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PHYSICS **9792/03**

Paper 3 Written Paper **May/June 2016**

MARK SCHEME

Maximum Mark: 140

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SECTION A

1 (a) (i) circumference = 40 000 000 m so radius = $4 \times 10^7/2\pi = 6.366 \times 10^6$ (m) [1] [1]

(ii) difference = $(6.366 - 6.357) \times 10^6$ (0.009×10^6) [1]
% error = 900/6357 = 0.14(%) [1] [2]

(b) (i) 1 day = $24 \times 60 \times 60$ s = 86 400 (s) [1] [1]

(ii) because the Earth rotates from west to east [1]
(if it is not over the equator) it would move N to S to N [1] [2]

(c) (i) $E_p = -6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 95/4.23 \times 10^7 = -9.0 \times 10^8$ J [1] [1]

(ii) **1.** speed = $2\pi \times 4.23 \times 10^7/86\,400 = 3076$ m s^{-1} [1]
k.e. = $½ \times 95 \times 3076^2 = (4.5 \times 10^8)$ (J) [1]
2. numerical value of p.e. is twice that of k.e. **and** has a negative sign [1] [3]

(iii) second row correct [1]
top row correct [1]
third row as a tenth of top row [1]
fourth row all zero [1] [4]

radius of orbit	gravitational p.e. / J $\times 10^8$	kinetic energy / J $\times 10^8$	total energy / J $\times 10^8$
geostationary	**–9.0**	**+ 4.5**	**–4.5**
2*R*	**–4.5**	+2.25	–2.25
10*R*	**–0.90**	**0.45**	**–0.45**
infinity	**0**	**0**	**0**

(iv) it would be travelling slowly **or** [1]
would take too long to get to Mars OR it stops before it gets there
it would need to gain extra p.e. to get further from the Sun **or** [1] [2]
at Mars its k.e. is zero

[16]

2 (a) (i) clear resonance peak on graph marked A and peak at f_o [1]
start at driver amplitude and peak at f_o [1] [2]

(ii) always beneath the first graph [1]
peak lower and to the left of resonant frequency [1] [2]

	(b)		when the oscillation is very fast there is little time for large movement and the energy supplied from the driver (per unit time) will be small	[1] [1]	 [2]
	(c)	**(i)**	$L = 8.6 \times 10^{-6}$ $C = 1/4\pi^2 f^2 L = 1/4\pi^2 \times (5.2 \times 10^6)^2 \times 8.6 \times 10^{-6} =$ 1.09×10^{-10} (F)	[1] [1] [1]	 [3]
		(ii)	$\lambda = c/f = 3.00 \times 10^8/f = 3.00 \times 10^8/5.2 \times 10^6 = 57.7$ (m)	[1]	[1]
					[10]
3	**(a)**	**(i)**	a region within which a charge experiences a force	[1]	[1]
		(ii)	force on charge q in field F = Eq work done in moving charge a distance d = Eqd p.d. = work done per unit charge = Eqd/q = Ed. So E = p.d.	 [1] [1]	 [2]
	(b)	**(i)**	2 vertical and 1 horizontal to the left at least two other lines meeting the cylinder at right angles (must reach the surface) at least three lines spreading out through the open end and diverging symmetrical top and bottom	[1] [1] [1] [1]	 [4]
		(ii)	lines egg-shaped and at right angles to field lines ¼, ½ and ¾ positions (approximately) correct and labelled	[1] [1]	 [2]
	(c)	**(i)**	$E = Q/4\pi\varepsilon_0 r^2$ $= 7.2 \times 10^{-8}/4\pi \times 8.385 \times 10^{-12} \times 2.8^2 = 82.6$ (N C^{-1}) **or** 28 (N C^{-1})	[1] [1]	 [2]
		(ii)	because of the earthed shield the field outside is less than the field would would be without the earth connection	[1]	[1]
					[12]
4	**(a)**		diagram / arrangement with suitable length of cord firmly fixed at one end measurement of initial length and use of suitable apparatus for diameter application of load and measurement of extension theory given any valid additional detail	[1] [1] [1] [1] [1]	 [5]

(b) diagram or replaced with corresponding words [1]
way of increasing load to cause large extension [1]
way of determining the maximum extension before it breaks [1]
method for calculating the maximum energy stored [1] [4]

[9]

5 (a) (i) (900 – 300)/900 = 0.667 / 66.7(%) [1] [1]

(ii) takes low temperature in the region of 300 K [1]
giving diesel engines (maximum) efficiency around 1200/1500 = 80%
petrol engines (maximum) efficiency around 950/1250 = 76% [1] [2]

(iii) T_1 temperature must not melt the metal [1]
T_2 minimum temperature: e.g. temperature of surroundings [1] [2]

(b) (i) 1. the gas is back to its original state **or** internal energy at start the same as at the end [1]
so the temperature is the same at the start and finish [1]
2. the gas is at the same temperature throughout the change [1]
3. the gas is expanding and work is being done by the gas [1] [4]

(ii) first row correct [1]
second row correct [1]
third row correct [1]
fourth row correct [1] [4]

stage	heat energy supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
1	**–702**	+702	0
2	**0**	+844	+844
3	**+936**	–936	**0**
4	0	**–844**	**–844**

(iii) efficiency = net work done/energy input [1]
= (936 – 702)/936 = 234/936 = 0.25 / 25 (%) [1] [2]

[15]

6	**(a)**		rising from zero at 0 to a peak then falling away	[1]	[1]
	(b)	**(i)**	λ_{max} T = 520 × 5800 = 210 × T so T = 14 400 (K)	[1]	[1]
		(ii)	luminosity = area × s × T^4 = 6.3 × 10^{17} × 5.67 × 10^{-8} × 14 400^4	[1]	
			= 1.5 × 10^{27} (W) with estimate only to 1, 2 or 3 significant figures	[1]	[2]
		(iii)	1.5359 × 10^{27}/4πR^2 = 1.6 × 10^{-9} W m^{-2}	[1]	
			R = √(1.5359 × 10^{27}/4π × 1.6 × 10^{-9}) = 2.75 × 10^{17} (m)	[1]	[2]
					[6]

7	**(a)**	**(i)**	${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\alpha$	[1]	[1]
		(ii)	correct beta particle	[1]	
			equation correct	[1]	[2]
			${}^{234}_{90}\mathrm{Th} \rightarrow {}^{234}_{91}\mathrm{Pa} + {}^{0}_{-1}\beta$		
	(b)		4 alpha decays reduce nucleon number to 222	[1]	
			so two beta decays are required to get to proton number 86	[1]	[2]
	(c)	**(i)**	5.48 MeV = 5.48 × 10^6 × 1.60 × 10^{-19} **or** 8.77 × 10^{-13} (J)	[1]	
			(m = E/c^2 =) 8.77 × 10^{-13}/(3.00 × 10^8)^2 **or** 9.74 × 10^{-30} (kg)	[1]	
			(1 u = 1.66 × 10^{-27}), (m =) 9.74 × 10^{-30} kg/1.66 × 10^{-27}) = 5.87 × 10^{-3} (u)	[1]	[3]
		(ii)	(λ = ln 2/t½ =) ln 2/3.83 = 0.181	[1]	
			(A/A_0 = $e^{-\lambda t}$ =) $e^{-(0.181 \times 20)}$ = 0.0268	[1]	[2]
	(d)		use of some barrier to stop radon entry existing house or during construction **or** using polythene film at top of foundations **or** under ground floor carpets	[1]	
			use an air pump in space (under floor) to drive out contaminated air	[1]	[2]
					[12]

SECTION B

8	**(a)**		2.8 joules of work done per coulomb of charge in conversion into electrical energy from chemical energy	[1] [1]	 [2]
	(b)	**(i)**	$E = I(R_F + R + r)$	[1]	[1]
		(ii)	(I = 1.63/180 = 9.06 mA; R_F = 0.45/0.00906 =) 49.7 (Ω) (p.d. across r) = 2.80 – 1.63 – 0.45 V OR 0.72 V (r = 0.72/0.00906) = 79.5(Ω)	[1] [1] [1]	 [3]
		(iii)	gradient = E intercept = –(Rf + r)	[1] [1]	 [2]
	(c)	**(i)**	Q = CV = It $I = 4.2 \times 10^{-6} \times 2.8/0.001 = 0.0118$ (A)	[1] [1]	 [2]
		(ii)	$5900/(60 \times 18.2 \times 10^{-6} \times (365 \times 24 \times 60)) = 10.3$ (year)	[1]	[1]
	(d)	**(i)**	differentiation done correctly **or** integration of expression	[1]	[1]
		(ii)	substituting $V_o/2$ to get $\ln 2 = t/CR$ $t_{½}$ = 0.693 CR/ln 2CR	[1] [1]	 [2]
		(iii)	**1.** obtain $t_{½}$ 0.46 ms R (= $0.46 \times 10^{-3}/0.693 \times 4.4 \times 10^{-6}$) = 150.8 ($\Omega$) **2.** energy = $18.2 \times 10^{-6} = ½ \times 4.4 \times 10^{-6} \times V^2$ V_0 = 2.8 V, and at end V = 0.28 V V/V0 = 0.1 = exp –(t/CR) **or** ln 0.1 = –t/CR = –2.30 (t = $2.30 \times 4.4 \times 10^{-6} \times 150.8$ =) 1.53×10^{-3} (s)	[1] [1] [1] [1] [1] [1]	 [6]
					[20]
9	**(a)**	**(i)**	v = 2πr/T, (= 2π × 6.2/4.1) = 9.5 (m s^{-1})(9.50)	[1] [1]	 [2]
		(ii)	acceleration = v^2/r (= $9.50^2/6.2$) = 14.6 (m s^{-2})	[1] [1]	 [2]
	(b)	**(i)**	mg unaltered (beyond arms but not beyond bottom of cage) $mv^2/r > mg$ contact force downward smaller than weight	[1] [1]	 [2]
		(ii)	$R + mg = ma$ $R = m(a - g)$ = 75(14.6 – 9.81) = 360 (N)	[1] [1]	 [2]

	(c)	**(i)**	his weight can give him an acceleration up to g	[1]	
			so acceleration must be larger than g for a contact force to be required	[1]	[2]
		(ii)	minimum speed when $v^2/r = g$	[1]	
			$v^2/6.2 = 9.81$	[1]	
			$v = 7.8\,(\mathrm{m\,s^{-1}})$	[1]	[3]
	(d)		recall $I = \Sigma\, mr^2$	[1]	
			torque = $I\alpha$	[1]	
			increased mass makes I larger	[1]	
			with larger inertia and same torque angular acceleration decreases	[1]	[4]
	(e)		$h = 4\pi^2 I/mg\,T^2$	[1]	
			correct substitution	[1]	
			$h = 4.48\,(\mathrm{m})$	[1]	[3]
					[20]
10	**(a)**	**(i)**	planets move in elliptical orbits with the Sun at one focus	[1]	
			line joining a planet to the Sun sweeps out equal areas in equal times	[1]	[2]
		(ii)	**1.** $F = m \times r\omega^2 = mr(2\pi/T)^2$ and $F = GMm/r^2$	[1]	
			rearrange to get $T^2 \propto r^3$	[1]	
			2. attempts to take logs of expression in **(a)(ii)1.** to get		
			$\ln T = ½ \ln(4\pi^2/GM) + 1½ \ln r$	[1]	
			intercept $½ \ln(4\pi^2/GM)$	[1]	
			gradient is 3/2	[1]	[5]
	(b)	**(i)**	all points ±½ small square	[1]	
			best fit straight line to be accurate	[1]	[2]
		(ii)	**1.** coordinates quoted from graph (not table of values)	[1]	
			evidence of calculation from values. range 1.48 – 1.53	[1]	
			2. (it is a straight line) of gradient 3/2	[1]	[3]
		(iii)	$\ln 153 = 5.03$		
			$\ln r = 12.77$ $r = 350\,000\,(\mathrm{km})$	[1]	[1]
		(iv)	Use of equation from **(a)(ii)** with km changed to m and hr to s	[1]	
			$M = \dfrac{4\pi^2 r^3}{GT^2} = \dfrac{4\pi^2(5.82\times10^8)^3}{6.67\times10^{-11}\times(323\times60\times60)^2} = 8.63\times10^{25}\,\mathrm{kg}$		
			reorganised to get mass and correct substitution	[1]	
			$M = 8.63 \times 10^{25}\,\mathrm{kg}$	[1]	[3]

	(c)	any **two** similarities from: both have radial and uniform field patterns both are conservative both have a potential forces between point masses/charges obey an inverse square law	[2]	
		any **two** differences from: gravitational fields act on mass but electric fields act on charge electric fields can be screened but gravitational fields cannot be screened force of attraction only for gravitational field but attraction and repulsion in electric fields	[2]	[4]
				[20]
11	(a)	diagram should be labelled and show any **four** points from: electron source with filter of some kind to reduce the intensity of the electron beam (compulsory) experiment carried out in a vacuum double slit drawn or labelled method of detection – e.g. ccd screen in an appropriate configuration	[4]	[4]
	(b)	any **one** point from: *particle:* electrons arrive discretely; each electron registers as a single point on the screen electrons are not 'smeared out' on the screen	[1]	
		any **one** point from: *wave:* pattern of regular maxima and minima characteristic of an interference pattern identical pattern to Young's double slit experiment	[1]	[2]
	(c) (i)	any **one** point from: velocities must be the same (or in a very small range) velocity such that wavelength comparable to slit separation	[1]	
		any **two** points from: significance of regular spacing in pattern velocity affects wavelength of electrons (de Broglie relation) different velocities would affect fringe spacing velocities too high or too low would not give pattern	[2]	[3]

		(ii)	any **four** points from: idea of electron waves / wave function fringe spacing depends on wavelength or velocity/momentum of electrons electron waves each slit interfere to form 2 slit interference pattern wave intensity is proportional to probability of electron arrival maxima have high arrival probability – and / or reverse wave function collapses at screen so individual electrons are detected as pattern builds gradually	[4]	[4]
	(d)		any **three** points from: each electron explores all paths from source to screen (quantum theory is indeterministic) so the same initial conditions do not necessarily lead to the same outcomes idea that phasors from different paths add up at screen each possible path contributes to the probability of the electron arriving at a particular point phasor as rotating vector probability of arrival linked to amplitude squared each electron has a probability of arriving anywhere on the screen (where probability is > 0) the chance of successive electrons ending up at same point is near zero	[3]	[3]
	(e)		predict outcome /future given initial values / determined by past and present		[2]
	(f)		any **two** points from: if two electrons enter the apparatus under the same initial conditions are likely to end up at different places on the screen knowing the initial conditions of an electron does not enable predictions of its outcome	[2]	[2]
					[20]
12	(a)	(i)	any **two** points from: particles are very close together / gas occupies a very small volume so particle volumes cannot be neglected inter-particle forces cannot be neglected	[2]	[2]
		(ii)	any **two** points from: particles have (very) large kinetic energy collisions might not be elastic ionisation might occur (change of state to plasma) there might be relatavistic effects time for collision approximately the time between collisions	[2]	[2]

(iii) any **two** points from:
particles have (very) low kinetic energy
gas might change state to a liquid
inter-particle forces cannot be neglected
p.e. due to inter-particle forces might be comparable with or exceed k.e.
quantum effects might be significant
volume becomes very small but cannot be zero [2] [2]

(b) (i) any **two** points from:
if speed of light is measured (relative to absolute space) it would be different for differently moving observers
however, speed of light is an invariant /has the same value for all observers
or
it would not have the same velocity relative to all inertial observers
explanation of expected shift in relative motion (c ± v) for expt. [2] [2]

(ii) any **two** points from:
calculation to show that gamma is about 1 for everyday velocities
velocities in everyday life are <<c
relativistic time differences are negligible in everyday life
[2] [2]

(c) (i) any **two** points from:
dependence of threshold on frequency and not on amplitude / intensity
dependence of max. k.e. on frequency not amplitude / intensity
instantaneous emission of electrons / no time delay
randomness of emission [2] [2]

(ii) any **two** points from:
intensity at minimum
intensity at maximum 4× intensity from one slit, not double
pattern of maxima and minima
destructive / constructive interference [2] [2]

(d) (i) both correct = 3 marks
one correct = 2 marks
correct method but wrong answer = 1 mark [3] [3]

1. de Broglie wavelength of Moon is about $h/mv = 9.5 \times 10^{-60}$ m
2. de Broglie wavelength of orbiting electron is about $h/mv = 3.7 \times 10^{-11}$ m

(ii) any **three** points from:
9.5×10^{-60} m << radius of orbit
insignificant
3.7×10^{-11} m comparable with radius of orbit
and therefore significant [3] [3]
must make comparison and draw conclusion for full marks

[20]

13 (a) any **three** points from:
no heat can flow into or out of the system
if the system was open then heat flow out of the system could reduce the system's entropy and violate the 2nd law
no matter flow in / no matter flow out of system
if the number of particles decreases then so does the number of ways
entropy decrease (is a violation of the second law) [3] [3]

(b) any **two** points from:
no external resultant forces / only forces are internal to the system
external resultant force would change the momentum of the system (and so violate the law of conservation of momentum
idea of F = d(mv)/dt where F is the external resultant force [2] [2]

(c) (i) any **two** points from:
living things increase order and complexity as they grow (e.g. seed to tree)
the entropy of a living thing (viewed in isolation) can decrease
the number of ways for a fully grown organism is greater than for the materials from which it grew [2] [2]

(ii) any **three** points from:
living things are not closed systems
they exchange energy or matter with their surroundings, (either to or from)
every process inside a living thing obeys the 2nd law
living things increase the entropy of their surroundings
(net) increase of the entropy of the universe or their surroundings
metabolic processes generate and dissipate heat [3] [3]

(d) (i) any **three** points from:
entropy is related to the number of ways in which energy / particles can be distributed among the various states within a system
removing heat reduces the amount of energy to be distributed
and so reduces the number of distinct microscopic configurations (ways in which energy and particles can be arranged) of the system [3] [3]

(ii) any **three** points from:
the refrigerator must compensate for this reduction in entropy by increasing the entropy of its surroundings
the increase in the entropy of the surroundings must be greater than the decrease in entropy of the object
(electrical) energy must be supplied to the refrigerator **or**
the refrigerator must generate heat which is dumped in the surroundings
heat which is dumped in the surroundings [3] [3]

(e) any **two** points from:
past – must have been a low probability configuration
past – a state achievable in a relatively small number of ways
future – must be a higher entropy than the past
there will be less energy available to do useful work in the future than the past
future will evolve towards an equilibrium state
the universe is heading towards a 'heat' death
there is an arrow of time that distinguishes the past from the future
extreme end point – no more energy available to do useful work [2] [2]

(f) any **two** points from, but at least one must relate to the second law:
energy dense fuels are running out – not energy
energy becomes disordered in the atmosphere
when fuels are burnt entropy increases/ number of ways of distributing energy increases
concentrating dispersed energy would decrease entropy (violate the second law)
[2] [2]

[20]