2022 DHS H2 Physics Prelim Paper 3 Suggested Solutions

Section A

1 **(a)** **(i)** $(50 \text{ to } 200) \times 10^{-3}$ 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 $C = \frac{A^2 s^2}{kg m^2 s^{-2}}$ = $kg^{-1}\, m^{-2}\, A^2\, s^4$ **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**

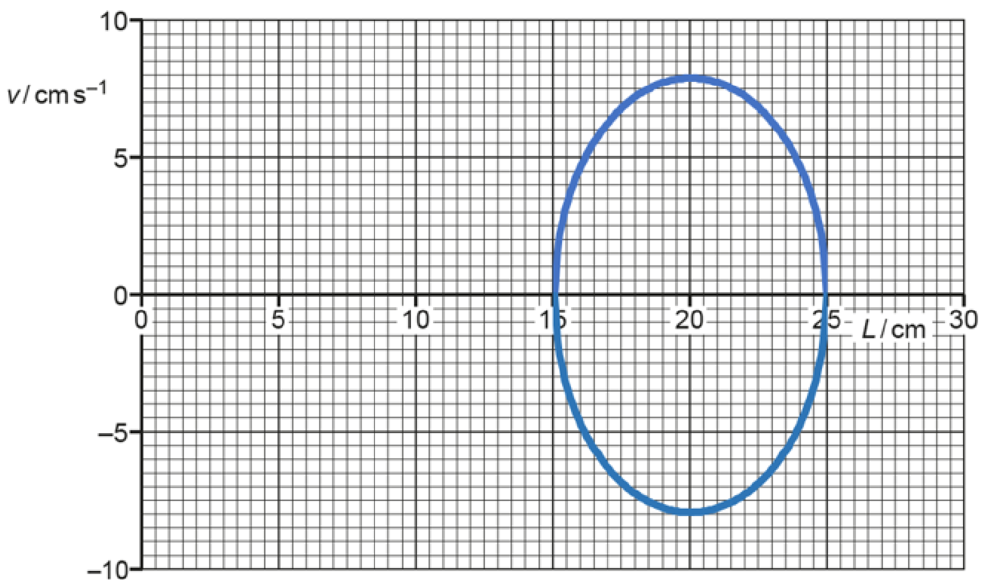
3	(a)	(i)	5.00 cm	A1
		(ii)	$\omega = \dfrac{2\pi}{T}$	C1
			$= \dfrac{2\pi}{4.0} = 1.6 \text{ rad s}^{-1}$	A1
		(iii)	$v_0 = \omega x_0$	C1
			$= (1.6)(5.0) = 8.0 \text{ cm s}^{-1}$	A1

(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**

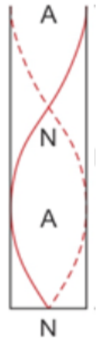


4 **(a)** **(i)** Fundamental mode of vibration, $\lambda = 4L = 0.680$ or $L = 0.17$ m (not formed)

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**

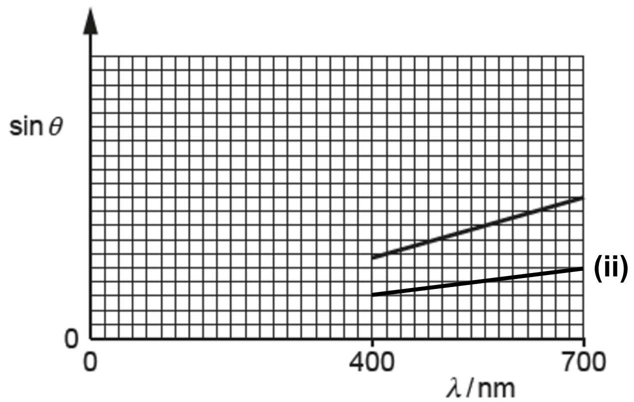
waves <u>spread out after</u> passing through/entering the slits **B1**

(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**

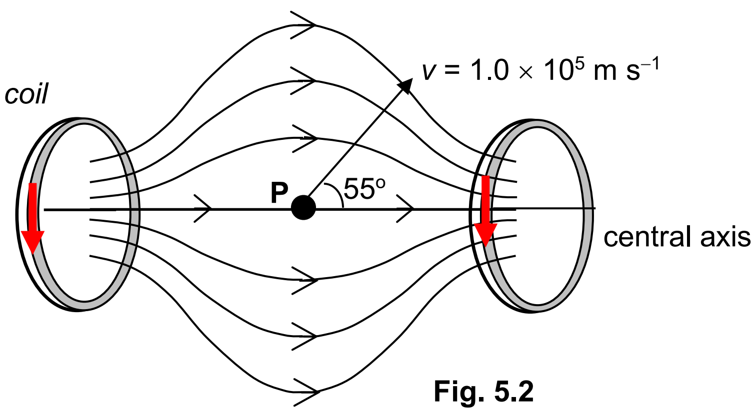


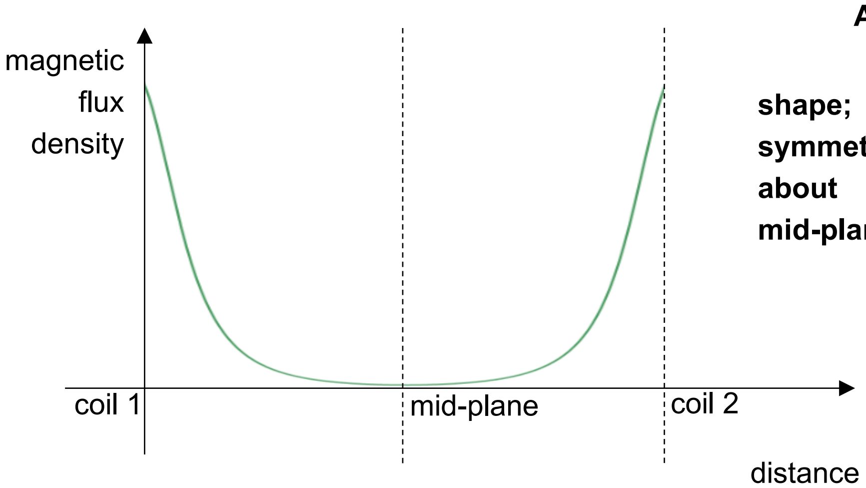
Fig. 5.2

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

$$F = 3.8\times10^{-4}\left(1.6\times10^{-19}\right)\left(1\times10^{5}\right)\sin 55^{0} = 4.98\times10^{-18}\ \text{N}$$ **A1**

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

(iii) **A1**

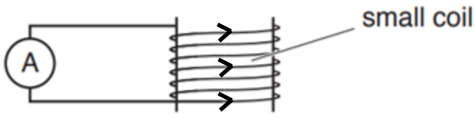


shape; symmetry about mid-plane

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 = $\frac{0.191 \times 1.6 \times 10^{-13}}{5.0 \times 10^{3}}$ **C1**

= 6.1×10^{-18} J **A1**

Section B

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**

(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 = $qE = \dfrac{qV}{d} = \dfrac{1.6\text{x}10^{-19}(270)}{1.8\text{x}10^{-2}}$ **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**

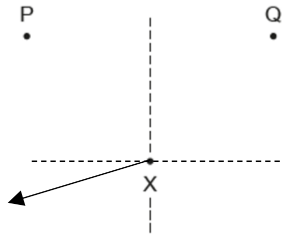
(c) **(i)** $V = \dfrac{Q}{4\pi\varepsilon_o r}$ **C1**

$$\frac{4.0\text{x}10^{-9}}{4\pi\varepsilon_o x} + \frac{-7.2\text{x}10^{-9}}{4\pi\varepsilon_o(0.12-x)} = 0$$

$4.0\,(0.12 - x) = 7.2x$
$x = 0.043$ 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 2*R* 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**