2022 DHS H2 Physics Prelim Paper 1 Suggested Solutions

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
D	**A**	**D**	**D**	**C**	**C**	**B**	**D**	**B**	**B**
Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
B	**C**	**C**	**B**	**A**	**B**	**D**	**A**	**D**	**D**
Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30
A	**B**	**C**	**A**	**C**	**C**	**D**	**A**	**B**	**A**

1 **D** 128 GB = 128 x 10^9 B = 1.28 x 10^{11} B

2 **A** measured length = 891.5 ± 0.5 mm but true length is 895 mm
891.5 mm is lower by 3.5 mm, so not accurate to within 1 mm
results have absolute uncertainty of 0.5 mm, so all are precise to within 1 mm

3 **D** Option A, B and C are the correct equations of motion.

4 **D** Gradient of displacement-time graph gives the magnitude of the velocity of the sphere. After sufficiently long time when the ball reaches terminal velocity (constant velocity), then the graph should be a straight line with positive gradient (velocity same direction as displacement).

5 **C** While it is true in this example that the weight of the book is equal to the force upwards acting on the book from the table, this is not the pair of forces in Newton's third law. The weight of the book is the gravitational pull of the Earth on the book; the 'reaction' force is the gravitational pull of the book on the Earth. The key points to remember for Newton's third law:

The two forces are

1) of the same magnitude (in this case, *W*)

2) in opposite directions (in this case, upwards)

3) acts on different objects (in this case, on the Earth)

4) of the same time (in this case, gravitational)

6 **C** As the ball bounces elastically, no kinetic energy is lost as heat and sound. When the ball hits the horizontal surface it decelerates, losing kinetic energy and gaining elastic potential energy as it is compressed. At some instant, the ball will momentarily have zero velocity and kinetic energy before springing back up, gaining back the original kinetic energy as it does so.

7 **B** Take moment about rear wheel on trailer.

$F(20) = 30(10)$,
$F = 15$ kN

8 **D** Downward force exerted by the cylinder on the surface = pA

By Newton's 3rd law,
downward force exerted by cylinder on surface
= upward force exerted by the surface on the cylinder, N

Since the cylinder is in equilibrium.
$N = W$
$pA = mg$
$p = \frac{mg}{A} = \frac{\rho Axg}{A} = \rho xg$
$\rho = \frac{p}{gx}$

9 **B** Loss in GPE = gain in KE + energy dissipated by frictional forces

energy dissipated by frictional forces = $mgh - \frac{1}{2}mv^2$

$= (500)(9.81)(30) - \frac{1}{2}(500)(11)^2$

$= 1.2 \times 10^5$ J

10 **B** Energy required per second to raise water

$= mgh/t = (V)gh/t$

$= (1000)(0.50)(9.81)(30)/(60)$

$= 2.45$ kW

As the pump is only 70% efficient, the engine's power = 2.45 / 0.70 = 3.5 kW

11 **B** The net force is the centripetal force = $mr\omega^2$

For the 5.0 kg mass, the net force = $(5.0)(2.0)\omega^2 = 10\omega^2$

For the 8.0 kg mass, the net force = $(8.0)(6.0)\omega^2 = 48\omega^2$

Same ω for both masses, hence the ratio is 10: 48 = 5: 24

12 **C** $g = \frac{GM}{r^2} = \frac{G}{r^2}\left(\rho\frac{4}{3}\pi r^3\right) = \frac{4\pi G\rho}{3}r$

For the sphere of twice the radius, the gravitational field strength is doubled i.e. $2X$.

BP~365

13 **C** For geostationary satellite, T = 24 hours.

For circular motion, $v = r\omega = \frac{2\pi r}{T} = \frac{2\pi(6.40 \times 10^6 + 3.59 \times 10^7)}{24\times60\times60} = 3.08 \text{ km s}^{-1}$

14 **B** a-t and x-t graphs for a body undergoing s.h.m. are π rad out of phase

15 **A** total $E \propto \omega^2 x_0^2 \propto \left(\frac{1}{T}\right)^2 x_0^2$ where T is period and x_0 amplitude

$$\frac{E_2}{E_1} = \left(\frac{T_1}{T_2}\right)^2\left[\frac{(x_0)_2}{(x_0)_1}\right]^2 = \left(\frac{T_1}{3T_1}\right)^2\left[\frac{2(x_0)_1}{(x_0)_1}\right]^2 = \frac{4}{9} \Rightarrow E_2 = \frac{4}{9}E_1 = \frac{4}{9}(18 \text{ mJ}) = 8 \text{ mJ}$$

16 **B** $T = \frac{1}{f} = \frac{1}{5000} = 0.20$ ms

Since T is represented by 2 horizontal squares (2 cm),

time base setting = $\frac{0.20}{2}$ = 0.10 ms cm^{-1} = 100 μs cm^{-1}

17 **D** If the waves meet in phase at O, then path difference = OY – OX = XY = $n\lambda$

Since λ = 0.75 m, then n = 2, for XY = 1.50 m

18 **A** From single slit diffraction formula, $\sin\theta = \lambda / b$

or $x / D = \lambda / b$ where D is the distance from slit to screen

B, C and D are correct as seen from the equation. However, when slit width is is increased, more light passes through the slit and the intensity increases. Hence the area under the graph increases.

19 **D** Time for electron to travel in electric field, $t = \frac{s_x}{u}$

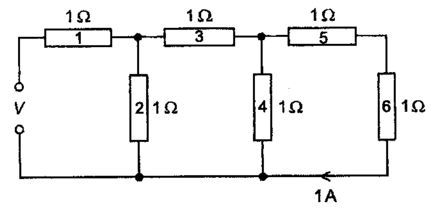
At t, displacement $s_y = \frac{1}{2}at^2 = \frac{1}{2}a\left(\frac{s_x}{u}\right)^2$

Since a, u are constants, $s_y \propto s_x^2$

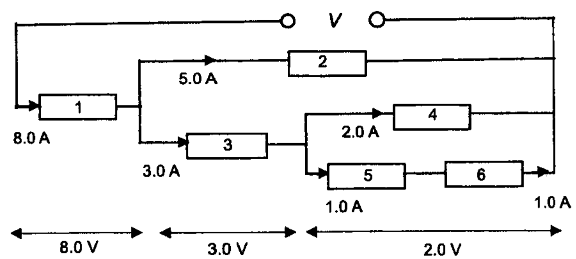
$p = kx^2 = 1.0$ mm

Thus $q = k(2x)^2 = 4p = 4.0$ mm and so on.

20 **D**



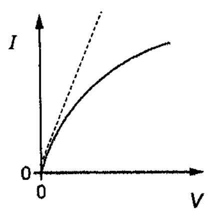
The above circuit when re-drawn is same as the circuit below



Then the currents and p.d. across the other resistors can be found.

V = 8.0 + 3.0 + 2.0 = 13.0 V

21 **A** The I-V graph for a filament lamp is as follows:



The corresponding V-I graph is a reflection of the graph about the dotted line.

22 **B** Resistors are connected in parallel, thus they have same p.d.

$2I_1 = 3I_2 = 4I_3$ (1)

$I_1 + I_2 + I_3 = I$ (current from power supply) (2)

Sub (1) into (2): $(3/2)I_2 + I_2 + (3/4)I_2 = I$

So $I_2 = (4/13)\ I$ (3)

Sub (3) into (1) gives $I_1 = (6/13)\ I$ and $I_3 = (3/13)\ I$

So $I_1 : I_2 : I_3 = 6 : 4 : 3$

23 C $F = BIL\sin\theta = (4\times10^{-5})(3)(2)\sin 90° = 240$ μN

24 A A neutral point (i.e., a point of zero magnetic field) is possible at a position where the magnetic flux densities from 2 current sources are in opposite direction and of the same magnitude.
Using Right-Hand Grip Rule, this point can only be achieved at region 2.

25 C Current is able to flow both ways due to two diodes in opposite directions. One of the diodes is connected in series to another resistor, which reduces current in that direction.

26 C Since magnitude of emf is proportional to rate of change of flux, when flux is constant, no emf is induced and when flux changes linearly, a constant emf is induced.

27 D Einstein's equation: $hc/\lambda = \phi + e V_S$

When wavelength is halved, the photon energy is doubled. Since the work function remains unchanged because the same metal is used, the max kinetic energy of the photoelectron and consequently the stopping voltage will be more than doubled.

28 A Uncertainty principle apply in the same direction and at the slit when the electron undergoes diffraction at the slit.

29 B $^{28}_{8}O$: 8 protons, 20 neutrons (doubly magic)

$^{40}_{20}Ca$: 20 protons, 20 neutrons (doubly magic)

$^{56}_{26}Fe$: 26 protons, 30 neutrons (**not** doubly magic)

$^{50}_{28}Ni$: 28 protons, 22 neutrons (**not** doubly magic)

$^{126}_{50}Sn$: 50 protons, 76 neutrons (**not** doubly magic)

30 A From the figure, background count rate can be estimated to be 8 s^{-1}.
Subsequently, half-life can be estimated as the time duration for the count rate to decrease from 58 (=50+8) to 33 (=25+8). Best option is 60 s.

2022 DHS H2 Physics Prelim Paper 2 Suggested Solutions

1 (a) $v_x = (6.0^2 - 4.8^2)^{1/2}$ **M1**

$= 3.6\ \text{m s}^{-1}$ **A0**

or

$6.0 \sin\theta = 4.8$, so $\theta = 53.1°$ and $v_x = 6.0 \cos 53.1°$ **M1**

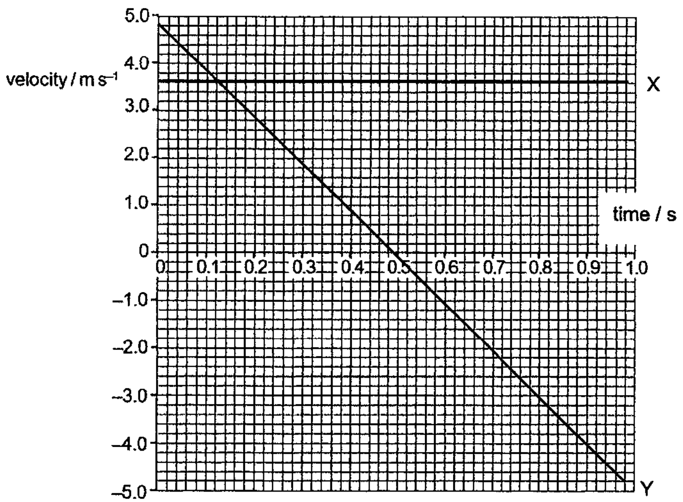
$= 3.6\ \text{m s}^{-1}$ **A0**

(b) (i) straight line from (0, 4.8) to (0.49, 0) **A1**

straight line continues with same slope to (0.98, –4.8), labelled Y **A1**

(ii) a horizontal line **A1**

from (0, 3.6) to (0.98, 3.6), labelled X **A1**



(c) $s = ut + \frac{1}{2}at^2 = (4.8 \times 0.49) + (\frac{1}{2} \times -9.81 \times 0.49^2)$ **C1**

$= 1.2$ m **A1**

or $s = \frac{1}{2}(u + v)t = \frac{1}{2} \times (4.8 + 0) \times 0.49$ **C1**

$= 1.2$ m **A1**

or $v^2 = u^2 + 2as$

$s = 4.8^2 / (2 \times 9.81)$ **C1**

$= 1.2$ m **A1**

(d) $\dfrac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}} = \dfrac{\frac{1}{2}(mv_x^2)}{mgh} = \dfrac{\frac{1}{2}(3.6^2)}{9.81(1.2)}$ **C1**

$= 0.56$ **A1**

or

$\dfrac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}} = \dfrac{\frac{1}{2}(mv_x^2)}{\frac{1}{2}(mv_Y^2)} = \dfrac{\frac{1}{2}(3.6^2)}{\frac{1}{2}(4.8^2)}$ **C1**

$= 0.56$ **A1**

(e) With air resistance, the resultant force is larger than weight, resulting in larger deceleration, hence the actual time is shorter. **B1**

2 (a) energy (stored) / work done represented by area under graph **B1**

energy = ½ (180) (4.0 x 10^{-2}) **C1**

= 3.6 J **A1**

(b) (i) *either* momentum before release is zero **M1**

so sum of momenta of trolleys after release is zero **A1**

or force = rate of change of momentum **M1**

force on trolleys equal and opposite **A1**

or impulse = change in momentum **M1**

impulse on each trolley is equal and opposite **A1**

(ii) 1. $M_1V_1 = M_2V_2$ **B1**

2. $E = \frac{1}{2} M_1V_1^2 + \frac{1}{2} M_2V_2^2$ **B1**

(iii) 1.

$E_K = \frac{1}{2}mv^2$

$= \frac{1}{2}(\frac{m}{m})mv^2$ **M1**

$= \frac{(mv)^2}{2m}$

$= \frac{p^2}{2m}$ **A0**

2. As trolley B has a smaller mass, it has a larger kinetic energy <u>because momentum is the same/ constant for both trolleys</u>. **B1**

BP-369

BP~370

3 (a) Phase difference = $\frac{2\pi t}{T} = \frac{2\pi(2.5-1.5)}{3} = \frac{2\pi}{3}$ = 120° **A1**

(b) At t = 0.75 ms, resultant displacement = $s_Y + s_Z$ = 4.0 – 1.0 = 3.0 μm **A1**

(c) $I \propto A^2$ **C1**

Thus $I = k\,(4)^2$

and $I_Z = k\,(2)^2 = 0.25I$ **A1**

(d) $v = f\lambda = \frac{\lambda}{T}$ **C1**

so $\lambda = vT$ = 330 (3.0 x 10^{-3}) = 0.99 m **A1**

4 (a) (i) Current in R_4 or R_1 = 0.30 + 0.30 = 0.60 A **C1**

$R = V / I$ **M1**

= 2.4 / 0.60

= 4.0 Ω **A0**

or

p.d. across R_3 or R_2 = 2.4 / 2 = 1.2 V **C1**

$R = V / I$ **M1**

= 1.2 / 0.30

= 4.0 Ω **A0**

(ii) E = 2.4 + 2.4 + 1.2 **C1**

= 6.0 V **A1**

or

total resistance = 10 Ω **C1**

E = 10 × 0.60

= 6.0 V **A1**

(b) total resistance increases **B1**

current decreases (in battery) so total power decreases **B1**

5 (a) (i) It is to increase the magnetic flux linkage between the coils **B1**

Comments: Most candidates answered correctly.

(ii) It is to reduce energy losses **B1**

by reducing induced currents **B1**

(b) (i) maximum $V_{OUT} = (N_s / N_p)\, V_p$

= (625 / 25 000) 12 000

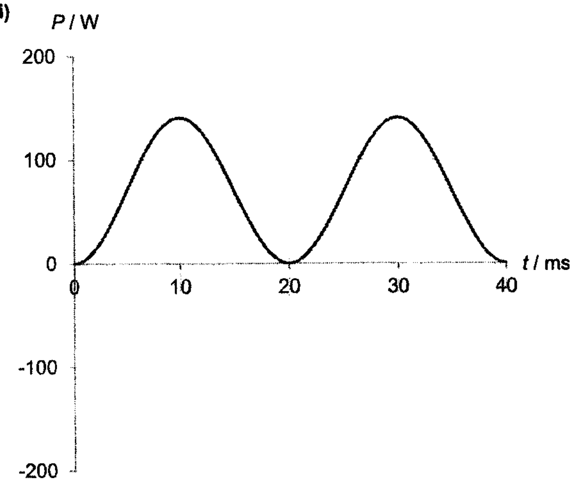
= 300 V **A1**

(ii) r.m.s. current = peak current /√2

= 300 / (640 × √2)

= 0.33 A **A1**

(iii)



positive sinusoidal squared shape, with P = 0 at t = 20, 40 ms

and maximum P shown as 140 W **B1**

two complete cycles, with period = 20 ms **B1**

(c) For sinusoidal squared graph, mean power is half the peak power (140 W) **B1**

6 (a) electron diffraction/ neutron diffraction **B1**

(b) $\frac{1}{2}mv^2 = eV$

½ × 9.11 × 10^{-31} × v^2 = 1.60 × 10^{-19} × 4800

v = 4.1 × 10^7 m s^{-1} **C1**

$\lambda = h / mv$

= 6.63 × 10^{-34} / (9.11 × 10^{-31} × 4.1 × 10^7) **C1**

= 1.8 × 10^{-11} m **A1**

(c) (i) Any two points, 1 mark each **B2**

- photons are (discrete) packets of energy
- energy of photons depends on frequency (of EM radiation)
- electrons can only absorb a single photon (of energy)
- emission only possible if photon energy is at least the work function **B1**

(ii) work function = hf = 6.63 × 10^{-34} × 6.93 × 10^{14} **C1**

= 4.59 × 10^{-19} J

= 4.59 × 10^{-19} / 1.60 × 10^{-19}

= 2.87 eV **A1**

7 (a) Half-life of a radioactive nuclide is defined as the time taken for half of the original number of radioactive nuclides in a sample to decay on average. **B1**

(b) The beta decay is exothermic / releases energy. **B1**

Thus, the total binding energy of $^{90}_{39}Y$ and $^{0}_{-1}e$ is more than that of $^{90}_{38}Sr$. **B1**

Since $^{0}_{-1}e$ has no binding energy, $^{90}_{39}Y$ has a greater binding energy. **B1**

(c) (i) 1. $A = \lambda N$

$3.7 \times 10^6 = \frac{\ln 2}{(27.7)(365)(24)(60)(60)} N$ **C1**

$N = 4.66 \times 10^{15}$ **A1**

2. 90 g of strontium contains 6.02×10^{23} atoms.

Mass of 4.66×10^{15} atoms = $\frac{4.66\times10^{15}}{6.02\times10^{23}}$ (90/1000) **C1**

$= 6.97 \times 10^{-10}$ kg **A1**

OR

Mass of 4.66×10^{15} atoms = $N(90u)$
$= (4.66 \times 10^{15})(90)(1.66 \times 10^{-27})$ **C1**
$= 6.97 \times 10^{-10}$ kg **A1**

Mass of 4.66×10^{15} atoms
$= N(38\ mass\ of\ electrons + 38\ mass\ of\ protons + 52\ mass\ of\ neutrons)$
$= (4.66 \times 10^{15})(38 \times 9.11 \times 10^{-31} + 38 \times 1.67 \times 10^{-27} + 52 \times 1.67 \times 10^{-27})$
$= 7.01 \times 10^{-10}$ kg

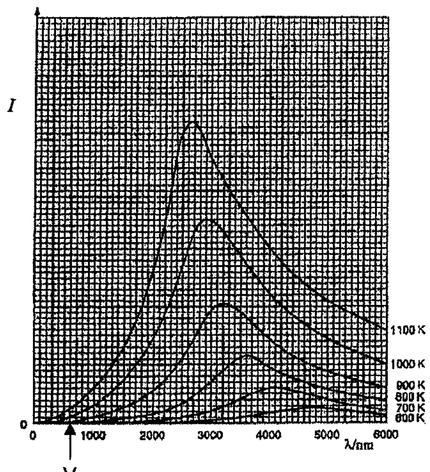
(ii) $A = A_0 e^{-\lambda t}$

$\frac{A}{A_0} = e^{-\left(\frac{\ln 2}{27.7}\right)(5.0)}$ **C1**

$= 0.882$ **A1**

8 (a) Energy has discrete/fixed values. **B1**
Comments: Generally poorly answered. Use of the word packet does not connote quantised.

(b) (i)



visible region in the range from 400 nm to 700 nm. **A1**

(ii) In the visible region, the intensity of the emitted radiation increases with increasing wavelength. **B1**
The red region has the longest wavelength and according to the graph highest intensity at 1100 K **B1**
The hot object is perceived by the eye as glowing red. **A0**

(c) (i) The wavelength, λ_{max}, that corresponds to the peak intensity of the emitted radiation. The higher the temperature, the shorter the λ_{max}. **B1**

(ii) advantage: The radiation can be detected at a distance. Hence there is no need for contact between device and the body to measure its temperature. **B1**
disadvantage: At lower temperature, the peak cannot be easily identified. **B1**

(d) (i) Electric force of attraction on electron provides the centripetal force for its motion about the nucleus. **B1**

$$\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$$ **C1**

$$v = \sqrt{\frac{e^2}{4\pi\varepsilon_0 mr}} = \sqrt{\frac{(1.6 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})(9.11 \times 10^{-31})r}}$$ **M1**

$$= \frac{15.9}{\sqrt{r}}$$ **A0**

(ii) $v = \frac{nh}{2\pi mr} = \frac{15.9}{\sqrt{r}}$

$n = 1$ so $\frac{h^2}{4\pi^2 m^2 r^2} = \frac{(15.9)^2}{r}$ **C1**

$r = \frac{h^2}{4\pi^2 m^2 (15.9)^2} = 0.053$ nm **A1**

(iii) Energy = potential energy + kinetic energy

$= -\frac{e^2}{4\pi\varepsilon_o r} + \frac{1}{2}mv^2$

$= -\frac{(1.6 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})(5.3 \times 10^{-11})} + \frac{1}{2}(9.11 \times 10^{-31})\frac{(15.9)^2}{(5.3 \times 10^{-11})}$ **C1**

$= -2.17 \times 10^{-18}$ J **M1**

$= -\frac{2.17 \times 10^{-18}}{1.6 \times 10^{-19}}$ eV

$= -13.6$ eV **A0**

(e) **(i)** For minimum wavelength, n is infinity

$\lambda = \frac{1}{1.097 \times 10^7} = 91.2$ nm **A1**

(ii) $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{\lambda}$ **C1**

$E\lambda = 1.99 \times 10^{-25}$ J m

$= 1.99 \times 10^{-25}$ J $(\times 10^9)$ nm **M1**

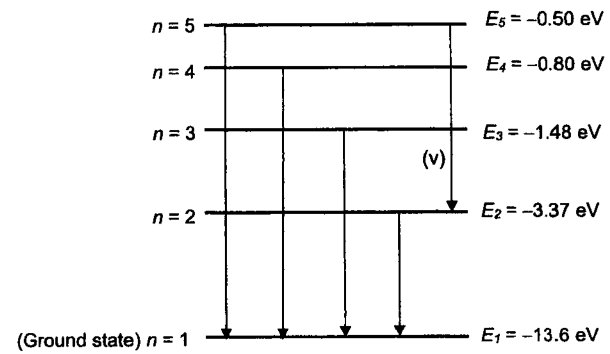
$= 1.99 \times 10^{-16}$ J nm **A0**

(iii)

wavelength λ / nm	$E = \frac{hc}{\lambda}$ / eV
121.6	10.23
102.6	12.12
97.3	12.8
95.0	13.1

energy in eV **A1**

(iv)



5 energy levels shown, with progressively smaller energy difference between higher energy levels **C1**

Correct energy values for each level **C1**

Correct electron transitions from higher to lower energy levels **C1**

(v) For $\lambda = 434.1$ nm, $E_h - E_l = 2.87$ eV.

Hence the transition is from $n = 5$ to $n = 2$ **A1**

2022 DHS H2 Physics Prelim Paper 3 Suggested Solutions

Section A

1 (a) (i) (50 to 200) x 10^{-3} kg **A1**

(ii) diameter of tennis ball is about 6 – 7 cm

volume = $\frac{4}{3}\pi r^3$ from 110 to 180 cm^3 **A1**

(b) units of Q: As **C1**

$C = \frac{Q^2}{2E}$

units of $C = \frac{A^2s^2}{kgm^2s^{-2}}$ = kg^{-1} m^{-2} A^2 s^4 **A1**

2 (a) (i) **1.** equal **B1**

2. density of ice is less than density of water **B1**

explanation: 1. at equilibrium, weight of ice = upthrust on ice

$m_{ice}g = m_{displaced\ water}g$

$m_{ice} = m_{displaced\ water}$

2. $V_{ice}\rho_{ice} = V_{displaced\ water}\rho_{water}$

since $V_{ice} > V_{displaced\ water}$, then $\rho_{ice} < \rho_{water}$

(ii) mass of ice becomes equal mass of water after melted/
mass of melted ice equal mass of displaced water **B1**
volume of melted ice equals volume of water displaced/
melted ice fills the space of water displaced by ice **B1**
so level does not change **A1**

(b) (i) Upthrust is **equal in magnitude** and **opposite in direction** to the weight of the fluid displaced by a submerged or floating object. **B1**

(ii) Upthrust = weight of water displaced by the anchor
= density of water x volume of anchor x g
= 1030 x 0.50 x 9.81 **C1**
= 5050 N **A1**

(iii) Let volume of air be V
Upthrust on lifting bag + upthrust on anchor – weight of anchor = ma
(1030)V (9.81) + 5050 – 7800(0.50)(9.81) = 7800(0.50)(2.50) **C1**
V = 4.25 m^3 **A1**

3 (a) (i) 5.00 cm **A1**

(ii) $\omega = \frac{2\pi}{T}$ **C1**

$= \frac{2\pi}{4.0}$ = 1.6 rad s^{-1} **A1**

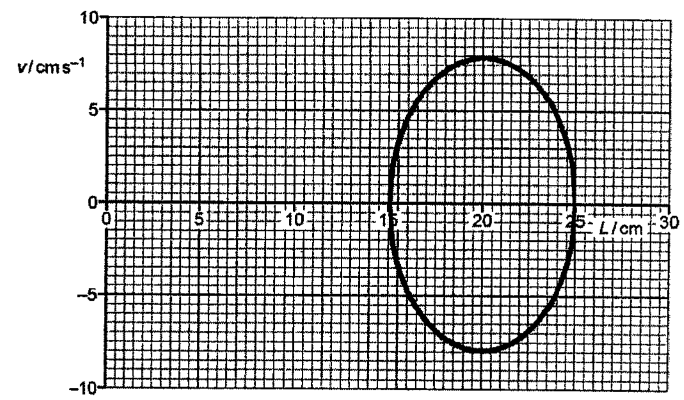
(iii) $v_0 = \omega x_0$ **C1**

= (1.6)(5.0) = 8.0 cm s^{-1} **A1**

(b) Any three points below, 1 mark each **B3**

- initial pull was to the right
- distance from X to trolley (at equilibrium) is 20 cm
- initial motion undamped
- motion becomes damped at/from 12 s
- damping is light
- maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc.

(c) sketch closed loop encircle (20,0) – see below **B1**
minimum L shown as 15 cm and maximum L shown as 25 cm **and**
minimum v shown as –8.0 cm s^{-1} and maximum v shown as 8.0 cm s^{-1} **B1**



BP~373

4 (a) (i) Fundamental mode of vibration, $\lambda = 4L = 0.680$ or $L = 0.17$ m (not formed)

1st overtone: $\lambda = \frac{4L}{3} = 0.680$ or $L = 0.51$ m (formed) **A1**

2nd overtone: $\lambda = \frac{4L}{5} = 0.680$ or $L = 0.85$ m (formed) **A1**

(ii)

A at open end, N at closed end; An A and N in between, equally spaced (by eye) **A1**

(b) waves <u>pass through/enter the slits</u> in the grating **B1**

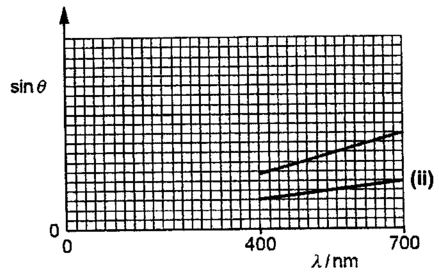
waves <u>spread out after</u> passing through/entering the slits **B1**

(c) (i) $d\sin\theta = n\lambda$ **C1**

or $\sin\theta = \frac{n}{d}\lambda$

Hence $G = \frac{n}{d}$ or $d = \frac{4}{G}$ **A1**

(ii)



straight line from 400 mm to 700 mm that is always below given line **M1**

straight line has smaller gradient than given line and is 5 small squares high at wavelength 700 nm **A1**

5 (a) The velocity v may be resolved into two components – one parallel to the magnetic field B, which is $v\cos\theta$, and the other perpendicular to B, which is $v\sin\theta$. **B0**

$v\sin\theta$ results in a <u>circular motion of the proton in the plane perpendicular to B</u>. **B1**

Using Fleming's Left-hand Rule, the <u>centripetal force is directed into the page</u> initially. **B1**

$v\cos\theta$ causes the proton / circle to move at <u>constant speed in the same direction as B</u>. **B1**

Consequently, the proton moves in a <u>helical</u> path. **B1**

(b) (i) **A1**

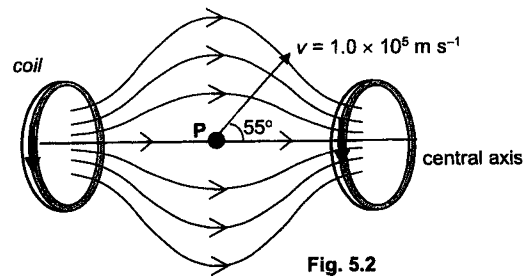


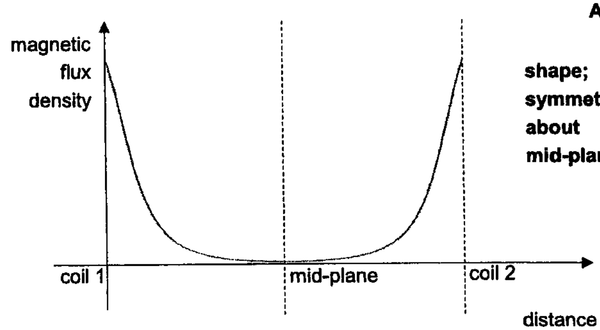
Fig. 5.2

(ii) Using $F = Bqv\sin\theta$, we get **C1**

$F = 3.8\times10^{-4}(1.6\times10^{-19})(1\times10^{5})\sin55^{0} = 4.98\times10^{-18}$ N **A1**

$= 5.0\times10^{-18}$ N (*to 2 sf*)

(iii) **A1**



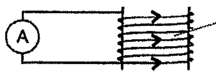
shape; symmetry about mid-plane

6 (a) (i) The direction of induced e.m.f. produces effects that oppose the change in magnetic flux **B1**

(ii) As the current in the solenoid is switched on, the <u>magnetic field in solenoid</u> is increases. **B1**
This causes an increase in <u>magnetic flux linkage</u> through <u>the small coil</u>. **B1**

By Lenz's law, the magnetic field in the coil <u>point upwards</u> to oppose the increase in flux linkage. **B1**

(iii) **B1**



(b) e.m.f. = $N\Delta\phi / \Delta t$ **C1**
= $(75 \times 1.4 \times 10^{-3} \times 7.0 \times 10^{-4}) / 0.12$ **C1**
= 6.1×10^{-4} V **A1**

7 (a) (i) $Q = (M_{Ra} - M_{Rn} - M_\alpha)c^2$
= $(226.0254 - 222.0176 - 4.0026) \times (3.00 \times 10^8)^2$
= 7.7688×10^{-13} J **C1**
= $(7.7688 \times 10^{-13}) / (10^6 \times 1.6 \times 10^{-19})$ **M1**
= 4.86 MeV **A0**

(ii) Conservation of momentum: $MV + M_\alpha V_\alpha = 0$ (1) **M1**

Conservation of energy: $Q = \frac{1}{2}MV^2 + \frac{1}{2}M_\alpha V_\alpha^2$ (2) **M1**

From (1): $V = -\left(\frac{M_\alpha}{M}\right)V_\alpha$ (3)

Sub (3) into (2)

$$Q = \frac{1}{2}M\left(-\left(\frac{M_\alpha}{M}\right)V_\alpha\right)^2 + \frac{1}{2}M_\alpha V_\alpha^2$$

$$= \frac{1}{2}M_\alpha V_\alpha^2\left(\frac{M_\alpha}{M} + 1\right)$$ **M1**

$$= K_\alpha\left(\frac{M_\alpha}{M} + 1\right)$$ **A0**

(iii) 1. $4.86 = K_\alpha\left(\frac{4.0026}{222.0176} + 1\right)$ **C1**

$K_\alpha = 4.77$ MeV **A1**

2. The alpha particles carries away most of the energy (98%). **B1**

(b) alpha particle kinetic energy per mm = $\frac{4.77}{25}$
= 0.191 MeV **C1**

energy to produce an ion pair = $\frac{0.191 \times 1.6\times10^{-13}}{5.0 \times 10^3}$ **C1**
= 6.1×10^{-18} J **A1**

<u>Section B</u>

8 (a) (i) $2mu$ **A1**
(ii) $2L / u$ **A1**
(iii) force = N x change in momentum / time = $N\,2mu / (2L / u)$
= Nmu^2 / L **A1**
(iv) pressure = force / area = $(Nmu^2 / L) / L^2$
= Nmu^2 / L^3 **A1**

(b) (i) Molecules has component of velocity in three directions. **B1**

or $c^2 = u_x^2 + u_y^2 + u_z^2$

or $<c^2> = <u_x^2> + <u_y^2> + <u_z^2>$

Since the molecules are in random motion, on average,

$<u_x^2> = <u_y^2> = <u_z^2>$ **B1**

Thus

$<c^2> = 3<u_x^2>$

$<u_x^2> = \frac{1}{3} < c^2 >$ **B1**

From (a) (iv), $p = Nmu^2 / L^3$
or $pV = Nmu^2$

$pV = \frac{1}{3}Nm < c^2 >$ **A0**

(ii) $pV = NkT$ **C1**

$NkT = \frac{1}{3}Nm<c^2>$

multiply $\frac{3}{2}$ to both sides: $\frac{1}{2}m<c^2> = \frac{3}{2}kT$ <u>and</u> $\frac{1}{2}m<c^2> = E_K$ **M1**

so $E_K = \frac{3}{2}kT$ **A0**

(c) $\frac{1}{2} \times 3.34 \times 10^{-27} \times <c^2> = \frac{3}{2} \times 1.38 \times 10^{-23} \times (25 + 273)$ **C1**

r.m.s. speed = 1.9×10^3 m s^{-1} **A1**

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(d) internal energy = ΣE_K of molecules + ΣE_P of molecules **B1**
no forces between molecules, so potential energy of molecules is zero **B1**

(e) (i) increase in internal energy = Q + work done **B1**
constant volume so no work done **B1**
(ii) thermal energy per unit mass to cause a unit change in temperature **B1**

(iii) $c = Q / Nm\Delta T$ **C1**
$= [N \times (3/2)k\Delta T] / (Nm\Delta T)$ **M1**
$= 3k / 2m$ **A0**

(f) As the gas expands, it does work against the atmosphere/external pressure **B1**
for same temperature rise, more thermal energy needed, so larger specific heat capacity **B1**

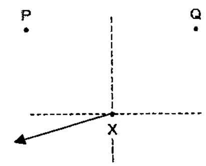
9 (a) similarity: both are radial or both have inverse square variation with distance **B1**
difference: direction is always/only towards the mass or direction can be towards or away from charge **B1**

(b) gravitational force = $mg = 1.67 \times 10^{-27}\ (9.81) = 1.64 \times 10^{-26}$ N **A1**
electric force = $qE = \frac{qV}{d} = \frac{1.6\times10^{-19}(270)}{1.8\times10^{-2}}$ **C1**
$= 2.4 \times 10^{-15}$ N **A1**
electric force is about 10^{11} times larger than gravitational force **B1**
hence gravitational field not taken into consideration **A0**

(c) (i) $V = \frac{Q}{4\pi\varepsilon_0 r}$ **C1**
$\frac{4.0\times10^{-9}}{4\pi\varepsilon_0 x} + \frac{-7.2\times10^{-9}}{4\pi\varepsilon_0(0.12-x)} = 0$
$4.0\ (0.12 - x) = 7.2x$
$x = 0.043$ m **A1**

(ii) At P, the electric field strengths due to both charges are in the same direction **B1**
so the electric field strength is not zero. **A1**

(iii) straight arrow drawn leftwards from X, in direction between extended line joining Q and X and the horizontal **A1**

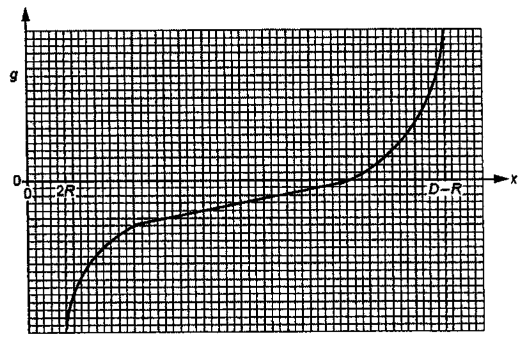


(d) The gravitational field strength equals the negative of the gravitational potential gradient. **B1**

(e) (i) gravitational potential is zero at infinity **B1**
gravitational force is attractive **B1**
mass getting closer to moon/planet loses potential energy or negative work done to bring mass from infinity to moon/planet **B1**

(ii) Any two points below, 1 mark each **B2**
- potential at surface of planet is smaller than at surface of moon
- potential gradient at surface of planet is smaller than at surface of moon
- magnitude of potential varies inversely with distance from centre near the spheres
- point of maximum potential is nearer to the moon than planet

(iii) curve, starting with gradient of decreasing magnitude at $2R$ and finishing with gradient of increasing magnitude at $D - R$ **B1**
field strength shown as zero at the point of maximum potential **B1**
negative field strength near one sphere and positive field strength near the other **B1**



2022 DHS H2 Physics Prelim Paper 4 Suggested Mark Scheme and Solutions

Qn	Marking Point	Marks
1(a)	R_Y to the nearest 0.1 Ω **and** final value in the range **9.5 Ω – 10.5 Ω**. I_1 to the nearest 0.1 mA **and** final value in the range **50.0 mA – 80.0 mA**. I_2 to the nearest 0.1 mA **and** final value in the range **70.0 mA – 110.0 mA**.	1
	Comments: All resistors have a tolerance of 5%, thus for a 10 Ω resistor, the actual uncertainty is 0.5 Ω and hence recorded to 1 d.p. Alternatively, it is sufficient to just record the given value of R. If current is recorded in A, then it will be to 4 d.p.	
1(b) (TABLE)	**Column headings:** Each column heading must contain a quantity, a unit, and a separating mark where appropriate. 6 sets of data The presentation of quantity and unit must conform to accepted scientific convention, e.g. R_Y / Ω, I_1 / mA, I_2 / mA and $\frac{I_1}{I_2}$ /.	1
	Consistency of presentation: All raw values of I must be given to 0.1 mA.	1
	Significant figures: All values of $\frac{I_1}{I_2}$ / must be given to the smallest number of s.f. as the number of s.f. in either I_1 or I_2. Calculation: Values of $\frac{I_1}{I_2}$ are correct.	1

R_Y / Ohm	I_1 / mA	I_2 / mA	I_1 / I_2
10.0	66.0	93.8	7.04E-01
12.0	64.8	83.3	7.78E-01
15.0	63.5	71.4	8.89E-01
22.0	61.5	53.6	1.15E+00
27.0	60.6	45.5	1.33E+00
33.0	59.8	38.5	1.56E+00

Fig. 1 Excel-Generated Theoretical Table for Q1b

Qn	Marking Point	Marks
1(c) (GRAPH)	• Sensible scales must be used. Awkward scales (e.g., 3:10) are not allowed. Scales must be chosen so that plotted points occupy at least half the graph grids in both x and y directions. • Axes must be labelled with the quantity which is being plotted.	1
	• Straight line of best fit- judge by scatter of points about the candidate's line. No curved lines allowed. • There must be an even distribution of points on either side of the line along the full length. • Allow maximum (correctly identified) one anomalous point if clearly indicated on graph i.e., circled or labelled. There must be at least five points left after the anomalous point is disregarded. • Lines must not be kinked or thick. No hairy lines. (No curved lines allowed). • All observations in table must be plotted. Work to an accuracy of plot ≤ 0.5 small square.	1
	Comments: Candidates should plot the line of best fit using 6 data points; the graph does **NOT** need to pass through the point (0, 1/3)!	
1(c) (CALN)	• Equation linearised correctly. • Plot a sensible graph that allows for straight line to be drawn and R_X to be determined from the gradient. e.g. $\frac{I_1}{I_2}$ / against R_Y / Ω • **Associated Statement:** Plot a graph of $\frac{I_1}{I_2}$ / against R_Y / Ω. If the relation is valid, a straight line graph will be obtained with gradient $\frac{2}{3}\left(\frac{1}{R_X}\right)$ and vertical intercept $\frac{1}{3}$.	1
	• Gradient calculated correctly with clear working. • The hypotenuse of the gradient triangle must be greater than half the length of the drawn line. • Read-offs must be accurate to half a small square.	1
	R_X determined correctly from gradient with unit **and** final value in the range **13.0 Ω – 23.0 Ω**.	1
1(d)	Draw a line $\frac{I_1}{I_2} = 1$ on the graph grid on page 4. The R_Y-odinate of intersection between the line $\frac{I_1}{I_2} = 1$ and the graph in **(c)** is equal to R_X.	1
	Comments: Many candidates did not give a detailed account in **words** of the correct **graphical** method.	

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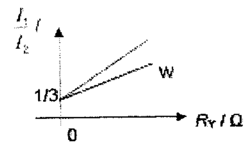
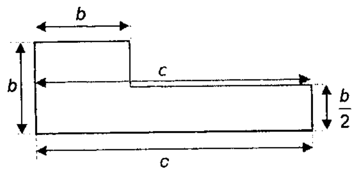
1(e)	Line W drawn such that it has **lower** gradient than the original graph **and** vertical intercept remains the same i.e., 1/3. 	1
	Comments: For graphs drawn with lower gradient, students also need to check that their drawn graph has the same vertical intercept value of 1/3.	
	Total	**11**

2(a)	*b* to the nearest 0.1 cm **and** final value in the range 20.5 cm – 21.5 cm. *c* to the nearest 0.1 cm **and** final value in the range 29.2 cm – 30.2 cm. Evidence of repeated *b* and *c*.	1
2(c)	*y* to the nearest 0.1 cm **and** final value in the range 9.1 cm – 10.1 cm.	1
2(d)(i)	*c* to the nearest 0.1 cm **and** final value in the range 26.2 cm – 27.2 cm. (3 cm decrease from (c) value) Evidence of repeated *c*.	1
		
2(d)(ii)	*y* to the nearest 0.1 cm **and** final value in the range 9.0 cm – 11.0 cm.	1
2(e)(i)	*y* = 10.2 cm (correct calculation for *y*)	1
2(e)(ii)	Stated appropriate graph to be plotted e.g. [redacted]	1
2(e)(iii)	Corresponding to graph in 2(e)(ii) :- Gradient: [redacted] y-intercept: [redacted] 4by + 4cy = 3b² + bc 4cy = 3b² + b (c – 4y) cy = [redacted] + [redacted] (c – 4y)	1 1

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2(f)	When $b = c$, the remaining shape is a square with length b = 21.0 cm. Thus, if the paper has uniform density, its centre of gravity is at its geometric centre i.e., at $b/2$ = 10.5 cm	1
	Total	**9**

3(a)(i)	*d* to the nearest 0.1 cm **and** final value in the range 39.5 cm – 40.5 cm. Evidence of repeated *d*.	1
3(a)(ii)	Percentage uncertainty based on an absolute uncertainty Δd in the range 2–5 mm and max 2 s.f. If repeat readings have been taken, then the absolute uncertainty can be half the range (but not zero) if the working is clearly shown. Correct method of calculation to obtain percentage uncertainty.	1
3(a)(iii)	*l* to the nearest 0.1 cm **and** final value in the range 29.5 cm – 30.5 cm. Evidence of repeated *l*.	1
3(a)(iv)	Percentage uncertainty based on an absolute uncertainty Δl in the range 2–5 mm and max 2 s.f. If repeat readings have been taken, then the absolute uncertainty can be half the range (but not zero) if the working is clearly shown. Correct method of calculation to obtain percentage uncertainty.	1
3(b)	All **raw times** measured either to the nearest 0.1 s. Evidence of measurement of nT repeated where nT > 10.0 s. Value of T in the range 0.500 s < T < 1.00 s.	1
3(c)(i)	*d* to the nearest 0.1 cm **and** final value in the range 29.5 cm – 30.5 cm. *l* to the nearest 0.1 cm **and** final value in the range 39.5 cm – 40.5 cm. All **raw times** measured either to the nearest 0.1 s. Evidence of measurement of nT repeated where nT > 10.0 s. Value of T in the range 1.00 s < T < 1.50 s. Value of T **larger** than 3(b).	1 1
3(c)(ii)	Justification of the number of significant figures in terms of the number of s.f. in **(raw) time** only.	1
3(d)(i)	Calculated correctly two values of *k* with unit and recorded to the least no. of sf among *l*, *d* and *T*. The final *k* values must not be fractions. Unit: [redacted] or equivalent	1 1
3(d)(ii)	Justification of Relationship **Note: The given relation is valid for a bifilar pendulum.** ☐ Calculated correctly $\%k_{uncertainty} = \frac{\Delta k}{k_{ave}} \times 100\%$ **OR** $\%k_{uncertainty} = \frac{\Delta k}{k_{smaller}} \times 100\%$	

For internal use only

- ☐ $\Delta k = |k_1 - k_2|$ **OR** $\Delta k = |k_1 - k_2|/2$
- ☐ Chose a criterion from the **sum** of the values in **(a)(ii) and (a)(iv)**
- ☐ Concluded that **results may not support the suggestion** if $\%k_{uncertainty}$ > the criterion chosen.

  OR

  Concluded **results support the suggestion** if $\%k_{uncertainty} \leq$ the criterion chosen. **(Expected)** — **1**

Comments: Some candidates are confused between fractional uncertainty and percentage uncertainty. This part of the question requires comparison of percentage uncertainty.

3(e) Correct calculation of g using candidate's second k **and** in range $9.00\ \text{m s}^{-2} \leq g \leq 11.0\ \text{m s}^{-2}$. — **1**

3(f) Evidence of constant l = 40.0 cm — **1**

Trend: with or without mass, as d increases, T decreases. — **1**

Two sets of tabulation of T, with mass and without mass.
All **raw times** measured either to the nearest 0.1 s.
Evidence of measurement of nT repeated where nT > 10.0 s. — **1**

Value of d in the range 27.0 cm < d < 31.0 cm. — **1**

L = 0.400 m

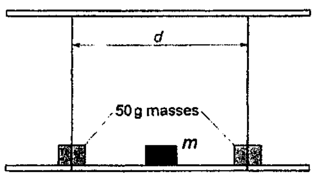
without mass				
d / m	n	t_1 / s	t_2 / s	T / s
0.400	15	13.8	13.8	0.917
0.300	10	12.2	12.2	1.223
0.289	10	12.7	12.7	1.269
0.200	10	18.3	18.3	1.834

with mass				
d / m	n	t_1 / s	t_2 / s	T / s
0.400	15	17.5	17.5	1.167
0.300	10	12.5	12.5	1.254
0.289	10	12.7	12.7	1.269
0.200	10	14.8	14.8	1.475

Fig. 3 Excel-Generated Theoretical Table for Q3f

3(g) Choice of l and d presented clearly:
Choose a small value of d so that % error in T is small e.g. d = 20.0 cm
Choose a large value of l so that % error in T is small e.g. l = 40.0 cm — **1**

Diagram (Optional) and tabulation:



l = 0.400 m
d = 0.200 m

m / g	n	t_1 / s	t_2 / s	T / s
0.050	15	19.1	19.1	1.275
0.100	15	17.1	17.1	1.139
0.150	15	15.6	15.6	1.039
0.200	15	14.4	14.4	0.962

4 sets of m values — **1**

Trend: as number of children m sitting at the centre increases, T decreases. — **1**

Comments:
- Some candidates have m = 0.300 g in their tabulation. This is only possible if there are no masses (children) placed at each string.
- Some candidates have m = 0.000 g in their tabulation. The question clearly stated the experiment involved "**one** or more children".
- Some candidates only collected two sets of data, which is insufficient to conclude the effect of m on T.

3(h) (MINI-PLANNING)

Design
Clearly labelled 2-D diagram with workable arrangement:
- planks are horizontal and parallel
- there is symmetry about axis of rotation
- planks are supported
- L, d and l are shown clearly — **1**

Procedure
- Method to measure length L of bottom plank (using metre rule).
- Method to measure period T of oscillation in the **correct mode** (using stopwatch).
- Method to monitor constant mass of bottom planks e.g., measure using electronic weighing machine — **1**

Control
- Use bottom planks of same material but different height H and L such that HL = constant
- Monitor that **both** d and l are constant using a metre rule. — **1**

How to use results to show direct proportionality
Method to verify relationship between T and L. e.g.
Plot a graph of T against L. If a straight line graph that passes through the **origin** is obtained, then the relationship is verified. — **1**

Note:
- 3(h) is stated to "suggest the use of any *additional* apparatus commonly found in a school physics laboratory".
- 3(h) is related to the experiment described prior in 3(a) and 3(b), so the steps in the procedures can be repeated.
- It is advisable that student draw a diagram pertaining to the required instructions, as there is space provided to do so in the question paper and the question mention the account should include a diagram.

Total **23**

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Qn	Marking Point	Marks
4	**Mark Scheme**	
	<u>Defining the problem</u> A1: identify independent (perpendicular distance x between the coils, current y in coil P) and dependent (induced e.m.f. E in coil Q) variables	1
	A2: identify control variable e.g. Keep the number of turns (on each coil) constant frequency of y constant.	1
	Comments • Controlled variable should be for the entire experiment (i.e., both runs) and not for one run only. • Only non-trivial control variables should be accepted.	
	<u>Method of data collection</u> B1: labelled diagram of workable experiment including: * showing coil P and coil Q supported * x marked on the diagram * coil P and coil Q labelled	1
	B2: Two circuit diagrams: * a.c. power supply or signal generator connected to coil P with ammeter in series * CRO connected to coil Q.	1
	B3: Method to determine x, e.g. use a ruler or ruler shown on diagram adjacent to coils <u>with x indicated</u>.	1
	B4: Method to measure r.m.s. value of y, $I_{y,rms}$ e.g. connect a c.r.o. in parallel with a resistor R with y flowing through it to measure the peak p.d. V_o across the resistor. $I_{y,rms} = \frac{V_o}{R\sqrt{2}}$	1 1
	B5: Method to determine E, e.g. use of c.r.o.	1
	Comments • Specific and appropriate instruments should be used for measuring associated physical quantities; not accepted e.g., computer or laptop. • If multi-meter is used, need to describe the multi-meter settings used.	
	<u>Method of Analysis</u> C1: linearization of relationship $\ln(E) = \ln(A) - Bx + C\ln(y)$ C2: identifying 2 runs required Run 1: vary x, keep y constant plot $\ln(E)$ against x, straight line with gradient $-B$, y-intercept $\ln(A) + C\ln(y)$ Run 2: vary r.m.s. / peak value y, keep x constant plot $\ln(E)$ against $\ln(y)$, straight line with gradient C, y-intercept $\ln(A) - Bx$	1 1

C3: Once B and C are determined, substitute known and corresponding values of $\ln(E)$, x & $\ln(y)$ into the equation $\ln(E) = \ln(A) - Bx + C\ln(y)$ to determine A.	1
<u>Safety</u> D1: Do not touch hot coil / use gloves to position hot coil / use heat-proof gloves to position coil.	1
<u>Additional details: (max 2)</u> Any two from: E1 Use large current / large number of turns / an iron core (to produce large magnetic field / induced e.m.f). E2 Use high frequency (to produce large induced e.m.f). E3 Method to position ruler horizontally to measure x described e.g. use a spirit level or same height from bench at both ends. E4 Method to keep coils parallel / co-axial e.g. adjust coil Q until maximum reading or use set square to ensure that coils are at right angles to the axis. E5 Method to measure x from <u>centre</u> of coil P to <u>centre</u> of coil Q, e.g. measure width of (each) coil and divide by 2 and add to separation of coils	1 1 1 1 1
Comments: • Only contextual and **significant** details will be credited. • Many candidates stated the electrocution, which means to "kill or severely injured by electric shock", could be a safety issue, without indicating that the presence of a large e.m.f. source e.g. the mains, was necessary (due to the high resistance of the human skin, between 1 to 100 kΩ). Studies have shown that the human body internal resistance to an e.m.f. source of less than 30 V is quite safe. • Some candidates stated that the presence of Earth's magnetic field may cause a systematic error in the experiment. Not that 1. the Earth's magnetic field is approximately constant in a locale on Earth and 2. it's mean magnitude is small ~10^{-5} T. However, answers that state other sources of errors due to a non-uniform, significant and/or changing magnetic field such as the presence of a (strong bar) magnet can be accepted. • Some candidates stated that the circuit should be opened with a switch to prevent the components from heating up and affecting the resistance. While it is true that components' resistance is dependent on temperature, while in operation, the components will inevitably heat up.	
MAX	**12**