

CAMBRIDGE INTERNATIONAL EXAMINATIONS

Cambridge International Advanced Subsidiary and Advanced Level

MARK SCHEME for the October/November 2015 series

9702 PHYSICS

9702/41

Paper 4 (A2 Structured Questions), maximum raw mark 100

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Section A

- 1 (a) (i) gravitational force provides/is the centripetal force B1
- $$GMm_S/x^2 = m_S v^2/x \text{ (allow } x \text{ or } r; \text{ allow } m \text{ or } m_S)$$
- M1
- $$E_K = \frac{1}{2}m_S v^2 \text{ and clear algebra leading to } E_K = GMm_S/2x$$
- A1 [3]
- (ii) $E_P = -GMm_S/x$ (sign essential) B1 [1]
- (iii) $E_T = E_K + E_P$
 $= GMm_S/2x - GMm_S/x$ C1
 $= -GMm_S/2x$ (allow ECF from (a)(ii)) A1 [2]
- (b) (i) decreases B1 [1]
- (ii) decreases B1 [1]
- (iii) decreases B1 [1]
- (iv) increases B1 [1]
- (for answers in (b) allow ECF from (a)(iii))
- 2 (a) obeys the equation $pV = nRT$ or $pV/T = \text{constant}$ M1
all symbols explained; T in kelvin/thermodynamic temperature A1 [2]
- (b) (i) temperature rise = 48 K A1 [1]
- (ii) $\langle c^2 \rangle \propto T$ or equivalent C1
 $\langle c^2 \rangle = (353/305) \times 1.9 \times 10^6$ C1
 $c_{r.m.s.} = 1480 \text{ m s}^{-1}$ A1 [3]
- 3 (a) heat/thermal energy gained by system or energy transferred to system by heating B1
plus work done on the system or minus work done by the system B1 [2]
- (b) (i) either volume decreases so work done on the system M1
or small volume change so work done on system negligible M1
(thermal) energy absorbed to break lattice structure A1 [3]
internal energy increases
- (ii) gas expands so work done by gas (against atmosphere) M1
no time for thermal energy to enter or leave the gas M1
internal energy decreases A1 [3]
- 4 (a) free: (body oscillates) without any loss of energy/no resistive forces/no external forces applied B1
forced: continuous energy input (required)/body is made to vibrate by an (external) periodic force/driving oscillator B1 [2]

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	(b) (i) idea of resonance maximum amplitude at natural frequency frequency = 2.1 Hz (<i>allow 2.08 to 2.12 Hz</i>)	B1 B1 B1	[3]
	(ii) peak not very sharp/amplitude not infinite so frictional forces are present	B1	[1]
	(c) $v = \omega x_0$ $= 2\pi \times 2.1 \times 4.7 \times 10^{-2}$ (<i>allow ECF from (b)(i)</i>) $= 0.62 \text{ m s}^{-1}$	C1 A1	[2]
5	(a) (i) force proportional to the product of the two/point charges and inversely proportional to the square of their separation	B1 B1	[2]
	(ii) 1. force radially away from sphere/to right/to east	B1	[1]
	2. (maximum) at/on surface of sphere or $x = r$	B1	[1]
	3. $F \propto 1/x^2$ or $F = q_1 q_2 / (4\pi \epsilon_0 x^2)$	C1	
	ratio = 16	A1	[2]
	(b) $E = q / (4\pi \epsilon_0 x^2)$ or $E \propto q$	C1	
	maximum charge = $(2.0 / 1.5) \times 6.0 \times 10^{-7}$ $= 8.0 \times 10^{-7} \text{ C}$	C1	
	additional charge = $2.0 \times 10^{-7} \text{ C}$	A1	[3]
6	(a) (i) force = mg along the direction of the field/of the motion	M1 A1	[2]
	(ii) no force	B1	[1]
	(b) (i) force due to E -field downwards so force due to B -field upwards into the plane of the paper	B1 B1	[2]
	(ii) force due to magnetic field = Bqv force due to electric field = Eq (<i>use of F_B and F_E not explained, allow 1/2</i>)	B1 B1	
	forces are equal (and opposite) so $Bv = E$ or $Eq = Bqv$ so $E = Bv$	B1	[3]
	(c) sketch: smooth curved path in 'upward' direction	M1 A1	[2]
7	(a) minimum frequency of e.m. radiation/a photon (not "light") for emission of electrons from a surface (<i>reference to light/UV rather than e.m. radiation, allow 1/2</i>)	M1 A1	[2]

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- (b) E_{MAX} corresponds to electron emitted from surface
electron (below surface) requires energy to bring it to surface, so less than E_{MAX} B1 [2]
- (c) (i) $1/\lambda_0 = 1.85 \times 10^6$ (allow 1.82 to 1.88) C1
- $$f_0 = c/\lambda_0$$
- $$= 3.00 \times 10^8 \times 1.85 \times 10^6$$
- $$= 5.55 \times 10^{14} \text{ Hz}$$
- A1 [2]
- (ii) $\Phi = hf_0$
 $= 6.63 \times 10^{-34} \times 5.55 \times 10^{14}$ (allow ECF from (c)(i)) C1
 $= 3.68 \times 10^{-19} \text{ J}$ A1 [2]
- (d) sketch: straight line with same gradient
intercept between 1.0 and 1.5 M1
A1 [2]
- 8 (a) nucleus: small central part/core of an atom B1
nucleon: proton or a neutron B1
particle contained within a nucleus B1 [3]
- (b) (i) 1. decay constant $= \ln 2 / (3.8 \times 24 \times 3600)$ C1
 $= 2.1 \times 10^{-6} \text{ s}^{-1}$ A1 [2]
2. $A = \lambda N$
 $97 = 2.1 \times 10^{-6} \times N$ C1
 $N = 4.6 \times 10^7$ A1 [2]
- (ii) 1.0 m^3 contains $(6.02 \times 10^{23}) / (2.5 \times 10^{-2})$ air molecules C1
- ratio $= (4.6 \times 10^7 \times 2.5 \times 10^{-2}) / (6.02 \times 10^{23})$
 $= 1.9 \times 10^{-18}$ A1 [2]

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Section B

- 9 (a) (i)** (+) 3.0 V B1 [1]
- (ii)** potential = $6.0 \times \{2.0 / (2.0 + 2.8)\}$
= 2.5 V C1
A1 [2]
- (iii)** potential = $6.0 \times \{2.0 / (2.0 + 1.8)\}$
= 3.2 V A1 [1]
- (b)** at 10 °C, $V_A > V_B$ M1
 V_{OUT} is –9.0 V (allow “negative saturation”) A1
- at 20 °C, V_{OUT} is +9.0 V B1
(if 20 °C considered initially, mark as M1,A1,B1)
- sudden switch (from –9 V to +9 V) when $V_A = V_B$ B1 [4]
- 10 (a)** sharpness: clarity of edges/resolution (of image) B1
contrast: difference in degree of blackening (of structures) B1 [2]
- (b) (i)** X-rays produced when (high speed) electrons hit target/anode B1
either electrons have been accelerated through 80 kV
or electrons have (kinetic) energy of 80 keV B1 [2]
- (ii)** $I_T / I = e^{-3.0 \times 1.4}$ C1
= 0.015 A1 [2]
- (c)** for good contrast, μ_X or e^{μ_X} or $e^{-\mu_X}$ must be very different B1
 μ_X or e^{μ_X} or $e^{-\mu_X}$ for bone and muscle will be different than that for muscle M1
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- 11 (a)** frequency of carrier wave varies M1
in synchrony with the displacement of the signal/information wave A1 [2]
- (b) (i)** 5.0 V A1 [1]
- (ii)** 720 kHz A1 [1]
- (iii)** 780 kHz A1 [1]
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- 12 (a) (i)** (gradual) loss of power/intensity/amplitude (not “signal”) B1 [1]
- (ii)** e.g. noise can be eliminated (not “there is no noise”) M1
because pulses can be regenerated A1
- e.g. much greater data handling/carrying capacity M1
because many messages can be carried at the same time/greater bandwidth A1
- e.g. more secure (M1)
because it can be encrypted (A1)
- e.g. error checking (M1)
because extra information/parity bit can be added (A1) [4]
- (allow any two sensible suggestions with ‘state’ M1 and ‘explain’ A1)*
- (b)** attenuation = $10 \lg(145/29)$ (= 7.0) C1
- attenuation per unit length = $7.0/36$
= 0.19 dB km^{-1} A1 [2]

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- 1 (a) (gravitational) force proportional to product of masses
and inversely proportional to square of separation
either point masses *or* particles *or* 'size' $\ll$ separation
M1
A1 [2]
- (b) gravitational force provides the centripetal force
B1
either $GMm/x^2 = mx\omega^2$ *or* mv^2/x
M1
either $\omega = 2\pi/T$ *or* $v = 2\pi x/T$ and working to $GM = 4\pi^2 x^3/T^2$
A1 [3]
- (c) *either* use of gradient of graph *or* line through origin so can use single point
or line shown extrapolated to origin
B1
gradient = $(4.5 \times 10^{14})/0.35$
 $6.67 \times 10^{-11} \times M = 4\pi^2 \times (4.5 \times 10^{14} \times 10^9)/(0.35 \times \{24 \times 3600\}^2)$
correct conversion for km^3 and power of 10
C1
correct conversion for day^2
C1
 $M = 1.02 \times 10^{26} \text{ kg}$
A1 [4]
- 2 (a) total volume of molecules negligible compared to that of containing vessel
no intermolecular forces
molecules in random motion
time of collision small compared with the time between collisions
large number of molecules
any two
B2 [2]
- (b) in a real gas there is a range of velocities *or* must take the average of v^2
B1 [1]
- (c) (i) *either* $p = \frac{1}{3} \rho \langle c^2 \rangle$
or $1.0 \times 10^5 = \frac{1}{3} \times 1.2 \times \langle c^2 \rangle$
C1
 $\langle c^2 \rangle = 2.5 \times 10^5$
 $c_{\text{r.m.s.}} = 500 \text{ m s}^{-1}$
C1
A1 [3]
- (ii) $T \propto \langle c^2 \rangle$
 $\langle c^2 \rangle = 2.5 \times 10^5 \times 480/300$
 $= 4.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$ (*allow ECF from (c)(i)*)
C1
A1 [2]
- 3 (a) same temperature
no (net) transfer of thermal energy (between the bodies)
B1
B1 [2]
- (b) (i) 41.3 K
B1 [1]
- (ii) 330.4 K
B1 [1]

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$$\begin{aligned} \text{(c)} \quad \Delta E_k &= \frac{3}{2} \times 1.9 \times 60 \\ &= 171 \text{ J} \end{aligned}$$

C1

$$\begin{aligned} \text{work done} &= p\Delta V \\ &= 1.2 \times 10^5 \times 950 \times 10^{-6} \\ &= 114 \text{ J} \end{aligned}$$

C1

C1

$$\begin{aligned} \text{thermal energy} &= 114 + 171 \\ &= 285 \text{ (290) J} \end{aligned}$$

A1 [4]

- 4 (a) acceleration/force proportional to distance from a fixed point or displacement

M1

either acceleration/force and displacement in opposite directions
or acceleration/force (always) directed towards a fixed point/mean position/equilibrium position

A1 [2]

$$\begin{aligned} \text{(b)} \quad h\rho g &= Mg/A \\ h \times 790 \times 4.9 \times 10^{-4} &= 70 \times 10^{-3} \text{ leading to } h = 0.18 \text{ m or } 18 \text{ cm} \end{aligned}$$

B1

A1 [2]

$$\begin{aligned} \text{(c) (i) 1.} \quad \omega^2 &= (790 \times 4.9 \times 10^{-4} \times 9.81) / (70 \times 10^{-3}) \\ &= 54.25 \end{aligned}$$

C1

$$\begin{aligned} \omega &= 7.37 \text{ (rad s}^{-1}\text{)} \\ \text{period } (= 2\pi / \omega) &= 0.85 \text{ s} \end{aligned}$$

C1

$$t_1 = 0.43 \text{ s}$$

A1 [3]

$$\text{2. } t_3 = 1.28 \text{ s (allow 2 s.f.)}$$

A1 [1]

$$\text{(ii) energy of peak} = \frac{1}{2} M \omega^2 x_0^2$$

B1

$$\begin{aligned} \text{change} &= \frac{1}{2} \times 70 \times 10^{-3} \times 54.25 \{ (2.2 \times 10^{-2})^2 - (1.0 \times 10^{-2})^2 \} \\ &= 7.3 \times 10^{-4} \text{ J} \end{aligned}$$

C1

A1 [3]

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- 5 (a) charges in metal do not move B1
no (resultant) force on charges so no (electric) field B1 [2]
(allow 1/2 for “no field inside sphere”)
- (b) either average field strength = $\frac{1}{2} (28 + 54) \text{ NC}^{-1}$ C1
average force = $8.5 \times 10^{-9} \times \frac{1}{2} (28 + 54)$ C1
= $3.49 \times 10^{-7} \text{ N}$
change in potential energy = $3.49 \times 10^{-7} \times 2.0 \times 10^{-2}$
= $7.0 \times 10^{-9} \text{ J}$ (allow 1 s.f.) A1
(allow range 54 ± 1)
- or (for a point charge) $V = Ex$ (C1)
 $\Delta V = (54 \times 5.0 \times 10^{-2}) - (28 \times 7.0 \times 10^{-2})$ (C1)
change in potential energy = $8.5 \times 10^{-9} \times (2.70 - 1.96)$
= $6.3 \times 10^{-9} \text{ J}$ (allow 1 s.f.) (A1)
(allow range 54 ± 1)
- or ΔV is area under curve (C1)
 $\Delta V = 0.74 \text{ V}$ (C1)
change in potential energy = $8.5 \times 10^{-9} \times 0.74$
= $6.3 \times 10^{-9} \text{ J}$ (allow 1 s.f.) (A1) [3]
(allow range 0.70 to 0.84)
- 6 (a) magnetic fields are equal in magnitude/strength/flux density M1
magnetic fields are opposite in direction M1
fields superpose/add/cancel to give zero/negligible resultant field A1 [3]
- (b) core causes increase in magnetic flux in the solenoid/induced poles in core B1
or field induced in core M1
changing flux threads/cuts the turns on the solenoid A1
(by Faraday’s law) an e.m.f. is induced in the solenoid A1 [4]
by Lenz’s law, this e.m.f. opposes the battery e.m.f.
- 7 (a) (i) $V_0 (= 14\sqrt{2}) = 19.8 (20) \text{ V}$ A1 [1]
(ii) $\omega (= 2\pi \times 750) = 4700 \text{ rad s}^{-1}$ A1 [1]
- (b) large amount of charge required to charge capacitor M1
capacitor would charge and discharge rapidly/in a very short time M1
or capacitor would charge and discharge 750/1500 times per second
 $I = Q/t$, so large current A1 [3]

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- 8 (a) $hc/\lambda = \Phi + E_{\text{MAX}}$ M1
 h = Planck constant, c = speed of light/e.m. radiation A1 [2]
- (b) (i) gradient of line is hc M1
 h and c are both constants A1 [2]
- (ii) $\Phi = 2.28 \times 1.6 \times 10^{-19}$ C1
 $= 3.65 \times 10^{-19} \text{ (J)}$
- $hc/\lambda_0 = 3.65 \times 10^{-19}$
- $\lambda_0 = (6.63 \times 10^{-34} \times 3.0 \times 10^8)/(3.65 \times 10^{-19})$ C1
 $= 5.45 \times 10^{-7} \text{ m}$ A1 [3]
- 9 (a) energy required to separate the nucleons (in a nucleus) M1
or energy required to separate the protons and neutrons in a nucleus
(or energy released when nucleons combine (to form a nucleus)/energy released
when protons and neutrons combine to form a nucleus)
- either completely or to infinity A1 [2]
(either free protons and neutrons or from infinity)
- (b) (i) either different forms of same element or nuclei having same number of M1
protons with different numbers of neutrons A1 [2]
- (ii) 1784 MeV (accept min. 3 s.f.) A1
7.57 MeV A1 [2]
- (c) (i) $\lambda = \ln 2/(7.1 \times 10^8 \times 365 \times 24 \times 3600) = 3.1 \times 10^{-17} \text{ s}^{-1}$ B1 [1]
- (ii) $A = \lambda N$
 $5000 = 3.1 \times 10^{-17} \times N$ C1
 $N = 1.61 \times 10^{20}$
- mass = $235 \times (1.61 \times 10^{20})/(6.02 \times 10^{23})$ C1
= 0.063 g (accept min. 2 s.f.) A1 [3]

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Section B

- 10 (a)** correct LED symbol B1
separately connected between V_{OUT} and earth with opposite polarities M1
diode B 'pointing' from V_{OUT} to earth A1 [3]
(ignore protective resistors)
- (b)** diode in V_{OUT} line M1
diode 'pointing' towards V_{OUT} from earth A1
relay coil connected between V_{OUT} and earth M1
switch connected across lamp A1 [4]
(if a diode is placed across the relay it must point down otherwise max. 2/4;
one diode but wrong direction max. 3/4)
- 11 (a)** e.g. scattering (in metal)
non-parallel beam (not just "A closer than B")
reflection (from metal)
diffraction in the metal/lattice
any two B2 [2]
- (b) (i)** 1. ratio = $e^{\mu x}$
= $\exp(0.27 \times 4.0)$ C1
= 2.94 (2.9) A1 [2]
2. ratio = $\exp(0.27 \times 2.5) \times \exp(3.0 \times 1.5)$ C1
= 1.96×90
= 177 (180) A1 [2]
- (do not penalise unit error more than once)
- (ii)** each ratio gives measure of transmission B1
ratios (in **(i)**) very different so good contrast B1 [2]
- 12 (a) (i)** serial-to-parallel converter B1 [1]
- (ii)** digital-to-analogue converter or DAC B1 [1]
- (iii)** (audio) amplifier or AF amplifier B1 [1]
- (b) (i)** 4 A1 [1]
- (ii)** 1011 A1 [1]
- (c)** correct levels at 0.25 ms intervals
0, 8, 11, 10, 15 A1
and 7, 4 A1
series of steps, each of depth 0.25 ms M1
voltage levels shown in correct intervals A1 [4]

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- 13 (a) advantage: e.g. shorter time delay
greater coverage over a long time B1
- disadvantage: e.g. satellite needs to be tracked
more satellites for (continuous) coverage/communication
(any sensible suggestions) B1 [2]
- (b) (i) frequencies linking Earth with satellite B1
- 6 GHz is uplink frequency }
4 GHz is downlink frequency } (allow vice versa) B1 [2]
- (ii) either signal from Earth to satellite is attenuated greatly
or downlink must be amplified greatly before transmission B1
- downlink would swamp uplink unless frequencies are different B1 [2]