1
(d)	an (electron) neutrino/$\nu_{(e)}$ is also produced (and this has energy)	B1

283. 9702_m16_qp_22 Q: 6

(a) ^1_1p B1

$^{0}_{-1}\beta^-$ and $^0_0\bar{\nu}$ B1

(b) an (electron) antineutrino B1

(c) lepton(s) B1

(d) **(i)** down, down, up / ddu B1

(ii) a down / d (quark) changes to an up / u (quark) **or** ddu → uud B1

284. 9702_s16_qp_21 Q: 7

(a) hadron: neutron/proton
and
lepton: electron/(electron) neutrino B1 [1]

(allow other correct particles)

(b) **(i)** proton: up up down or uud B1 [1]

(ii) neutron: up down down or udd B1 [1]

(c) **(i)** neutron → proton + electron + (electron) antineutrino B1 [1]

(ii) up down down (quarks) change to up up down (quarks)
or
down (quark) changes to up (quark) B1 [1]

285. 9702_s16_qp_22 Q: 8

(a) both electron and neutrino: lepton(s) B1

both neutron and proton: hadron(s)/baryon(s) B1 [2]

(b) **(i)** $^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{0}_{1}\beta + {}^{0}_{0}\nu$

correct symbols for particles M1

correct numerical values (allow no values on neutrino) A1 [2]

(ii) up up down or uud → up down down or udd B1 [1]

(iii) weak (nuclear) B1 [1]

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286. 9702_s16_qp_23 Q: 8

(a) α-particle is 2 protons and 2 neutrons; β^{+}-particle is positive electron/positron
α-particle has charge +2*e*; β^{+}-particle has +*e* charge
α-particle has mass 4u; β-particle has mass (1/2000)u
α-particle made up of hadrons; β^{+}-particle a lepton

any three B3 [3]

(b) $^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{0}_{1}\beta + {}^{0}_{0}\nu$

all terms correct M1

all numerical values correct (ignore missing values on ν) A1 [2]

(c) **(i)** **1.** proton: up, up, down / uud B1

2. neutron: up, down, down / udd B1 [2]

(ii) up quark has charge +2 / 3 (e) and down quark has charge –1 / 3 (e)
total is +1(e) B1 [1]

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287. 9702_w16_qp_21 Q: 7

(a)		hadron not a fundamental particle/lepton is fundamental particle *or* hadron made of quarks/lepton not made of quarks *or* strong force/interaction acts on hadrons/does not act on leptons	B1	[1]
(b)	**(i)**	proton: up, up, down / uud	B1	
		neutron: up, down, down / udd	B1	[2]
	(ii)	composition: 2(uud) + 2(udd) = 6 up, 6 down / 6u, 6d	B1	[1]
(c)	**(i)**	most of the atom is empty space *or* the nucleus (volume) is (very) small compared to the atom	B1	[1]
	(ii)	nucleus is (positively) charged	B1	
		the mass is concentrated in (very small) nucleus/small region/small volume/small core *or* the majority of mass in (very small) nucleus/small region/small volume/small core	B1	[2]

288. 9702_w16_qp_22 Q: 6

(a) hadron not a fundamental particle/lepton is fundamental particle
or
hadron made of quarks/lepton not made of quarks
or
strong force/interaction acts on hadrons/does not act on leptons B1 [1]

(b) **(i)** ${}^{0}_{1}e^{(+)}$ or ${}^{0}_{1}\beta^{(+)}$ B1

${}^{0}_{0}\nu_{(e)}$ B1 [2]

(ii) weak (nuclear force / interaction) B1 [1]

(iii)
- mass-energy
- momentum
- proton number
- nucleon number
- charge

Any three of the above quantities, 1 mark each B3 [3]

(c) (quark structure of proton is) up, up, down or uud B1

up/u (quark charge) is (+)⅔(*e*), down/d (quark charge) is –⅓(*e*) C1

⅔*e* + ⅔*e* – ⅓*e* = (+)*e* A1 [3]

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289. 9702_w16_qp_23 Q: 7

(a) hadron not a fundamental particle/lepton is fundamental particle
or
hadron made of quarks/lepton not made of quarks
or
strong force/interaction acts on hadrons/does not act on leptons B1 [1]

(b) **(i)** proton: up, up, down / uud B1
neutron: up, down, down / udd B1 [2]

(ii) composition: 2(uud) + 2(udd)
= 6 up, 6 down / 6u, 6d B1 [1]

(c) **(i)** most of the atom is empty space
or
the nucleus (volume) is (very) small compared to the atom B1 [1]

(ii) nucleus is (positively) charged B1

the mass is concentrated in (very small) nucleus/small region/small volume/small core
or
the majority of mass in (very small) nucleus/small region/small volume/small core B1 [2]
