
PHYSICS

9702/21

Paper 2 AS Level Structured Questions

May/June 2016

MARK SCHEME

Maximum Mark: 60

Published

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Page 2	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	21

- 1 (a) (i) $(50 \text{ to } 200) \times 10^{-3} \text{ kg}$ or $(0.05 \text{ to } 0.2) \text{ kg}$ B1 [1]
- (ii) $(50 \text{ to } 300) \text{ cm}^3$ 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
- $\rho = (0.225 \times 10^{-3})/2.835 \times 10^{-8}$
 $= 7940 \text{ (kg m}^{-3}\text{)}$ 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
- $\Delta\rho = 0.061 \times 7940 = 480 \text{ (kg m}^{-3}\text{)}$
- density = $(7.9 \pm 0.5) \times 10^3 \text{ kg m}^{-3}$ or $(7900 \pm 500) \text{ kg m}^{-3}$ A1 [5]
- 2 (a) (i) horizontal component $(= 12 \cos 50^\circ) = 7.7 \text{ m s}^{-1}$ A1 [1]
- (ii) vertical component $(= 12 \sin 50^\circ \text{ or } 7.7 \tan 50^\circ) = 9.2 \text{ m s}^{-1}$ A1 [1]
- (b) $v^2 = u^2 + 2as$ and $v = 0$ or $mgh = \frac{1}{2}mv^2$ or $s = v^2 \sin^2 \theta / 2g$ C1
- $9.2^2 = 2 \times 9.81 \times h$ hence $h = 4.3 \text{ (4.31) m}$ A1 [2]
- alternative methods using time to maximum height of 0.94 s:
- $s = ut + \frac{1}{2}at^2$ and $t = 0.94 \text{ (s)}$ (C1)
 $s = 9.2 \times 0.94 - \frac{1}{2} \times 9.81 \times 0.94^2$ hence $s = 4.3 \text{ m}$ (A1)
- or
 $s = vt - \frac{1}{2}at^2$ and $t = 0.94 \text{ (s)}$ (C1)
 $s = \frac{1}{2} \times 9.81 \times 0.94^2$ hence $s = 4.3 \text{ m}$ (A1)
- or
 $s = \frac{1}{2}(u + v)t$ and $t = 0.94 \text{ (s)}$ (C1)
 $s = \frac{1}{2} \times 9.2 \times 0.94$ hence $s = 4.3 \text{ m}$ (A1)
- (c) $t (= 9.2/9.81) = 0.94 \text{ (0.938) s}$ C1
- horizontal distance = $0.938 \times 7.7 (= 7.23 \text{ m})$ C1
- displacement = $[4.3^2 + 7.23^2]^{1/2}$ C1
- $= 8.4 \text{ m}$ A1 [4]

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	21

- 3 (a) (i) force ($= mg = 0.15 \times 9.81$) = 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 = $0.15 \times (6.2 + 2.5)$ (= 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 ms^{-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 ball and floor is zero (M1)
so momentum is conserved (A1)
- or*
- (total) momentum of ball and floor before is equal to the (total) momentum of ball and floor after (M1)
so momentum is conserved (A1)

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	21

- 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 $k = \text{gradient}$ 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 $\frac{1}{2}Fx$ or $\frac{1}{2}(F_2 + F_1)(x_2 - x_1)$
or $\frac{1}{2}kx^2$ or $\frac{1}{2}k(x_2^2 - x_1^2)$ C1
- = $\frac{1}{2} \times 10.4 \times 0.4 - \frac{1}{2} \times 5.2 \times 0.2$ C1
or $\frac{1}{2} \times (5.2 + 10.4) \times 20 \times 10^{-2}$
or $\frac{1}{2} \times 26 \times (0.4^2 - 0.2^2)$
- = 1.6 J A1 [3]
- (c) remove the force and the spring goes back to its original length B1 [1]
- 5 (a) $T = 4 \text{ (ms)}$ or $4 \times 10^{-3} \text{ (s)}$ C1
- $f = 1/T = 1/0.004$
- = 250 Hz A1 [2]
- (b) intensity $\propto (\text{amplitude})^2$ 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]

Page 5	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	21

- (c) (i) gradient = $(4.5 - 2.4) \times 10^{-3} / (3.25 - 1.75) [= 1.4 \times 10^{-3}]$ B1
- wavelength = $0.45 \times 10^{-3} \times 1.4 \times 10^{-3}$ C1
- = $6.30 \times 10^{-7} \text{ (m)}$ 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]
- 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 = $(I/nA_Y e) / (I/nA_Z e)$ 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 = $I^2 R_Y / I^2 R_Z$ or $(V_Y^2 / R_Y) / (V_Z^2 / R_Z)$ or $(V_Y I) / (V_Z I)$
- = 2 A1 [1]

Page 6	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	21

- 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 $\rightarrow$ 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]

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	Cambridge International AS/A Level – May/June 2016	9702	22

- 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
 $(a = 36/19 =) 1.9 (1.8947) \text{ m s}^{-2}$ A1 [2]
- (ii) $s = \frac{1}{2}(u + v)t$ or $s = v^2/2a$ or $s = \frac{1}{2}at^2$
 $= \frac{1}{2} \times 36 \times 19 = 36^2/(2 \times 1.89) = \frac{1}{2} \times 1.89 \times 19^2$
 $= 340 \text{ m} (342 \text{ m}/343 \text{ m}/341 \text{ m})$ M1 [1]
- (iii) 1. $(\Delta KE =) \frac{1}{2} \times 95 \times (36)^2$ C1
 $= 62\,000 (61\,560) \text{ J}$ A1 [2]
2. $(\Delta PE =) 95 \times 9.81 \times 340 \sin 40^\circ$ or $95 \times 9.81 \times 218.5$ C1
 $= 200\,000 \text{ J}$ A1 [2]
- (iv) work done (by frictional force) = $\Delta PE - \Delta KE$
or
work done = $200\,000 - 62\,000$ (values from 1b(iii) 1. and 2.) C1
(frictional force = $138\,000/340 =$) $410 (406) \text{ N}$ [420 N if full figures used] A1 [2]
- (v) $-ma = mg \sin 20^\circ - f$ or $ma = -mg \sin 20^\circ + f$ C1
 $-95 \times 3.0 = 95 \times 3.36 - f$
 $f = 600 (604) \text{ N}$ A1 [2]
- 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 $p = \rho gh$ 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 $P - 1.0 \times 10^5 = \rho gh$ C1
e.g. $\rho g = 1.0 \times 10^5/0.75 (= 133333)$
 $\rho = 133\,333/9.81$
 $= 14\,000 (13\,592) \text{ kg m}^{-3}$ A1 [2]

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	22

- 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]
- 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: $\text{kg m s}^{-2} \times \text{m} \times \text{s}^{-1} \times \text{m}^{-2}$ or $\text{kg m}^2 \text{s}^{-3} \times \text{m}^{-2}$ B1
- RHS: units: $\text{m s}^{-1} \times \text{kg m}^{-3} \times \text{s}^{-2} \times \text{m}^2$ M1
- LHS and RHS both kg s^{-3} A1 [3]
- (c) (i) change/difference in the observed/apparent frequency when the source is moving (relative to the observer) B1 [1]
- (ii) wavelength increases/frequency decreases/red shift B1 [1]
- (d) observed frequency = $\nu f_S / (\nu - \nu_S)$ C1
- $550 = (340 \times 510) / (340 - \nu_S)$ C1
- $\nu_S = 25$ (24.7) m s^{-1} A1 [3]
- 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 $360(^{\circ})/2\pi$ (produces the first order) B1 [3]
- (b) $d \sin \theta = n\lambda$ or $\sin \theta = Nn\lambda$ C1
- $d = (2 \times 486 \times 10^{-9}) / \sin 29.7^{\circ}$ ($= 1.962 \times 10^{-6}$) C1
- number of lines = 510 (509.7) mm^{-1} A1 [3]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	22

6 (a) at least six horizontal lines equally spaced and arrow to the right B1 [1]

(b) charge used $2e$ C1

$$\text{gain in KE} = 15 \times 1.6 \times 10^{-19} \times 10^3 = 2 \times 1.6 \times 10^{-19} \times V \text{ (p.d. across plates)}$$

or

$$F (= W/d) = 15 \times 1.6 \times 10^{-19} \times 10^3 / 16 \times 10^{-3} \quad \text{C1}$$

$$\text{(hence } V = 7500 \text{ V or } F = 1.5 \times 10^{-13} \text{ N)}$$

$$E = V/d \quad \text{or} \quad E = F/Q \quad \text{C1}$$

$$E = (7500 / 16 \times 10^{-3}) \quad \text{or} \quad E = (1.5 \times 10^{-13} / 3.2 \times 10^{-19})$$

$$E = 4.7 \times 10^5 \text{ (468 750) } \text{V m}^{-1} \quad \text{A1 [4]}$$

or

$$\text{KE } (= \frac{1}{2}mv^2) = 15 \times 10^3 \times 1.6 \times 10^{-19}$$

$$v = [(2 \times 15 \times 10^3 \times 1.6 \times 10^{-19}) / (6.68 \times 10^{-27})]^{1/2} = 8.5 \times 10^5 \text{ ms}^{-1} \quad \text{(C1)}$$

$$a (= v^2/2s) = (8.5 \times 10^5)^2 / 2 \times 16 \times 10^{-3} = 2.25 \times 10^{13} \text{ ms}^{-2}$$

$$F (= 6.68 \times 10^{-27} \times 2.25 \times 10^{13}) = 1.5 \times 10^{-13} \text{ N}$$

$$E = F/Q \quad \text{(C1)}$$

$$Q = 2e \quad \text{(C1)}$$

$$E = 4.7 \times 10^5 \text{ V m}^{-1} \quad \text{(A1)}$$

Page 5	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	22

- 7 (a) charge exists only in discrete amounts B1 [1]
- (b) (i) $E = I(R + r)$ or $V = IR$ C1
- (total resistance =) $2.7 + 0.30 + 0.25 (= 3.25 \Omega)$ M1
- $I = 9.0 / (2.7 + 0.30 + 0.25)$ or $9.0 / 3.25 = 2.8 \text{ A}$ A1 [3]
- (ii) $V = IR_{\text{ext}}$ C1
- $= 2.77 \times 3.0$ or 2.8×3.0
- or
- $V = E - Ir$ (C1)
- $= 9.0 - 2.77 \times 0.25$ or $9.0 - 2.8 \times 0.25$
- $V = 8.3 (8.31) \text{ V}$ 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]
- 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 $\rightarrow$ up down down or udd B1 [1]
- (iii) weak (nuclear) B1 [1]

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- 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 $(= 200/27) = 7.4 \text{ m s}^{-1}$ A1 [1]
2. resultant displacement $(= [120^2 + 80^2]^{1/2}) = 144 \text{ (m)}$ C1
- average velocity $(= 144/27) = 5.3(3) \text{ m s}^{-1}$ A1
- direction $(= \tan^{-1} 80/120) = 34^\circ (33.7)$ A1 [3]
- 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]
- 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
- $= [(7.8 + 3.9) \times 0.4]/2$ or $s = 3.9 \times 0.4 + \frac{1}{2} \times 9.75 \times (0.4)^2$ C1
- $s = 2.3(4) \text{ m}$ A1 [3]
- (ii) $a = (v - u)/t$ or gradient of line C1
- $= (7.8 - 3.9)/0.4 = 9.8 (9.75) \text{ m s}^{-2}$ (allow $\pm \frac{1}{2}$ small square in readings) A1 [2]

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	23

(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 $\times$ distance (moved) or Fd or Fx or mgh or mgd or mgx M1

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

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 $V = 5.0 \times 13 \times 10^{-6} \text{ (m}^3\text{)}$ C1

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

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

5 (a) the total 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 total kinetic energy before (the collision) is equal to the total kinetic energy after (the collision)

B1 [1]

(ii) $p (= mv = 1.67 \times 10^{-27} \times 500) = 8.4$ (8.35) $\times 10^{-25} \text{ N s}$ A1 [1]

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

2. $mv_A \sin 60^\circ + mv_B \sin 30^\circ$ B1 [2]

(iv) 8.35×10^{-25} or $500m = mv_A \cos 60^\circ + mv_B \cos 30^\circ$
and

$0 = mv_A \sin 60^\circ + mv_B \sin 30^\circ$

or using a vector triangle

C1

$v_A = 250 \text{ m s}^{-1}$ A1

$v_B = 430$ (433) m s^{-1} A1 [3]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2016	9702	23

- 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
- $R_Q (= 4\rho l / \pi 4d^2) = \rho l / \pi d^2$
 $= R_P / 8$
 $(= 12/8) = 1.5 \Omega$ A1 [3]
- (ii) power = $I^2 R$ 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]
- 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 amplitudes 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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- 8 (a) α -particle is 2 protons and 2 neutrons; β^+ -particle is positive electron/positron
 α -particle has charge $+2e$; 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]