RAFFLES INSTITUTION
YEAR 5-6 PHYSICS DEPARTMENT

GCE A–level 2017

H2 PHYSICS 9749/1 answers

1	**A**	11	**D**	21	**A**
2	**B**	12	**B**	22	**D**
3	**C**	13	**D**	23	**D**
4	**D**	14	**D**	24	**C**
5	**C**	15	**B**	25	**A**
6	**A**	16	**C**	26	**B**
7	**D**	17	**D**	27	**D**
8	**C**	18	**C**	28	**C**
9	**D**	19	**B**	29	**B**
10	**A**	20	**C**	30	**C**

Suggested detailed solutions:

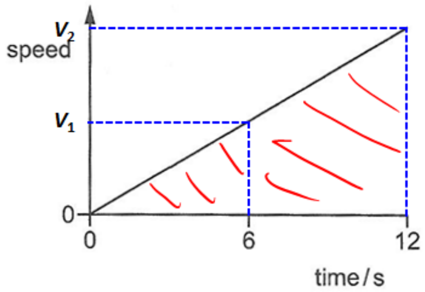
1 **A**

2 **B** Let $A = \dfrac{xy^2}{z}$, then $\dfrac{\Delta A}{A} = \dfrac{\Delta x}{x} + 2\dfrac{\Delta y}{y} + \dfrac{\Delta z}{z} = 2\% + 2 \times 1\% + 2\% = 6\%$.

3 **C** Distance travelled is given by the area under the speed-time graph.

$$\frac{v_1 - 0}{6 - 0} = \frac{v_2 - 0}{12 - 0} \Rightarrow v_2 = 2v_1$$

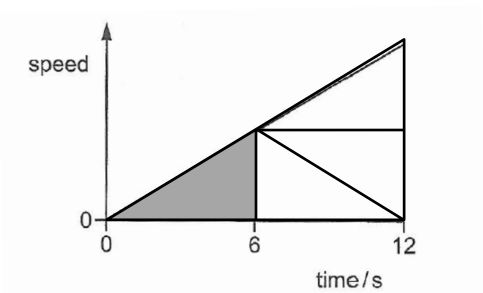
$$\text{ratio} = \frac{\frac{1}{2}(v_1 + v_2) \times 6}{\frac{1}{2} \times 6 \times v_1} = \frac{3v_1}{v_1} = 3$$



OR

By similar triangles, from the graph:

$$Ratio = \frac{3}{1} = 3$$



4 **D** The maximum velocity (terminal velocity v_T) happens when air resistance is equal to weight:

$$0.60 v_T = mg\,.$$

$$v_T = v_{max} = \frac{3.0 \times 9.81}{0.60} = 49 \text{ ms}^{-1}$$

The acceleration a at any speed is found using Newton's 2nd Law:

$$a = \frac{F_{net}}{m} = \frac{mg - 0.60v}{m} = \frac{3.0(9.81) - 0.60(12)}{3.0} = 7.4 \text{ ms}^{-2}$$

Acceleration when v = 12 ms^{-1} :

$$3.0 \times 9.81 - 0.60 \times 12 = 3.0 \times a$$
$$\therefore a = 7.4 \text{ ms}^{-2}$$

5 **C** Since the momentum reverses direction in the collision, the change in momentum is greater than p. Since the collision is inelastic, the final momentum must be less than p in magnitude (so that the final KE is less than the initial KE). So the change in momentum must be some value in between p and $2p$.

6 **A** Action-reaction pairs satisfy the (A exerts on B) and (B exerts on A) relations.

7 **D** KE is converted into GPE on the way up, so it decreases; it increases on the downward trip since GPE is converted into KE.

8 **C** For a satellite in orbit,

$$\frac{GMm}{R^2} = \frac{mv^2}{R}$$
$$\Rightarrow \frac{GMm}{R} = mv^2$$

Total energy of satellite,

$$E_T = -\frac{GMm}{2R} = -\frac{mv^2}{2}$$

Change in total energy of satellite,

$$\Delta E_T = -\frac{6.9 \times 10^2}{2}\left[7900^2 - 7500^2\right] = -2.1 \times 10^9 \text{ J}$$

OR

$$\Delta E_T = -\frac{GMm}{2}\left(\frac{1}{R_f} - \frac{1}{R_i}\right)$$
$$= -\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 6.9 \times 10^2}{2}\left(\frac{1}{6.5 \times 10^6} - \frac{1}{7.2 \times 10^6}\right)$$
$$= -2.1 \times 10^9 \text{ J}$$

9 **D** Angular velocity ω is common to every point on the disc.

Since $a = \omega^2 r$ and ω is a constant, a $\propto$ r,

$$a_{r=2} = \frac{1}{2}a_{r=4} = 8 \text{ ms}^{-2}$$

10 **A**

$$\phi = -\frac{GM}{R} \propto \frac{1}{R}$$

$$\frac{\phi_X}{\phi_S} = \frac{R_S}{R_X}$$

$$\Rightarrow \phi_X = \frac{6.371 \times 10^6}{6.371 \times 10^6 + 50000} \times \left(-6.257 \times 10^7\right) = -6.208 \times 10^7 \text{ J kg}^{-1}$$

11 **D** Note that $T / K = T / {}^{\circ}C + 273.15$.

12 **B** The system is insulated from heat supply, therefore Q = 0. Since temperature increases, internal energy increase.

From the first law of thermodynamics: $\Delta U = Q + W_{doneonsystem}$

Since Q =0, $W_{doneonsystem} = \Delta U > 0$

By stirring, work is done on the system.

13 **D** For a good car suspension system, the oscillation should stop as quickly as possible so that the system may return to and stay at equilibrium position. A and C are light damping. B is over damping. D is critical damping.

14 **D** The dotted wave is lagging the solid wave by $\pi / 2$ (quarter of a period), or leading it by $3\pi / 2$.

15 **B** When going from one medium to another, the frequency of the wave does not change (frequency is source dependent). Since speed is halved, wavelength is also halved. Intensity is proportional to square of amplitude.

$$I = kA^2$$

$$\frac{I'}{I} = \frac{\left(A/2\right)^2}{A^2} \Rightarrow I' = 0.25I$$

16 **C** It is a fact that $\theta_1 < \frac{\theta_2}{2}$, and higher order maximas are dimmer because most of the light passes straight through.

17 **D** Since $v \propto \sqrt{T} \Rightarrow v \propto \sqrt{mg} \Rightarrow v = k\sqrt{m} = f\lambda \Rightarrow \lambda = \frac{k\sqrt{m}}{f}$ ----------(1)

and for a stationary wave to form, $L = n\left(\frac{\lambda}{2}\right) \Rightarrow \lambda = \frac{2L}{n}$ ----------- (2)

$\lambda = \frac{k\sqrt{m}}{f} = \frac{2L}{n} \Rightarrow n = \frac{2Lf}{k\sqrt{m}}$ ------------- (3)

When f = 15 Hz, m = 400 g and n =1

$k = 2L\frac{15}{\sqrt{400}} = \frac{3}{4}(2L)$ -----------(4)

Subt (4) into (3)

$$n = \frac{2Lf}{k\sqrt{m}} = \frac{2Lf}{(\frac{3}{4}2L)\sqrt{m}} = \frac{4f}{3\sqrt{m}}$$

Since *n* is an integer, only option **D** gives an integer of *n* = 4

OR

$v \propto \sqrt{T} \propto \sqrt{mg} \propto \sqrt{m} \Rightarrow v = k\sqrt{m}$

$L = \frac{n\lambda}{2} = \frac{nv}{2f}$ where $n = 1, 2, 3, 4, ...$

Fundamental mode,

$0.900 = \frac{1 \times k\sqrt{0.400}}{2 \times 15} \Rightarrow k = 42.6907$

Higher harmonics,

$0.900 = \frac{n \times 42.6907 \times \sqrt{0.900}}{2 \times 90} \Rightarrow n = 4$

The other options did not yield integer values for n.

18 **C** Electric field strength

$$|E| \propto \frac{1}{r^2}$$

$\frac{|E|_{-q}}{|E|_{+q}} = \frac{0.30^2}{0.60^2} \Rightarrow |E|_{-q} = \frac{1}{4} \times 10.0 = 2.5 \text{ NC}^{-1}$

At P, the directions of the field strengths for both charges are pointing to the right. Thus, the net field strength is 10.0 + 2.5 = 12.5 N C^{-1}

19 **B** If the resistor obeys Ohm's law, then the graph of I vs V will be a straight line passing through the origin for both + and $-V$. Since there is a diode present, we get only the $+V$ side of the straight line.

20 **C** $P_{input} = IV = 5.7 \times 280, \quad P_{output} = 0.9 \times 5.7 \times 280 = I_{rms}V_{rms}$

$\therefore \quad I_{rms} = 6.245 \text{ A}$

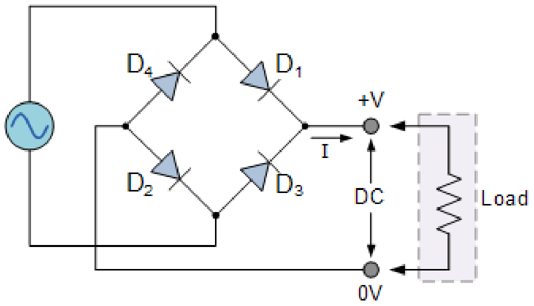
21 **A** $R \propto \frac{L}{A}$ Since the lengths of the sections are equal, $R \propto \frac{1}{A}$. This means that the gradient increases as the area A of cross-section decreases.

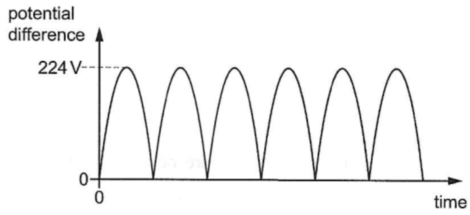
22 **D** Because the current in the bottom 30 Ω resistor is 4A + 2A = 6A, therefore the total p.d. across both resistors is (6 x 30) + (4 x 30) = 300 V.

23 **D** $F = Bqv_{perpen} = Bqv\,sin\,20^0 \Rightarrow v = \frac{4.3 \times 10^{-14}}{0.88 \times 1.6 \times 10^{-19}\,sin\,20^0} = 8.93 \times 10^6 \text{ m s}^{-1}$

24 **C** Segments MN and QP cut through the magnetic field whereas MQ and NP do not. From $E = BLv$, L and v for MQ and NP are parallel $\therefore$ $E = 0$. L and v for MN and QP are 90° to each other $\therefore$ $E = BLv$. Hence emf is induced across MN and QP only.

25 **A**





$V^2 - t$ graph is the same as that for a sinusoidal p.d, hence

$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{224}{\sqrt{2}},$$

$$\therefore I_{rms} = \frac{V_{rms}}{R} = \frac{224}{\sqrt{2} \times 70.0} = 2.26 \text{ A}$$

$$\langle P \rangle = I_{rms} V_{rms} = 2.26 \times \frac{224}{\sqrt{2}} = 358 \text{ W}$$

26 **B**

$$\frac{N_s}{N_p} = \frac{1}{16}$$

$$P = 32 = \frac{V^2}{R} = \frac{\left(\frac{V_{s0}}{\sqrt{2}}\right)^2}{R} \Rightarrow R = 1.98 \approx 2.0\ \Omega$$

27 **D** Factual question

28 **C**

$$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2 \times 10^7} = 3.63 \times 10^{-11} \text{ m}$$

29 **B** Because in an α-decay, both the numbers of protons and neutrons decrease by 2

30 **C**

$$A_0 = \lambda N_0 \Rightarrow \lambda = \frac{3.7 \times 10^7}{4.8 \times 10^{20}} = 7.708 \times 10^{-14} \text{ s}^{-1}$$

Next, apply $N = N_0 e^{-\lambda t}$ to solve for the time t

$$N = 1.5 \times 10^{19} = 4.8 \times 10^{20}\, e^{-0.7708 \times 10^{-13}\, t} \quad \Rightarrow \quad t = 4.5 \text{ x } 10^{13} \text{ s}$$

OR

$$A_0 = \lambda N_0 \Rightarrow \lambda = \frac{3.7 \times 10^7}{4.8 \times 10^{20}} = 7.708 \times 10^{-14} \text{ s}^{-1}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{7.708 \times 10^{-14}} = 8.992 \times 10^{12} \text{ s}$$

$$\frac{N}{N_0} = \frac{1.5 \times 10^{19}}{4.8 \times 10^{20}} = \frac{1}{32} = \frac{1}{2^5}$$

Time taken is $5T_{\frac{1}{2}} = 5 \times 8.992 \times 10^{12} = 4.496 \times 10^{13}$ s

2017 A-level H2 Physics Paper 2 Solutions (9749/02)

1 **(a)** Extension x = 10.8 – 8.0 = 2.8 cm
$F = k\,x$
$k = F / x$ = (0.140)(9.81) / (0.028)
= 49.05 = 49 N (2 s.f.)

(b) **(i)** $x = L_2 - L_1$
$\Delta x = \Delta L_2 + \Delta L_1$ = 1 + 1 = 2 mm

$k = F / x = mg / x$ (g has no uncertainty)

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{\Delta x}{x}$$

$$= \frac{1.0}{100} + \frac{0.2}{2.8}$$

= 0.081

Percentage uncertainty = 8.1 %

(ii) $\Delta k = 0.081 \times 49.05$ = 4 (1 s.f.)
Force constant = 49 ± 4

(c) **(i)** $T + U = mg$ (where T = tension; U = upthrust)
$U = mg - T$
= (0.140)(9.81) – (49)(0.103 – 0.080)
= 0.246
= 0.25 N (shown)

(ii) U = weight of fluid displaced
$= V \rho_{liquid}\, g$
$= (m / \rho_{block})\, \rho_{liquid}\, g$

$\rho_{liquid} = (U)(\rho_{block}) / mg$
= (0.25) (7750) / (0.140)(9.81)
=1400 kg m^{-3} (2 s.f.)

2 **(a)** **(i)**

$$v = r\omega = r\left(\frac{2\pi}{T}\right)$$

$$T = \frac{2\pi r}{v} = \frac{2\pi(1.75\times10^7)}{0.200\times10^3}$$

$$= 5.49\times10^5\, s$$

$$= \frac{5.495.49\times10^5}{24\times60\times60}$$

$$= 6.36 \text{ days}$$

(ii) 1. The probe will always see Charon.
2. The probe will always see the same face of Charon.

Part (1) assumed that the direction of orbit of Charon is in the same direction as that of the rotation of Pluto about its axis. Hence, the more correct answer would be that Charon will appear at the same position relative to a fixed position on Pluto after each period. (It is not mentioned that the orbit of Charon is in the equatorial plane of Pluto. Hence, a "geostationary" answer is incorrect).
Part (2) requires the assumptions of part (1). Otherwise, there is no significance to the fact that both Charon and Pluto have the same period.

(b) $g_P = \dfrac{GM}{r^2} = \dfrac{(6.67\times10^{-11})(1.31\times10^{22})}{(1.20\times10^{6})^2}$

$= 0.607 \text{ N kg}^{-1}$

(c) **(i)** Using the principle of conservation of energy,

Loss in GPE $=$ Gain in KE

$$\frac{GM_pM}{r} - 0 = \frac{1}{2}Mv^2 - 0$$

$$v = \sqrt{\frac{2GM_p}{r}}$$

Since $g_p = \dfrac{GM_p}{r^2}$

$\Rightarrow v = \sqrt{2g_pr}$ (shown)

(ii) $v = \sqrt{2g_Pr} = \sqrt{2(0.607)(1.20\times10^{6})} = 1.21 \times 10^3 \text{ m s}^{-1}$

3 **(a)** A polarised wave is a transverse wave which has its <u>oscillations restricted to a single plane of vibration.</u> This plane of vibration is <u>always perpendicular to the direction of energy transfer</u>.

(b) In a time of one period ($t = T$), the waveform moves a distance of one wavelength ($x = \lambda$).

speed, $v = \dfrac{\text{distance}}{\text{time}} = \dfrac{x}{t} = \dfrac{\lambda}{T}$

Since $f = \dfrac{1}{T}$,

$v = f\lambda$

(c) **(i)** Wavelength $= v / f = (3.00 \times 10^8) / (1200 \times 10^3) = 250$ m
By Pythagoras' theorem, BP $= (12^2+5^2)^{1/2} = 13$ km

Path difference = BP – AP = 13 – 12 = 1 km = 1000 m = 4λ

Since the waves are in phase at the transmitters, and their path difference is an integral number of wavelengths at point P, constructive interference takes place.

(ii) The amplitude varies periodically from a maximum to a minimum.

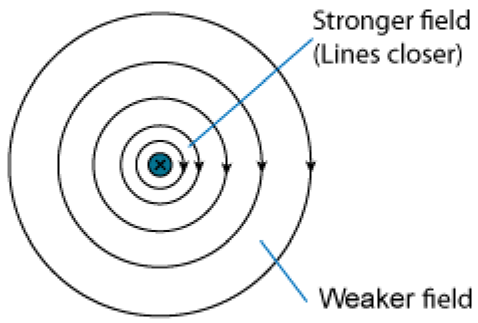
(iii) Make the two sources incoherent.
Two waves of the same frequency can be incoherent if there are sudden (uncorrelated) changes in phase in either or both waves.
OR
Make the polarizations of the two waves perpendicular to each other.
An observable interference pattern is produced only if they are polarized in the same plane or are both unpolarized.

(d) Intensity $I \propto 1/r^2$

$$\frac{\text{Intensity}_A}{\text{Intensity}_B} = \frac{r_B^2}{r_A^2} = \frac{13^2}{12^2}$$

$= 1.2$

4 **(a)**



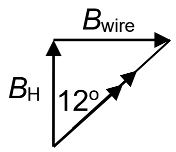
Correct magnetic field direction
Magnetic field lines spacing increases with increasing r

(b)

$$B = \frac{\mu_0 I}{2\pi d} = \frac{2\times10^{-7}(8.5)}{(0.19)}$$

$= 8.9 \times 10^{-6}$ T

(c) **(i)** $\tan\theta = B_{wire} / B_H$
$B_H = B_{wire} / \tan\theta = 8.9 \times 10^{-6} / \tan 12°$
$= 4.2 \times 10^{-5}$ T



(ii) Mark on X on the east side of the wire

Reasoning: A point to the right of the wire will have B_{wire} pointing to the South (right-hand grip rule) to cancel the Earth's B_H which is pointing to the North. From (c)(i), X needs to be less than 19 cm for the resultant flux density is zero.

5 **(a)** **(i)**

$$R = \rho\frac{l}{A}$$

$$= (1.7\times10^{-8})\frac{(96)}{\pi(0.090\times10^{-3})^2}$$

[1] for conversion

$$= 64\,\Omega$$

(ii) As the length increases, the cross-sectional area decreases. Since volume is constant (Al = constant), cross-sectional A is inversely proportional to l. Hence, resistance is proportional to l^2 and the resistance increases.

(iii) The 16 strands of wire are in parallel.
Hence, effective resistance of cable = 64 / 16 = 4.0 Ω

(b) **(i)** $P = I^2 R = (2.5)^2 (4)$
$= 25$ W

(ii) $I = Anvq$
$v = I / Anq$

$$= \frac{2.5\left(\frac{1}{16}\right)}{\pi(0.090\times10^{-3})^2\times(8.5\times10^{28})(1.60\times10^{-19})}$$

$= 4.5 \times 10^{-4}$ m s^{-1}

6 **(a)** The accelerated electrons behave like waves as they pass through the spaces between the carbon atoms, which acts like diffraction gratings in different orientations.

The waves interfere constructively and destructively to give regions of bright and dark fringes, respectively, to from the concentric rings.

(b) As p.d. increases, the momentum p of the electrons increases.

From de Broglie relationship $\lambda = h/p$, the wavelength of the electrons decreases.

Using the diffraction grating equation as an approximation ($d \sin\theta = n\lambda$ is not correct for a crystal), the angle of diffraction decreases for the same order ring. Hence, the radii of the circles decreases.

(c) From the principle of conservation of energy,
loss in electric potential energy = gain in kinetic energy

$$qV = \tfrac{1}{2} mv^2$$

$$(1.60 \times 10^{-19})(1.2 \times 10^{3}) = \tfrac{1}{2} (9.11 \times 10^{-31})\, v^2$$

$$v = 20.53 \times 10^{6} \text{ m s}^{-1}$$

$\lambda = h / p$
$= (6.63 \times 10^{-34}) / (9.11 \times 10^{-31}) (20.53 \times 10^{6})$
$= 3.5 \times 10^{-11}$ m

7 **(a)** **(i)** Glide ratio = horizontal distance / vertical drop = 40
Vertical drop = 8500 – 1500 = 7000 m
Horizontal distance = 40 $\times$7000 = 280 000 m

(ii) Since glide ratio = lift / drag, to increase glide ratio,
1. reduce drag by using streamline design and smooth body.
2. increase lift by curving upper part of the wings to push more air downwards.
3. Increase lift by having large wing span area

Note: TYS answers include "small mass", however, we do not believe mass would affect the lift or drag forces on the glider. It only affects the weight. Hence, we do not believe that the mass / weight has an effect on the glide ratio.

(iii) For horizontal flight, lift = weight = (2300 + 633)(9.81) = 28772 N

Note: TYS answers did not include 633 kg, the mass of the batteries. TYS assumes 633 kg is already included in the 2300 kg, but according to the examiner's report, it subtly implies that students should have added 633 kg to the total mass. Hence, we believe that the correct working should be as above.

Glide ratio = lift / drag = 40,
drag = 28772 / 40 = 719 N

(b) **(i)** kW h is unit for energy.
kW h kg^{-1} is the unit for the amount of energy per unit mass.
Hence energy density refers to amount of energy per unit mass.

(ii) Total energy = 41 kW h × 4 = (41 × 1000 × 3600) × 4 = 5.9×10^8 J
OR
Total energy = mass x energy density = 633 × 0.260 × 1000 × 3600 = 5.9×10^8 J

(iii) The energy provided by the batteries goes into work done against drag force so that the aircraft can move at constant speed.

work done = force × distance
distance = work done / force = 5.9×10^8 / 719
= 8.2×10^5 m

(c) At higher altitudes, the aircraft is closer to the sun and there is lower absorption and scattering by the atmosphere.

Hence, the higher intensity of light incident on the photovoltaic cells at higher altitudes leads to greater energy being collected by the cells.

(d) The aircraft needs to also collect energy for its flight during the night, when there is no sunlight.

(e)
1. Draw two cells in parallel.
2. Draw two cells in series.

(f) **(i)** Power is directly proportional to area.

(ii) Intensity of light incident on the cells.

(iii) I_c = gradient = 73.0×10^3 / 300 = 243 W m^{-2}

(g) **(i)** M = 1 / cos 50° = 1.556 ;
$I_i = 1.353 \times 0.700^k$ (where $k = M^{0.678}$)
= 0.836

(ii) Plot point to ½-square precision

(iii) Draw best fit curve. (Note that "line" can be straight or curved.)

(iv) From graph, at θ = 36.0°, $I_i \approx$ between 0.890 to 0.900 kW m^{-2}

(v) Efficiency = $I_c / I_i \times 100$ %
= 243 / (0.890 ×1000) ×100 %
= 27 %

(h) With the added weight of passengers,
1. the aircraft will have a greater weight and drag. Hence, a longer time is needed to reach a destination.
2. more energy must be stored for use at night. Hence, large amount of batteries is needed, which will add a lot of weight on the aircraft.
3. more solar cells are needed to produce energy for the flight. Hence, the surface area of the cells will need to be very large, which will also increase the weight and drag.

RAFFLES INSTITUTION
YEAR 5-6 PHYSICS DEPARTMENT

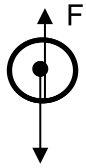
2017 A-level H2 Physics P3 solutions (9749/03)

SECTION A

1 (a) When released, the only force acting on the object is its weight (mg) acting downwards, and it experiences a downward acceleration due to gravity, g = 9.81 m s^{-2}.
As the velocity of the object increases, air resistance acting upwards (F_{drag}) on the object also increases, causing a decrease in the net force (F_{net}) downwards acting on the object. The objects velocity increases at a decreasing rate.
The velocity of the object will increase till the magnitude of F_{drag} equals to the magnitude of its weight. Hence the net force on the object will become zero (no more acceleration) and the object reaches a constant velocity.

(b) (i) By Newton's 2nd Law,

$$F_{net} = ma$$
$$mg - F = ma$$
$$mg - kv = ma$$
$$(g-a) = \frac{kv}{m} \quad \text{(shown)}$$



Comment : "F" is defined in the question as "resistive force".
Hence do not use the symbol "F" as resultant force.

(ii)

Velocity	Acceleration	($g - a$)
0	9.81	0.00
20	8.2	1.6
30	5.66	4.15
40	0	9.81

At 0 m s^{-1}, no air resistance, hence acceleration = g

At 30 m s^{-1}, gradient of tangent $\frac{40.0-10.0}{5.30-0.00} = 5.66$

At 40 m s^{-1}, terminal velocity, no acceleration.

(iii) Student's suggestion is (g–a) = $\frac{kv}{m}$.

If student is correct, $\frac{k}{m}$ should be a constant for v = 20 and 30 m s^{-1}.

At 20 m s^{-1},

$$(g-a) = \frac{kv}{m}$$
$$1.6 = \frac{k}{m}(20)$$
$$\frac{k}{m} = 0.080$$

At 30 m s^{-1},

$$4.15 = \frac{k}{m}(30)$$
$$\frac{k}{m} = 0.14$$

$$< \frac{k}{m} > = 0.11$$

% difference from mean = $\frac{0.14-0.11}{0.11}\times 100\% = 27\%$ hence the student's suggestion is incorrect (% difference too large).

2 **(a)** **(i)** $p_{initial} = (1.5)(0.90)+(1.2)(-2.2)$

$= 1.35 - 2.64$

$= -1.29 \text{ kg m s}^{-1}$

Since total initial momentum is non zero, by the principle of conservation of momentum, the momentum of the both trolleys during collision cannot be zero. Hence they cannot be stationary at the same time.

Or

By the principle of conservation of momentum, total momentum of the system remains constant unless a net external force acts on it. The total initial momentum is (1.5)(0.09) + (1.2)(–2.2) = –1.29 kg m s^{-1}, hence the trolleys cannot be stationary at the same time.

Comments: spell out conservation of momentum, do not write COM

(ii) Average force on A (due to B) :

$$F_{avg} = \frac{\Delta p}{\Delta t}$$

$$= \frac{(1.5)[0.70-(-0.90)]}{0.30} \qquad \text{(taking left as positive)}$$

$$= 8.0 \text{ N}$$

(b) **(i)** By Newton's 3rd Law, force on each trolley is of the same magnitude but acting in opposite directions.

Taking right as positive,

$$8.0 = \frac{(1.2)[v-(-2.2)]}{0.30}$$

$$v = -0.20 \text{ m s}^{-1}$$

$$\text{speed} = 0.20 \text{ m s}^{-1}$$

(ii) The direction of motion of trolley B is to the left. From **b(i)**, motion to the right was taken as positive, and the velocity of B was calculated to be –0.20 m s^{-1} which implies that the motion is towards the left.

(c) Relative speed of approach $= u_1 - u_2 = 0.90 + 2.2 = 3.1 \text{ m s}^{-1}$

Relative speed of separation = $v_2 - v_1 = -0.20 - (-0.70) = 0.50 \text{ m s}^{-1}$

Since both values are not the same, the collision is inelastic.

3 **(a)** A gravitational field is a region of space in which a mass placed in that region experiences a gravitational force.

Comment : some candidates gave definition of *gravitational field strength* instead of what is required in the question.

(b) (i) The <u>gravitational force provides the centripetal force</u>,

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

(ii) Let m be the mass of the Sun.

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$\frac{M}{m} = \frac{v^2 r}{Gm}$$

$$= \frac{(230000)^2 (2.4 \times 10^{20})}{(6.67 \times 10^{-11})(2.0 \times 10^{30})}$$

$$= 9.52 \times 10^{10}$$

OR

$$v = \sqrt{\frac{GM}{r}}$$

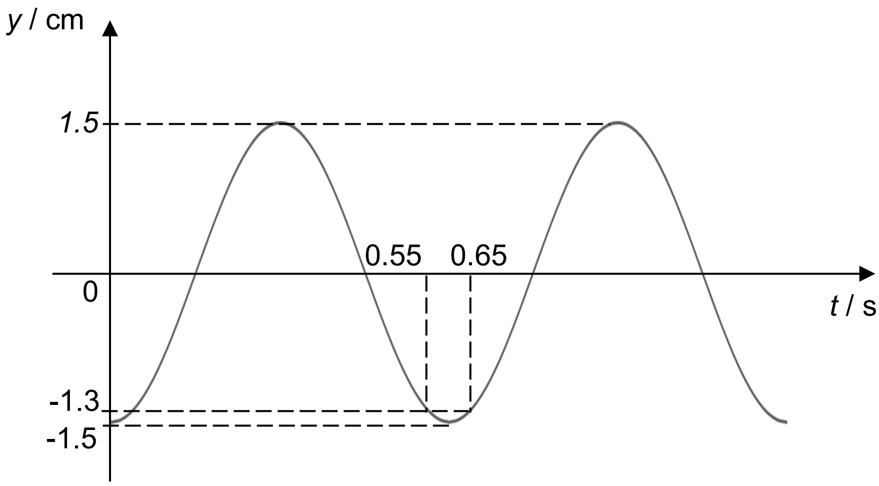
$$M = \frac{rv^2}{G} = \frac{(2.4 \times 10^{20})(230 \times 10^3)}{6.67 \times 10^{-11}}$$

$$= 1.90345 \times 10^{41}$$

$$\text{Ratio} = \frac{M}{m} = \frac{1.90345 \times 10^{41}}{2.0 \times 10^{30}}$$

$$= 9.52 \times 10^{10}$$

4 (a)



(b) **(i)**

$$T = \frac{12.0}{20} = 0.60 \text{ s}$$

$$y = -1.5\cos\left(\frac{2\pi}{0.60}t\right)$$

when $y = +0.20$ cm,

$$0.20 = -1.5\cos\left(\frac{2\pi}{0.60}t\right)$$

$t = 0.16277$ s, 0.43723 s

when $y = -0.20$ cm,

$$-0.20 = -1.5\cos\left(\frac{2\pi}{0.60}t\right)$$

$t = 0.13723$ s, 0.46277 s

minimum time $= 0.46277 - 0.43723 = 0.0255$ s (3 s.f.)

OR

$$T = \frac{12.0}{20} = 0.60 \text{ s}$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.60} = 20.9439 \text{ s}$$

From graph, amplitude = 1.5 cm = 15 mm
Let oscillation equation be: $x = x_0 \sin \omega t$
Time taken to travel from equilibrium to $+2.0$ mm

$$2.0 = 15\sin\left(\frac{2\pi}{0.60}t\right)$$

$t = 0.01277$ s
By symmetry, time taken to travel from +2.0 mm to –2.0 mm
= 2t = (2)(0.01277) = 0.0255 s

(ii) From the graph (refer to 4(a) solution), reading off the graph,

minimum time taken $= 0.65 - 0.55 = 0.10$ s

(c) At zero displacement.
As the time it takes for the cube to move past zero is very fast, the error of timing will be smaller.
If timing is made at maximum, the cube stays near the maximum position for a longer duration, the range of timing taken is larger.

Comment : some candidates failed to follow instructions “use answers in **(b)**. Candidates should use the calculations in **(b)** to provide some theoretical backing for good practice in experimental work. (Ignore answers given in TYS.)

5 **(a)** **(i)** $a\sin\theta = \lambda$

$\tan\theta = \dfrac{y}{D}$

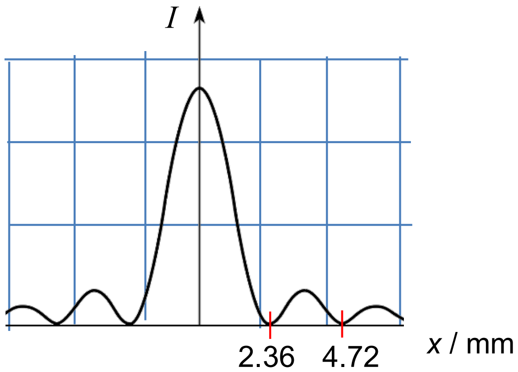
since θ is small,

$\sin\theta = \tan\theta$

$\Rightarrow y \simeq \dfrac{\lambda D}{a} = \dfrac{(590\times10^{-9})(2.4)}{0.60\times10^{-3}}$

width $= 2y = 2.36\times10^{-3} = 4.72\times10^{-3}$ m

(ii)



Note: 1 central maxima and at least 2 other maxima (of decreasing amplitudes) on either sides.
Central fridge should be twice the width of the subsidiary fringes.

(b) **(i)** For the two patterns to be just distinguishable, the central maximum of one must lie to the first minimum of the other.
This is satisfied when the minimum angular separation of the sources follows $\theta_{min} \approx \dfrac{\lambda}{b}$.
Comment : Most candidates referred to the patterns being *resolved*, without giving any explanation as to the meaning of *resolution* in this context. Instead of saying *resolved*, candidates may say *distinguishable* or words to that effect.

(ii) $\theta = \dfrac{\lambda}{b} = \dfrac{590\times10^{-9}}{0.60\times10^{-3}}$

$= 9.83\times10^{-4}$ rad

6 **(a)** Magnitude of uniform E field across parallel plates = $\dfrac{\Delta V}{d} = \dfrac{750}{d}$

At x = $\dfrac{d}{3}$, potential $= 750 - \dfrac{1}{3}(750) = 500$ V

At x = $\dfrac{2d}{3}$, potential $= 750 - \dfrac{2}{3}(750) = 250$ V

Loss in electric potential energy $= q\,\Delta V$
=(2e)(500 - 250)
$= 500e$

Since the term has no *d* in the expression, it is independent of *d*.

(b) $\alpha-$ particle has charge of 2e.

From $x = 0$ to $x = \frac{d}{3}$,

Loss in electric potential energy = Gain in kinetic energy

$$q\,\Delta V = \frac{1}{2}mv_1^2$$

$$(2e)(750 - 500) = \frac{1}{2}\left(4 \times 1.66 \times 10^{-27}\right)v_1^2$$

$$v_1 = \sqrt{\frac{4\left(1.6 \times 10^{-19}\right)(250)}{4 \times 1.66 \times 10^{-27}}}$$

$$= 1.55230 \times 10^5 \text{ m s}^{-1}$$

From $x = \frac{d}{3}$ to $x = \frac{2d}{3}$

Loss in electric potential energy = Gain in kinetic energy

$$q\,\Delta V = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

$$(2e)(500 - 250) = \frac{1}{2}mv_2^2 - (2e)(750 - 500)$$

$$(2e)(500) = \frac{1}{2}\left(4 \times 1.66 \times 10^{-27}\right)v_2^2$$

$$v_2 = \sqrt{\frac{4\left(1.6 \times 10^{-19}\right)(500)}{4 \times 1.66 \times 10^{-27}}}$$

$$= 2.19529 \times 10^5 \text{ m s}^{-1}$$

$$\text{Change in speed} = 2.19529 \times 10^5 - 1.55230 \times 10^5$$

$$= 6.43 \times 10^4 \text{ m s}^{-1}$$

7 **(a)** To eject electrons, the energy of the photon must have energy greater or equal to the work function, ϕ.
Ultraviolet light has photon energy greater than ϕ while red light has photon energy less than ϕ.

(b) β-particles are <u>high speed (or fast moving) electrons.</u>
These charged particles are stopped <u>suddenly</u> by the aluminium container, and undergo <u>large</u> acceleration (or deceleration), producing X-ray photons.

(c) The nucleus is <u>very</u> small compared to the atom.
Hence only a small proportion of α-particles approach closely to a nucleus.
Each atom contains a charged nucleus.
Since α-particles are also charged, the <u>electrostatic repulsive</u> between the nucleus and α-particles cause a large deflection of the α-particles.
<u>**Comment**</u>:
Comparison of the size of the nucleus to the atom is required.

8 **(a)** **(i)** The two bodies at thermal equilibrium have the same temperature.

(ii) There is no net flow (or transfer) of thermal energy from one body to another.

Comment: if the word "net" is missing, candidates do not get full credit.

(b) **(i)** No.
The ice and the surrounding are at different temperature. Hence there is thermal energy being transferred from the surroundings to the ice.

(ii) 5.0 minutes = 300 s.

$$\text{electrical energy supplied} + \text{energy supplied by surrounding}$$
$$= \text{energy to melt ice}$$
$$IVt + R\,t = \Delta mL$$
$$(6.3)(12.0)(300) + 300R = (114.0 - 32.4)(330)$$
$$R = 14.16 = 14.2 \text{ W (2 or 3 s.f.)}$$

(c) **(i)** Ideal gas has no intermolecular forces, hence its potential energy is zero.
The internal energy of the ideal gas is therefore just the kinetic energy of its molecules.
Since kinetic energy is proportional to thermodynamic temperature, the internal energy of an ideal gas is therefore proportional to its thermodynamic temperature.

(ii) **1.** Ideal gas eqn: $\frac{pV}{T} = nR$ and $n = \frac{m}{m_r}$ where m: mass and m_r: molar mass

$$\text{Initially : } \frac{pV}{T} = \frac{(1.0\times10^5)(2.0\times10^{-2})}{(25+273.15)}$$
$$= 6.71$$

$$\text{after heating, } \frac{pV}{T} = \frac{(1.5\times10^5)(2.0\times10^{-2})}{(174+273.15)}$$
$$= 6.71$$

Since $\frac{pV}{T}$ is a constant, implies nR is a constant , and n = $\frac{m}{m_r}$ where R and m_r are constants, therefore m is a constant.

2. From (1.) , $\frac{pV}{T}$ = nR = 6.71

Hence n = $= \frac{6.71}{8.31}$

Mass m = $n \times m_r$

$$= \frac{6.71}{8.31} \times 20$$

$$Q = mc\Delta\theta$$
$$1220 = (\frac{6.71}{8.31} \times 20)\, c\,(174 - 25)$$
$$c = 0.507 \text{ J g}^{-1}\text{ K}^{-1} \text{ (2 or 3 s.f.)}$$

(c) (iii) $\Delta U = Q + W$

For the same rise in temperature ΔT, the change in internal energy ΔU is the same for both processes (internal energy proportional to thermodynamic temperature for ideal gas).

At constant volume, W = 0.

At constant pressure, work is done by the gas against external pressure, hence W is negative. Therefore Q is larger at constant pressure.

$Q = m\,c\,\Delta T$; therefore c at constant pressure is larger.

Additional thermal energy needs to be supplied when heating at constant pressure.

9 (a) The root-mean-square value of the alternating current has the same rate of heating in a resistive load of a circuit as the steady direct current of the same value.

Comment:
Since question requires a reference to "heating effect", students should modify the definition given in lecture notes.

(b) (i)

$$\omega = 377 = 2\pi f$$
$$f = 60.0 \text{ Hz}$$

(ii)

$$V_o = 240 \text{ V}$$
$$V_{rms} = 240/\sqrt{2}$$
$$P = \frac{{V_{rms}}^2}{R}$$
$$= \frac{\left(240/\sqrt{2}\right)^2}{38}$$
$$= 758 \text{ W}$$

(c) (i) 1. Faraday's law of electromagnetic induction states that the induced e.m.f. is proportional to the **rate of change** of magnetic flux linkage.

2. When the alternating current flows in the primary coil, an alternating magnetic field (produced by the current in the coil) is set up.

This causes flux changes in the core linking the secondary coil.

By Faraday's law, an alternating e.m.f. is induced in the secondary coil which is proportional to the rate of change of flux linkage.

Since the rate of change of the magnetic flux linkage alternates due to the alternating primary current, the induced e.m.f. in the secondary coil also alternates with the same frequency as the primary current.

Comments:
many candidates did not make any reference to flux changes *in the core*.

(ii) 1. The transformer is 100% efficient with no power loss such that the input power is equal to the output power.

2.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\frac{240/\sqrt{2}}{12} = \frac{5000}{N_s}$$

$$N_s = 354 \text{ turns}$$

(iii) **1.** Soft iron has high permeability (so it provides excellent linkage of the magnetic flux of the primary coil to the secondary coil).

Soft iron has low hysteresis loss. (Therefore, energy dissipated per unit volume per cycle of magnetisation is small.)

2. The alternating magnetic flux linkage with the core induces eddy currents.
The laminated sheets block the path of eddy currents and prevents it from forming large currents within the whole iron core. As a results, <u>smaller loops of eddy currents</u> form within each laminate (or the size of eddy currents formed will be small), hence reducing thermal energy losses.