

CAMBRIDGE INTERNATIONAL EXAMINATIONS

Cambridge International Advanced Subsidiary and Advanced Level

MARK SCHEME for the October/November 2015 series

9702 PHYSICS

9702/21

Paper 2 (AS Structured Questions), maximum raw mark 60

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- 1 (a) temperature B1
current B1 [2]
(allow amount of substance, luminous intensity)
- (b) (i) 1. $E = (\text{stress/strain}) = [\text{force/area}] / [\text{extension/original length}]$
units of stress: $\text{kg m s}^{-2} / \text{m}^2$ and no units for strain B1
units of E : $\text{kg m}^{-1} \text{s}^{-2}$ A0 [1]
2. units for T : s, l : m and M : kg
 $K^2 = T^2 E / M l^3$ hence units: $\text{s}^2 \text{kg m}^{-1} \text{s}^{-2} / \text{kg}^3 (= \text{m}^{-4})$ 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
- $E = (1.6 \pm 0.1) \times 10^{10} \text{ kg m}^{-1} \text{s}^{-2}$ A1 [4]
- 2 (a) $\text{ps} = 10^{-12}(\text{s})$ or $T = 4 \times 50 \times 10^{-12}(\text{s})$ B1
- $v = f\lambda$ or $v = \lambda / T$ C1
- $\lambda = 3.0 \times 10^8 \times 4 \times 50 \times 10^{-12}$ C1
 $= 0.06(0) \text{ m}$ A1 [4]
- (b) $1500 = 3.0 \times 10^8 \times 4 \times \text{time-base setting}$ or $T = 5 \times 10^{-6} \text{ s}$ C1
time-base setting = $1.3 (1.25) \mu\text{s cm}^{-1}$ A1 [2]
- 3 (a) work done is force $\times$ 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]

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(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

$$V_v = 0 + 9.81 \times 1.5$$

$$V_v = (11 \times 2) / 1.5$$

$$= 15 \text{ (14.7) ms}^{-1}$$

A1 [2]

(ii) straight line from (0,0) to (3.00, 25.5)

B1 [1]

(iii) at maximum height $V_h = 25.5/3 (= 8.5 \text{ ms}^{-1})$

B1

$$\text{ratio} = mgh / \frac{1}{2}mv^2$$

C1

$$= (2 \times 9.81 \times 11.0) / (8.5)^2$$

$$= 3.0 \text{ (2.99)}$$

A1 [3]

(iv) deceleration is greater/resultant force (weight and friction force) is greater

M1

time is less

A1 [2]

4 (a) density = mass/volume

C1

$$\text{mass} = 7900 \times 4.5 \times 24 \times 10^{-6} = 0.85 \text{ (0.853) kg}$$

M1 [2]

(b) pressure = force/area

C1

$$\text{force} = W \cos 40^\circ$$

C1

$$\text{pressure} = (0.85 \times 9.81 \cos 40^\circ) / 24 \times 10^{-4}$$

$$= 2.7 \text{ (2.66) } \times 10^3 \text{ Pa}$$

A1 [3]

(c) $F = ma$

C1

$$W \sin 40^\circ - f = ma$$

C1

$$0.85 \times 9.81 \times \sin 40^\circ - f = 0.85 \times 3.8$$

$$f (= 5.36 - 3.23) = 2.1 \text{ N [5.38 - 3.242 if 0.8532 kg is used for the mass]}$$

A1 [3]

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- 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]
- 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. = $(0.36 \times 16) = 5.8$ 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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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

$= 140 \times 10^6 \times 12 \times 10^{-3} = 1.7 \text{ (1.68) MV}$ 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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- 1 (a) $v = f\lambda$ C1
- $\lambda = (3.0 \times 10^8)/(4.6 \times 10^{20})$ C1
- $(= 6.52 \times 10^{-13} =) 0.65(2) \text{ pm}$ A1 [3]
- (b) $t = (8.5 \times 10^{16})/(3.0 \times 10^8)$ C1
- $(= 2.83 \times 10^8 =) 0.28(3) \text{ Gs}$ 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 C1
- e.g. $[14^2 + 8.0^2 - 2(14)(8.0) \cos 60^\circ]^{1/2}$
- or $[(14 - 8.0 \cos 60^\circ)^2 + (8.0 \sin 60^\circ)^2]^{1/2}$
- resultant velocity = $12(.2)$ (or 12.0 to 12.4 from scale diagram) m s^{-1} A1 [2]
- 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 = $(3.6 \times 1.2)/2 =$) 2.2 (2.16) m A1 [1]
- or
- $[0 - (3.6)^2]/[2 \times (-3.0)] = 2.2$ (2.16) m
- or
- $3.6 \times 1.2 - \frac{1}{2} \times 3.0 \times (1.2)^2 = 2.2$ (2.16) m
- or
- $0 + \frac{1}{2} \times 3.0 \times (1.2)^2 = 2.2$ (2.16) m
- (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 $x = 1.68$ (m) (C1)
- $v^2 = 3.6^2 + 2 \times 1.68 \times 3.0 (= 23.04)$ (M1)
- or correct method with intermediate time calculated ($t = 1.6 \text{ s}$ from Q to R)
- $v = 4.8 \text{ m s}^{-1}$ A0 [2]

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- (c) straight line from $v = 3.6 \text{ m s}^{-1}$ 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 $v = -4.8 \text{ m s}^{-1}$ 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]
- 3 (a) (i) $k = F/x$ or $1/\text{gradient}$ C1
 $(k = 4.4 / (5.4 \times 10^{-2}) =) 81 (81.48) \text{ N m}^{-1}$ A1 [2]
- (ii) work done = area under line or $\frac{1}{2}Fx$ or $\frac{1}{2}kx^2$ C1
 $(= 0.5 \times 4.4 \times 5.4 \times 10^{-2} =) 0.12 (0.119) \text{ J}$ 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
 $= 0.25 (0.75 + 1.2) = 0.49 (0.488) \text{ N s}$ A1 [2]
- 4 (a) product of the force and the perpendicular distance to/from a point/pivot B1 [1]
- (b) (i) $4000 \times 2.8 \times \sin 30^\circ$ or $500 \times 1.4 \times \sin 30^\circ$ or $T \times 2.8$
or 4000×1.4 or 500×0.7 B1
 $4000 \times 2.8 \times \sin 30^\circ + 500 \times 1.4 \times \sin 30^\circ = T \times 2.8$ M1
hence $T = 2100 (2125) \text{ N}$ A0 [2]
- (ii) ($T_v = 2100 \cos 60^\circ =$) $1100 (1050) \text{ N}$ 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]

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

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- (c) (i) path difference is λ B1
- water vibrates/oscillates with amplitude about $2 \times 3.2 \text{ mm}$ B1 [2]
- (ii) path difference is $\lambda/2$ so little/no motion/displacement/amplitude B1 [1]

- 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 $>90^\circ$ 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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- 1 (a) energy or W : $\text{kg m}^2 \text{s}^{-2}$
or
power or P : $\text{kg m}^2 \text{s}^{-3}$ M1
- intensity or I : $\text{kg m}^2 \text{s}^{-2} \text{m}^{-2} \text{s}^{-1}$ (from use of energy expression)
or
 $\text{kg m}^2 \text{s}^{-3} \text{m}^{-2}$ (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
- $= 3.1 \times 10^{-11} (\text{W m}^{-2})$ C1
- $= 31 (30.8) \text{ pW m}^{-2}$ A1 [3]
- 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 $(n + \frac{1}{2}) \times 360^\circ$ or $(n + \frac{1}{2}) \times 2\pi$ rad or path difference of $(n + \frac{1}{2})\lambda$ and so
either destructive interference
or displacements cancel/smaller B1 [1]
3. the waves (that overlap) are in phase or have phase difference of $n360^\circ$ 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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- 3 (a) (i) 1. $s = ut + \frac{1}{2}at^2$
- $192 = \frac{1}{2} \times 9.81 \times t^2$ 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 $E_k (= \frac{1}{2}mv^2) = \frac{1}{2} \times 0.27 \times (61.4)^2$ (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 $E = \frac{1}{2}mv^2$ to give $v = 61(.4)\text{ms}^{-1}$ 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 $v = 40\text{ms}^{-1}$, $R = 0.6\text{N}$ C1
- $0.27 \times 9.8 - 0.6 = 0.27 \times a$
- $a = 7.6$ (7.58) ms^{-2} A1 [2]
- (iii) $R = \text{weight}$ for terminal velocity B1
- either* weight requires velocity to be about 80ms^{-1}
- or* at 60ms^{-1} , R is less than weight
- so does not reach terminal velocity B1 [2]
- 4 (a) (i) reaction/vertical force = weight – $P \cos 60^\circ$ C1
- $= 180 - 35 \cos 60^\circ$
- $= 160$ (163) N A1 [2]
- (ii) work done = $35 \sin 60^\circ \times 20$ C1
- $= 610$ (606) J A1 [2]

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- (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]
- 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]
- 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 A1
- 0.85 m A1 [2]
- (ii) A at open end, N at closed end, with an N and A in between, equally spaced (by eye) B1 [1]

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- 7 (a) stress or $\sigma = F/A$ C1
- max. tension = $UTS \times A = 4.5 \times 10^8 \times 15 \times 10^{-6} = 6800$ (6750) N A1 [2]
- (b) $\rho = m/V$ C1
- weight = $mg = \rho Vg = \rho ALg$
- $6750 = 7.8 \times 10^3 \times 15 \times 10^{-6} \times L \times 9.81$ C1
- $L = 5.9$ (5.88) $\times 10^3$ m A1
- or
- maximum mass = $6750/9.81 = 688$ kg (C1)
- mass per unit length = $\rho A = 0.117$ kg m⁻¹ (C1)
- $L = 688/0.117 = 5.9 \times 10^3$ m (A1)
- or
- maximum mass = $6750/9.81 = 688$ kg (C1)
- volume = $m/\rho = 0.0882$ m³ = LA (C1)
- $L = 0.0882/15 \times 10^{-6} = 5.9 \times 10^3$ m (A1) [3]
- 8 (a) mass-energy
proton number or charge
nucleon number B2 [2]
- (b) (i) $E_k = \frac{1}{2}mv^2$ and $p = mv$ with working leading to
- [via $E_k = \frac{1}{2}m^2v^2/m$ or $\frac{1}{2}m(p/m)^2$]
- to $E_k = \frac{p^2}{2m}$ B1 [1]
- (ii) $p = (2E_k m)^{1/2}$ hence $(2[E_k m]_\alpha)^{1/2} = (2[E_k m]_{Th})^{1/2}$ 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 = 1.42×10^7 m s⁻¹
- calculation of momentum of α -particle/nucleus = 9.43×10^{-20} N s (C1)
- $[E_k]_{Th} = 1.14 \times 10^{-14}$ J (C1)
= 71(.5) keV (A1) [3]