Answers to 2013 Prelim Paper 1 (H2 Physics)

1	D	**11**	A	**21**	B	**31**	C
2	A	**12**	C	**22**	C	**32**	A
3	B	**13**	A	**23**	B	**33**	B
4	B	**14**	A	**24**	D	**34**	A
5	D	**15**	B	**25**	A	**35**	A
6	A	**16**	D	**26**	B	**36**	C
7	A	**17**	C	**27**	B	**37**	C
8	C	**18**	A	**28**	C	**38**	D
9	A	**19**	C	**29**	B	**39**	C
10	B	**20**	B	**30**	D	**40**	C

MCQ 1: (D)
Reasoning:

Random errors cannot be eliminated but it can be reduced by averaging repeated measurements. By nature, random errors are of varying sign and magnitude.

MCQ 2: (A)
Reasoning:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\mathrm{g} = 4\pi^2\frac{l}{T^2}$$

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$$

$$= y + 2x$$

MCQ 3: (B)
Reasoning:

Since the area under the acceleration time graph is the change in speed and the initial speed of the object is zero, the biggest area under the graph will correspond to the largest speed. At B, the area under the graph is the largest, following which the area is negative which means that the speed decreases from B.

MCQ 4: (B)
Reasoning:

Using: $\boldsymbol{v^2 = u^2 + 2as}$

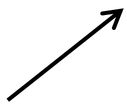
$15^2 = 20^2 + 2a\,(70)$

$a = -1.25\ m\ s^{-2}$

$0^2 = 15^2 + 2a(x)$

$x = 90\ m$

MCQ 5: (D)
Reasoning:
The resultant of the two forces 3 N and 4 N will be 5 N pointing in this direction.



Hence the resultant of all three forces will then be 1 N pointing in the similar direction.

MCQ 6: (A)
Reasoning:
The 3 forces acting on the rod is weight, *F* and the hinge force

For equilibrium, all 3 forces must pass through a common point (concurrent) and form a closed triangle.

MCQ 7: (A)
Reasoning:
By Hooke's Law,

$$mg\sin\theta - f = ke$$
$$e = \frac{3.00(9.81)(\sin 25) - 2.0}{500}$$
$$= 0.0208m$$

MCQ 8: (C)
Reasoning
For elastic collision,
Relative speed of approach = relative speed of separation
$v_2 - v_1 = u_1 - u_2$ (*where* the sign conventions of u_1, u_2, v_1, v_2 are to the right)

Hence $u_x - (-u_y) = v_y - (-v_x)$
$u_x + u_y = v_x + v_y$

MCQ 9: (A)
Reasoning:
Work done by friction = 60 x 10 = 600 J = Increase in internal energy

$$\Delta E_k + \Delta E_p + \Delta E_e = W_{supplied} - W_{dissipated}$$
Kinetic energy = 150(10) -600 – 100(10 sin 30) = 400 J

MCQ 10: (B)
Reasoning:
For each jet engine, $\dfrac{\text{Power output}}{\text{Power input}} = 0.80$

Power input = $\dfrac{\text{power output}}{0.8}$

Power input = $\dfrac{Fv}{0.8}$ where *F* = half of total thrust

Power input = $\dfrac{\left(\frac{1}{2} \text{ x } 200\,000\right)(250)}{0.8}$

$\approx$ 31.3 MW

MCQ 11: (A)
Reasoning:

$$F = MR\omega^2 = MR\left(\frac{2\pi}{T}\right)^2 = \frac{4\pi^2 MR}{T^2}$$

MCQ 12: (C)
Reasoning:
Net force acting on the satellite at that instant is now zero. Since the satellite is already moving with a speed tangent to the orbit, Newton's 1st law says that it will continue to move along the tangent to the orbit.

MCQ 13: (A)
Reasoning:

$$\phi = -\frac{GM}{\left(\frac{d}{2}\right)} - \frac{GM}{\left(\frac{d}{2}\right)} = -\frac{4GM}{d}$$

MCQ 14: (A)
Reasoning:

$$a = \frac{GM}{R^2} = \frac{G\rho V}{R^2} = \frac{G\rho(\frac{4}{3}\pi R^3)}{R^2} = \frac{4G\rho R\pi}{3}$$

$$a \propto \rho R$$

Since ρ and R is doubled, a' is 4a.

MCQ 15: (B)
Reasoning:
Frequency = 50/47 Hz

$KE_{max} = \frac{1}{2}m(\omega x_0)^2 = \frac{1}{2}m(2\pi f x_0)^2 = (0.5)(5.0 \times 10^{-3})(2\pi\ (50/47)(150 \times 10^{-3}))^2 = 2.5 \times 10^{-3}$ J

MCQ 16: (D)
Reasoning:
Amplitude, x_0 = 22/2 = 11 mm

When the point of needle is about to move downwards through the cloth, displacement of needle from origin is 3 mm.

$v = \omega\sqrt{x_o^2 - x^2} = (2\pi\ (4.5))(\sqrt{(11 \times 10^{-3})^2 - (3 \times 10^{-3})^2} = 0.299\ ms^{-1}$

MCQ 17: (C)
Reasoning:
The pulse reflects off the fixed support with a 180^o phase change. Hence, the reflected pulse superimpose with the incoming pulse to give a resultant pulse that is of a higher amplitude than before.

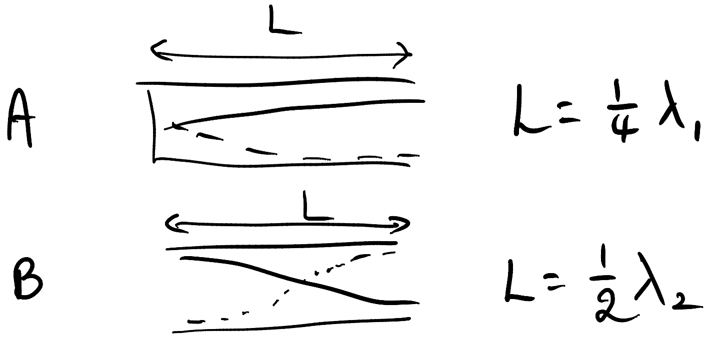
MCQ 18: (A)
Reasoning:

At T/4 seconds later, the wood is moving downwards at position A. The wood is oscillating vertically, not travelling to the right.

MCQ 19: (C)
Reasoning:

Maxima closest = Fringe separation, x, is the smallest
Using $x = \frac{\lambda D}{a}$
For same D, $x \propto \frac{\lambda}{a}$
Smallest $\frac{\lambda}{a}$ ratio is option C

MCQ 20: (B)
Reasoning:



For pipe A, $L = 1/4\ \lambda_1$
$\lambda_1 = 4L$
$f_1 = v/4L$

For pipe B, $L = ½\ \lambda_2$
$\lambda_2 = 2L$
$f_2 = v/2L = 2(v/4L) = 2f_1 = 2(220) = 440$ Hz

MCQ 21: (B)
Reasoning:

$$\Delta U = Q + W$$
$$= 80 - p(\Delta V)$$
$$= 80 - (1.0 \times 10^5)(0.2 \times 10^{-3})$$
$$= 60 \text{ J}$$

MCQ 22: (C)
Reasoning:

The temperature at which boiling occurs for a liquid is dependent on whether the molecules of the liquid have sufficient energy to completely overcome the force of attraction between the molecules in the liquid state as well as to do work against atmospheric pressure. Hence the pressure exerted on the liquid surface will affect the boiling temperature.

MCQ 23: (B)
Reasoning:

By definition.

MCQ 24: (D)
Reasoning:

Option A is wrong because electric charge needs to be quantized
Option B is wrong because gravitation potential cannot be positive
Option C is wrong because electric field strength at a point due to the two point charges should be proportional to the sum of the field strength due to the two charges.

MCQ 25: (A)
Reasoning:

Let r be resistance of R and S; then 0.5r is the resistance of R and S.
When bulb S blows, total circuit resistance increases from r/3 to r/2 → total circuit current decreases from I_o to $(2/3)I_o$.
Since current through each bulb unchanged, bulb brightness unchanged.

MCQ 26: (B)
Reasoning:

Current depends on the motion of both positive and negative charges.

Total charge flowing past a point in 1 minute

$$Q = 1.5\times10^{15}\times1.6\times10^{-19} + 4.4\times10^{15}\times1.6\times10^{-19}$$
$$= 9.44\times10^{-4}\ \text{C}$$

Total current = $\dfrac{Q}{t} = \dfrac{9.44\times10^{-4}}{60} = 1.57\times10^{-5} \approx 16\ \mu\text{A}$

MCQ 27: (B)
Reasoning:

The voltmeter and the 2.0 kΩ resistor has a combined equivalent resistance of 0.667 kΩ. The p.d. across the equivalent resistor can be determined using the potential divider principle, = $\dfrac{0.667}{0.667+1.5}$ x 10 = 3.07 V.

MCQ 28: (C)
Reasoning:

Adding a resistor in series with the secondary cell does not alter the balance length as no current flows through the resistor when the balance length is attained.

MCQ 29: (B)
Reasoning:

When the current and magnetic field are both on the horizontal plane and are perpendicular to each other, there is force and the force is vertical. When the current and magnetic field are parallel to each other, then there's no magnetic force. Force is zero.

MCQ 30: (D)
Reasoning:

Induced E is directly proportional to dB/dt, which is proportional to d*I*/dt.
d*I*/dt is the gradient of the given graph.

Consider one cycle:

For the first ¼ of the cycle, gradient becomes steeper, hence induced E increases.
For the second ¼ of the cycle, gradient becomes gentler, hence induced E decreases.
For the third ¼ of the cycle, gradient becomes steeper but is now negative, hence induced E increases in magnitude but reverse in direction.
For the fourth ¼ of the cycle, gradient becomes gentler, hence induced E decreases in magnitude.

MCQ 31: (C)
Reasoning:

The coil is turn over 180^o. The flux linkage therefore undergoes a change of 2AB.

$$\varepsilon_{ave} = \frac{\Delta\Phi}{\Delta t} = \frac{2AB}{t}$$

MCQ 32: (A)
Reasoning:

Since one particle has –q, the other particle must have +q charge as they separated from a neutral charge.
By COM, the two particles separated with the same speed, opposite direction. But since their charges are opposite, the magnetic force acting on them is the same. So, they will move along the same circle and meet after completing half a circle (half T)

$$F = Bqv = \frac{mv^2}{r}$$

$$r\omega = v = \frac{Bqr}{m}$$

$$\frac{2\pi}{T} = \frac{Bq}{m}$$

$$T = \frac{2\pi m}{Bq}$$

Therefore, time taken, ½ T is $\frac{\pi m}{Bq}$.

MCQ 33: (B)
Reasoning:

$$P_{generated\,(mean)} = V_{rms\ (generated)} I_{rms\ (generated)} = 120 \times 60 = 7200\ W$$

$$P_{generated\,(mean)} = V_{rms\ (transmission)} I_{rms\ (transmission)} = 4500 \times I_{rms\ (transmission)} = 7200\ W$$

$$I_{rms\ (transmission)} = 1.6\ A$$

$$P_{lost} = I_{rms\ (transmission)}{}^2 R = 1.6^2 \times 1 = 2.6\ W$$

Percentage power loss $= \dfrac{2.6}{7200} \times 100\% = 0.036\ \%$

MCQ 34: (A)
Reasoning:

When soft-iron core is removed, the magnetic flux linkage decreases. Thus induced emf decreases and the height of trace decreases. The number of cycles remains the same.

MCQ 35: (A)
Reasoning:

Sodium atoms will be excited after absorbing photon of certain frequencies from the beam of white light. These excited atoms will de-excite quickly to release photons in random directions.

MCQ 36: (C)
Reasoning:

As could be seen from the diagram, the energy transitions of excited atoms are the largest in Lyman Series, followed by Balmer Series and is the smallest in Paschen Series. Hence the frequency of photons emitted as a result of these transitions is the highest for Lyman Series and the lowest in Paschen Series. Since ultra-violet is the highest frequency, infra-red is the lowest frequency and visible light is in between, only option C is possible.

MCQ 37: (C)
Reasoning:

A: Incorrect. There is no donor energy level in an intrinsic semiconductor.
B: Incorrect. There are equal number of holes in the valence band and the electrons in the conduction band.
C: Correct. At very low temperature, a semiconductor behaves like an insulator.
D: Incorrect. Energy gap is around 1eV between the valence and conduction band.

MCQ 38: (D)
Reasoning:

A: Incorrect. The emitted photon will be of the same phase as the incident photon.
B: Incorrect. Not all photons can trigger stimulated emission; only photons of matching energy level can do so.
C: Incorrect. Only photons of matching energy level can trigger stimulated emission.
D: Correct. With photon of the correct energy, stimulated emission is just as likely to happen as stimulated absorption.

MCQ 39: (C)
Reasoning:

ratio of one sample is greater than the other by a factor of 16 (ie 2^4).
=> one sample has decayed 4 more half-lifes
=> The difference in age between the two samples is 4x 5740 = 22 960 yrs

MCQ 40: (C)
Reasoning:

background count, B + radioactive source count, R = 120 – eqn (1)
After one half-life, R would be halved. $\Rightarrow$ B + ½R = 64 – eqn (2)
(1) – (2): ½R = 56 $\Rightarrow$ R = 112 counts
B + 112 = 120 $\Rightarrow$ B = 8 counts
When a 5 mm thick lead is inserted between the α-source and the detector, R = 0 (alpha radiation blocked by lead), therefore only the background count can be detected.

Suggested Solutions to 2013 Prelim Paper 2 (H2 Physics)

1 **(a)** **(i)** $F = W - U$

$= 0.200(9.81) - (50x10^{-6})(1000)(9.81)$

$= 1.962 - 0.4905$ M1

$= 1.47N$ A1

(ii) Since $U = V\ell g$ and the density of oil is lesser than the density of water, upthrust experienced by the stone decreases given that the volume of liquid displaced remained unchanged. M1

Thus this would result in the force sensor reading to increase given that the weight of the stone remain unchanged. A1

(b) **(i)** The resultant force on the object must be zero *(translational equilibrium)* B1

The resultant torque on the object about any axis must be zero *(rotational equilibrium* B1

(ii) Taking moments about A,

$N_B \times 8.80 = 1.50 \times 2.00 + 3.50 \times 3.80$

$N_B = 1.85$ kN M1

Therefore, $N_A = 5.00 - 1.85 = 3.15$ kN A1

(iii) The gradient of a velocity – time graph is acceleration. Hence since acceleration can never be infinite, the gradient of a velocity-time graph cannot be a vertical line. B1

Acceleration on the other hand is proportional to force, hence if the acceleration-time graph is almost vertical, it would indicate that the force changes suddenly with respect to time. B1

2 **(a)** **Gravitational field strength** at a point in a gravitational field is defined as the gravitational force per unit mass acting on a body placed at that point. [B1]

(b) **(i)** Gravitational force provides for centripetal force.

$F = ma$

$\frac{GMM}{(2R)^2} = \frac{Mv^2}{R}$ [M1]

$v = \sqrt{\frac{GM}{4R}}$ [A1]

Note: Students must indicate either "Gravitational force provides for centripetal force" or "F = ma" if not minus 1

(ii)

$$v = R\omega = R\frac{2\pi}{T}$$ [B1]

$$R\frac{2\pi}{T} = \sqrt{\frac{GM}{4R}}$$ [B1]

rearranging,

$$T = \sqrt{\frac{16\pi^2 R^3}{GM}}$$

(c) **(i)** By conservation of energy,

$E_{total} = E_k + E_p$

$$= \frac{1}{2}(2M)\left(\frac{GM}{4R}\right) + \left(-\frac{GMM}{2R}\right)$$ [M1]

$$= -\frac{GM^2}{4R}$$ [A0]

(ii) From the equation, a loss of energy means that $-\frac{GM^2}{4R}$ decreases, hence, $\frac{GM^2}{4R}$ increases and R decreases. [M1]

From the equation for T, when R decreases, T decreases. [A1]

(iii)

$$T = \sqrt{\frac{16\pi^2 R^3}{GM}}$$

= 14721 s [M1]

time to crash = 14721 / (7x10^{-5}) [M1]
= 2.1 x 10^8 years [A1]

3 **(a)** **(i)** When the coil is rotating, there is a continuous change in the angle between the magnetic field and the area enclosed by the coil, thus the magnetic flux linkage is continuously changing. By Faraday's Law of Electromagnetic Induction, an e.m.f. is induced. [M1]

Since the induced e.m.f. is formed in a closed circuit, induced current will flow. [A1]

Note: Do not accept "flux cutting".

(ii) Angular velocity, ω = 2πf = 2π(50) = 100π
Magnetic flix linkage, Φ = NBA sin ωt (since at t = 0 s, Φ = 0 Wb)
= (30)(0.8)(2.5) sin (100πt)
= 60 sin (100πt)

Induced e.m.f., E = $-\frac{d\phi}{dt}$

$= -\dfrac{d[60\sin(100\pi t)]}{dt}$ [B1]

$= -100\pi(60)\cos(100\pi t)$

$= -6000\pi\cos(100\pi t)$

Current, $I = \dfrac{E}{R}$

$= -\dfrac{6000\pi\cos(100\pi t)}{40}$ [B1]

$= -150\,\pi\cos(100\pi t)$

$= -471\,\cos(100\pi t)$

(iii)

The series diode produce half wave rectification→ $I_{rms} = I_o/2$

Power dissipated = $(I_o/2)^2 \times R$ [M1]

$= (471/2)^2 \times 40 = 2220$ kW [A1]

(b) **(i)**

- As the conductor rotates through a small region of constant magnetic field directed into the conductor it experiences a change in magnetic flux linkage and therefore according to Faraday's Law an emf is induced. This generates eddy currents on its surfaces (perpendicular to the field of the permanent magnet) [M1]
- By Lenz's law these circulating currents produce a magnetic field that opposes the magnetic field produced by the permanent magnets. [M1]
- In the event the disc deviates from the axis XX', the repulsive force experienced by the surface closer to one magnet will be greater and thus restore the conductor to the central axis. [A1]

(ii) There is no contact between the electrodynamic bearing and the rotating part thus practically no wear and tear. Traditional ball bearings align through contact and therefore have a limited lifetime. [B1]

4 **(a)** **(i)** From graph, $\lambda_{min} \approx 35$ pm [C1]

$$\frac{p^2}{2m_e} = \frac{hc}{\lambda}$$

$$p = \sqrt{\frac{2m_e hc}{\lambda}}$$

$$= \sqrt{\frac{2(9.11\times10^{-31})(6.63\times10^{-34})(3.0\times10^{8})}{35\times10^{-12}}}$$ [M1]

[A1]

$= 1.02\times10^{-22}$ N s

(ii) The rate of emission of the electrons from the cathode can be increased (by increasing the temperature of the heating element) while keeping the accelerating potential constant. [A1]

This will increase the number of electrons incident on the target per unit time, which will in turn increase the rate of production of the X-ray photons. [M1]

(b) **(i)** Existence of the *L* lines suggest that the photons emitted during the de-excitation of the electrons to the *L* shell are of higher energy (hence they are X-rays), compared to those emitted by the old target atoms. [M1]

This indicates that the energy gaps between the levels are greater due to the stronger attraction of the nucleus. [M1]

Hence, the new target has a larger atomic mass. [A1]

(ii) The variations in the wavelengths of the photons are due to the variations in the energies of the photons emitted. [A1]

OR

This is due to the uncertainty in the energy levels of the atom (Heisenberg Uncertainty Principle)

5 **(a)** Stimulated emission is triggered by an external photon whereas spontaneous emission happens on its own accord. [B1]

(b) **Laser:** Stimulated emission [B1]
Incandescent bulb: Spontaneous emission
Award [1] if both are correct.

(c) In laser, the emitted photons from stimulated emission have the same frequency and phase as incident photons. These emitted photons will trigger further stimulated emission causing a cascading effect, producing photons that have constant phase difference, i.e. coherent light. [B1]

In the candescent bulbs, the randomly emitted photons from spontaneous emission will have different direction and phase independent of each other. Hence the photons will have different phase, i.e. incoherent light. [B1]

(d) When light from the laser is directed through a diffraction grating onto a screen, an interference pattern is obtained on the screen. However no such pattern is seen when a filament bulb is used. [B1]

(e) Any one of the following:
Light from laser is monochromatic. [B1]
Light from laser is highly directional.
Light from laser has high intensity.

6 **(a)** energy transferred, E = power x time
= 250 x 8.0 x 60 x 60
= 7.2×10^6 J [C1]

heat gained, $E = mc\Delta\theta$, if heat loss to surrounding is negligible

$c = E / (m\Delta\theta)$ [M1]
= 7.2×10^6 / (20)((500-20)
= 750 J Kg^{-1} K^{-1} [A1]

(b) heat gained by water, $Q_w = m_w c_w \Delta\theta_w$
= $(1.2 \times 4.2 \times 10^3)(100-20)$
= 4.03×10^5 J [M1]
≈ 4.0×10^5 J

heat loss by the pebble, $Q_p = m_p c_p \Delta\theta_p$ [M1]
= (20)(750)(500-460)
≈ 6.0×10^5 J

Efficiency, η = $[Q_w / Q_p]$ x 100% [M1]
= (4.0×10^5/ 6.0×10^5) x 100 %
= 67 % [A1]

(c) average power output $P_o = Q_p / \Delta t$
= 6.0×10^5 / (12 x 60)
= 830 W [A1]

(d) rate of air flow = $(\Delta M_a/\Delta t)$
= volume flow rate x density
= (1.5×10^{-3}) x (1.3)
= 1.95×10^{-3} kg s^{-1} [M1]

power output , P_o= mean energy gained by air per unit time [M1]
= $(\Delta M_a c_a \Delta\theta_a)/\Delta t$

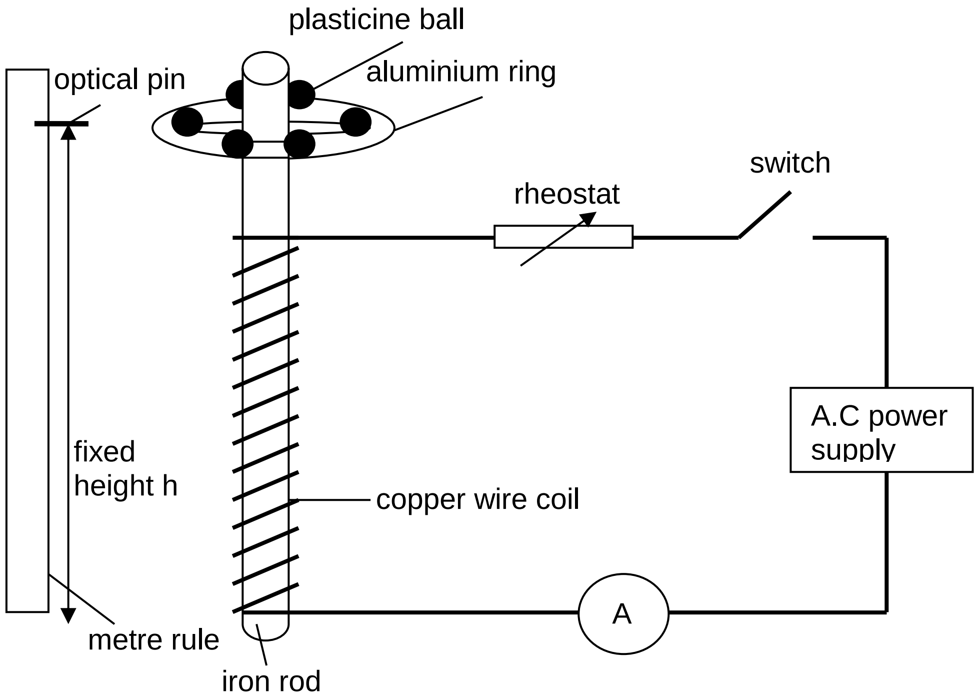
mean rise in the temperature of air :
$\Delta\theta_a$ = $P_o / (\Delta M_a/\Delta t)(c_a)$
= (830)/ (1.95×10^{-3})(990)
= 430 °C [M1]

Since initial temperature of air = 20 °C
mean temperature of heated air = 430 + 20 [M1]
= 450 °C [A0]

(e) When the heated air is at temperature of 150 °C,
Power output $P'_o = (\Delta M_a/\Delta t) c_a \Delta\theta'_a$
= (1.95×10^{-3})(990)(150-20) [M1]
= 250 W [A1]

(f) One improvement is to recycle the spent air by rechanneling the warm air leaving the hob to the air inlet port of the stove. [B1]

7 Diagram



- Set up the experiment as shown in the diagram.
- Ensure that the ruler and iron rod are vertical by using a set square to check. [R]
- Set the rehostat to maximum value and set the A.C. power supply to a suitable value.
- Turn on the ciruit and check the height *h* that an unloaded aluminium ring is able to attain. Adjust the power supply so that *h* is a suitable value for easy measurement. [R]
- Fix this height by using an optical pin as a marker and turn off the circuit. [R]
- Prepare a number of plasticine balls of equal mass, using an electronic balance to measure.
- Add some some plasticine balls on the aluminium ring, ensuring that they are evenly distributed. Measure the mass *M* of the plasticine balls and the aluminium ring using the electronic mass balance.
- Turn on the switch and adjust the rehostat so that the aluminium ring can reach the fixed height *h*. Record the current value as *I*.
- Repeat the experiment for 5 further values of *M*.
- Plot a graph of *I* vs *M* to show how the current in the coil vaires with load *M*.

Control Variables

- Number of turns of the coil must be kept constant.
- Aluminium ring used must be the same throughout.
- Power supply to be kept constant.

Reliability

- Ensure that aluminium ring is horizontal before taking measurement to increase accuracy.

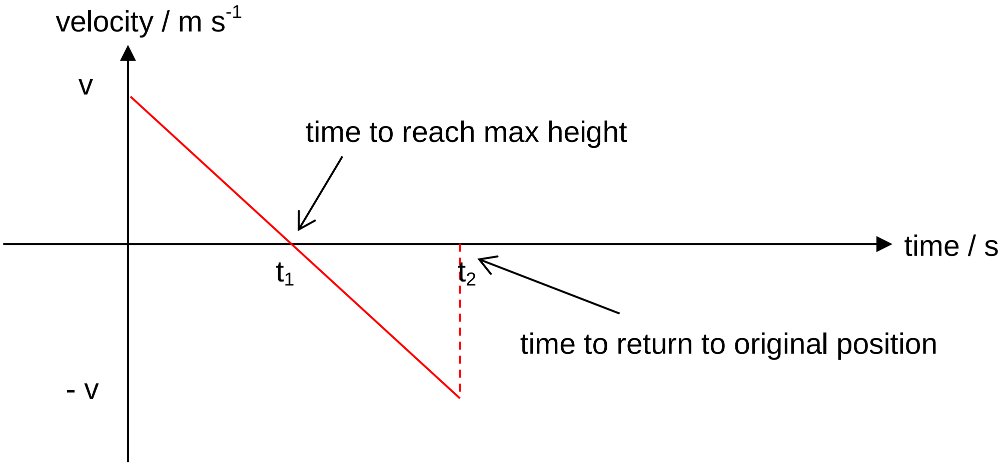
Safety Precautions

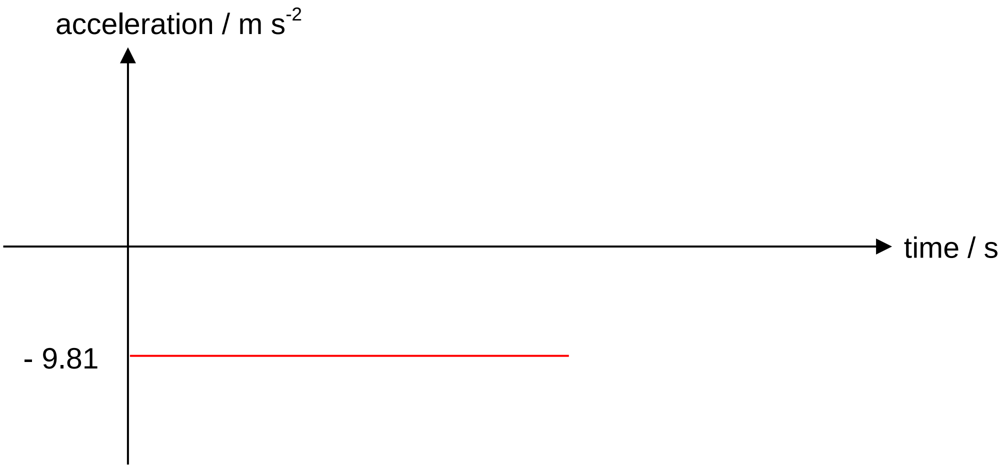
- Set rheostat to max value before starting to ensure that current value is not too big to damage the electrical components.
- Coil can be heated up after prolonged use – care must be taken when handling coil during experiment

Item	**Description**	**Marks awarded**
Basic **P**rocedure [2]	• Varying load on aluminium ring using a suitable method. • Raising aluminium ring to fixed height.	P1 P1
Diagram [2]	• Suitable experiment set-up showing the following: ○ Correct circuit components and connections ○ Method of measuring and fixing height ○ Correct arrangement of the coil and aluminium ring	D1 D1
Method of • Varying and Measuring/ Determining the IV. • Measuring/ determining the DV • Analysing the data [3]	• (IV) Varying load on aluminium ring by adding plasticine balls of equal mass • (DV) Measure current flow using ammeter • Plotting of graph of current vs load	M1 M1 M1
Control of other **V**ariables [1]	• Number of turns of the coil must be kept constant • Aluminium ring used must be the same throughout • Power supply to be kept constant	max 2
Other details (**R**eliability) [3]	• Ensure that aluminium ring is horiztonal before taking measurement • Ensure that the no.of turns of the coil is sufficient to create a strong enough B-field to left the aluminium ring to a measureable height • Using an optical pin to aid in the measurement of height • Ensure that rod and ruler are vertical	max 2
Safety **P**recautions [1]	• Set rheostat to max value before starting • Coil can be heated up after prolonged use – care must be taken when handling coil during experiment	max 1

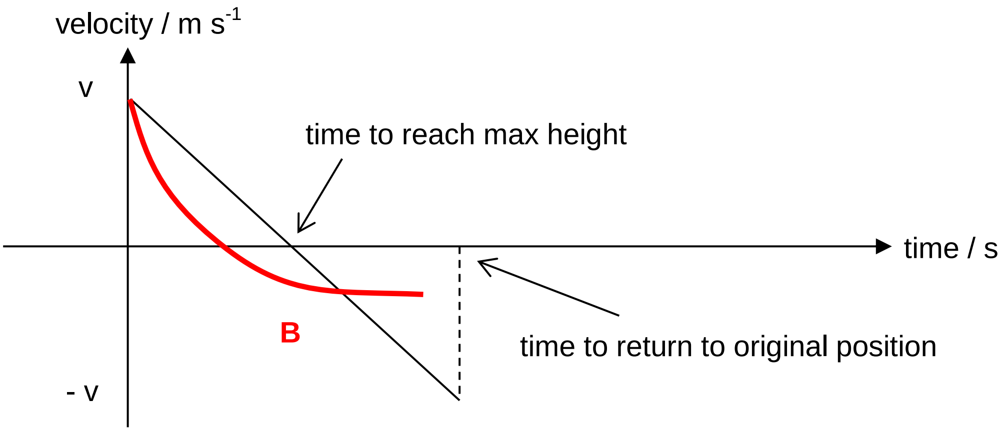
Suggested Solutions to 2013 Prelim Paper 3 (H2 Physics)
Section A

1 (a)





[M1] shape of v-t and label of v
[A1] correct labelling of times on v-t graph
[A1] correct shape of a-t graph with correct sign based on v-t graph.



[B1] shape of graph: gradient of velocity steeper at start, then becomes gentler till v=0 gradient is parallel to original graph, then gradient continues to become gentler.

[B1] time taken to reach max height shorter than time to return to original position.
Note: a max of 1 mark can be awarded for graphs without label provided everything is correct.

(c) (i) $s_y = u_y t + ½ a_y t^2$

$-0.80 = 5 \sin\theta\, t - \frac{1}{2} \times 9.81 \times t^2$ --- (1) [B1]

$s_x = u_x t + \frac{1}{2} a_x t^2$
$1.00 = 5.0 \cos\theta\, t$ --- (2) [B1]

(ii)

sub (2) in terms of t in (1)

$-0.80 = \tan\theta - 0.1962(1/\cos\theta)^2$

Using the relationship given($\frac{1}{\cos^2\theta} = 1 + \tan^2\theta$)

$-0.80 = \tan\theta - 0.1962\,(1 + \tan^2\theta)$
$-0.80 = \tan\theta - 0.1962 - 0.1962 \tan^2\theta$

$0.1962 \tan^2\theta - \tan\theta - 0.6038 = 0$ [M1]

$\tan\theta = 5.64227$ or -0.545431 (rej) [M1]

$\theta = 79.9^o$ [A1]

2 (a) Let v_A = final velocity of ball A
v_B = final velocity of ball B

Taking rightwards to be positive
By conservation of momentum,

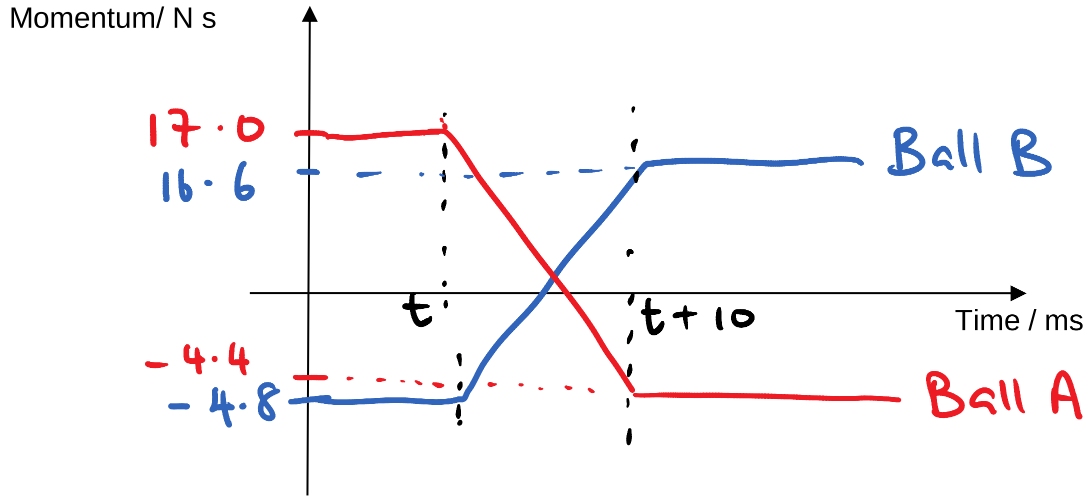
$m_A u_A + m_B u_B = m_A v_A + m_B v_B$
$1.7(10.0) - 1.6(3.0) = 1.7 v_A + 1.6 v_B$ --(1) [M1]
velocity of approach = velocity of separation
$10.0 - (-3.0) = v_B - v_A$
$v_B = 13.0 + v_A$ --(2) [M1]

Solving both equations (1) and (2)
$V_A = -2.61\ ms^{-1}$
$V_B = 10.4\ ms^{-1}$

Final speed of ball A = $2.61\ ms^{-1}$
Direction of travel of ball A = towards the left

Final speed of ball B = $10.4\ ms^{-1}$ [A1]
Direction of travel of ball B = towards the right

(b) (i)



M1 for correct shape
A1 for correct labels (for p of both balls and time)

N.B if both graphs are not labeled, no marks will be awarded.

(ii) A horizontal straight line drawn on the above graph with vertical intercept at 12.2 N s. [B1]

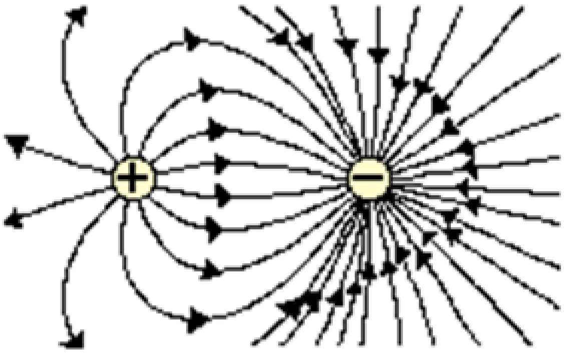
(iii) Some of the kinetic energy is converted to elastic potential energy as the balls are deformed during the impact. [M1]

Hence the total kinetic energy does not remain constant throughout the entire duration of impact. [A1]

N.B – the total kinetic energy of the two balls is still conserved because the elastic potential energy is converted back to kinetic energy when the balls separate.

(iv) If collision is inelastic, there would be loss of energy and the total kinetic energy of the system is not conserved. [M1]
Hence the final speed of ball A and ball B would be lesser than calculated in (a). [A1]

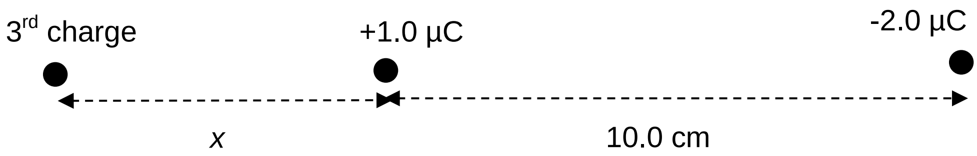
3 (a) (i)



B1 mark for labelling of charges and arrows clearly shown, with the correct direction (field-lines need to be shown all around the charges).

B1 mark for showing that it is non-symmetrical and that the no of field-lines for both charges are not equal.

(ii)



$$\frac{(1.0\times10^{-6})q}{4\pi\varepsilon_0 x^2}=\frac{(2.0\times10^{-6})q}{4\pi\varepsilon_0(0.10+x)^2}$$ M1

$$0.10+x=\sqrt{2}x$$

$$x=0.10/(\sqrt{2}-1)=0.24\text{ m}$$ A1

Note: student needs to clearly indicate if x is to the left or right of the positive charge.

(b) (i) The path taken by both charges would be <u>circular.</u> B1
The path taken by the positive charge would be <u>opposite in direction</u> to that of the negative charge. B1
The <u>radius of the path</u> taken by the positive charge, which is lesser in magnitude, would be <u>greater</u> than that of the negative charges. B1

(ii) The component of the velocity perpendicular to the field will result in a <u>centripetal force perpendicular to the motion</u> whereas the <u>component of the velocity parallel to the field will provide for a horizontal displacement</u>. B1

Hence the path taken would now be <u>helical</u>. B1

(c) A <u>**moving**</u> charged particle of mass m and charge +q is placed within a region where <u>both a uniform electric field and a uniform magnetic field act perpendicular</u> to one another. B1

The charge experiences an electrostatic force, F_E and an electromagnetic force, F_B B1 acting in opposite direction.

If the magnitudes of the forces exerted by the two fields are equal, the resultant force on the particle will be zero, and it will travel in a straight line undeflected.

$F_B = F_E$

$Bqv = qE$ [B1]

$v = \frac{E}{B}$

OR

B1

Hence, for a particular value of the electric field strength E and magnetic flux density B, only particles travelling with a velocity equal to the ratio of E to B, will be able to travel undeflected between the two plates.

⇨ This is the principle used in a velocity selector.

4 (a) (i) Energy released in a reaction

$= (4(1.007825) - (4.002603 + 2(0.000549))\text{u}\,c^2$

$= 0.027599\text{uc}^2$ [M1]

$= 0.028697(1.66\times10^{-27})(3 \times 10^{8})^2$

$= 4.1233 \times 10^{-12}$ J

= 25.8 MeV [A1]

(ii) Let the energy emitted out by the sun per unit time be E,

$1.35\times10^{3} = \frac{E}{4\pi(1.5\times10^{11})^2}$ [M1]

$E = 3.817 \times 10^{26}$

Rate at which a hydrogen is converted

$= 4\,[3.817 \times 10^{26} / 4.1233 \times 10^{-12}]$ [M1]

$= 3.70 \times 10^{38}$ [A1]

(b) (i) Energy released in a nuclear reaction is equal to the difference in binding energies between the products and the original reactants. [B1] From graph, the steeper slope of the binding energy curve for lighter nuclei indicates that the change in binding energy in fusion is larger , compared to that for fission reactions. [B1] [2]

(ii) A very high temperature is required to enable fusion to occur AND High pressure to overcome electrostatic repulsion. They must be within 1×10^{-15} meters of each other to fuse. [1]

Section B

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

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

$$= \frac{5.60 \times 10^{-8} \times 0.005}{0.005 \times 0.001}$$ [M1]

$$= 5.60 \times 10^{-5}\ \Omega$$ [A1]

(ii) The resistor ensures that the current from the supply is a maximum

$I = \dfrac{6.3}{10} = 0.63$ A OR

$I = \dfrac{6.3}{10 + 5.60 \times 10^{-5}} \approx 0.63$ A [M1]

Without the series resistor, the current drawn from the supply might be too large thus damaging the supply.

OR

Without the resistor, supply experiences a short circuit [A1]

(b) **(i)** At 2000 °C, J = 40000 A m^{-2} [C1]

Current extracted from cathode = 40000 x 0.005 x 0.005
= 1.0 A [B1]

(ii)

$$Q = I \times t = N \times e$$

$$N = \frac{I \times t}{e}$$ [M1]

$$= \frac{1 \times 60}{1.60 \times 10^{-19}}$$ [A1]

$$= 3.75 \times 10^{20} \text{ electrons}$$

(iii)

Melting point of Tungsten [B1]

When the tungsten melts the cathode is damaged. The emission of electrons stops and the gun system does not work

(c) Energy of a single electron, $E_e = e \times V_{acc}$

Number of electrons hitting target per sec, $\dfrac{N}{t} = \dfrac{I}{e} \times (0.2)$ [M1]

Energy delivered per second (Power) = $\frac{N}{t} \times E_e$

$$= \frac{I}{e} \times (0.2) \times e \times V_{acc}$$

$$= I \times V_{acc} \times 0.2$$ [M1]

$$= 10 \times 100 \times 10^3 \times 0.2$$

$$= 2.0 \times 10^5 \text{ W}$$ [A1]

OR

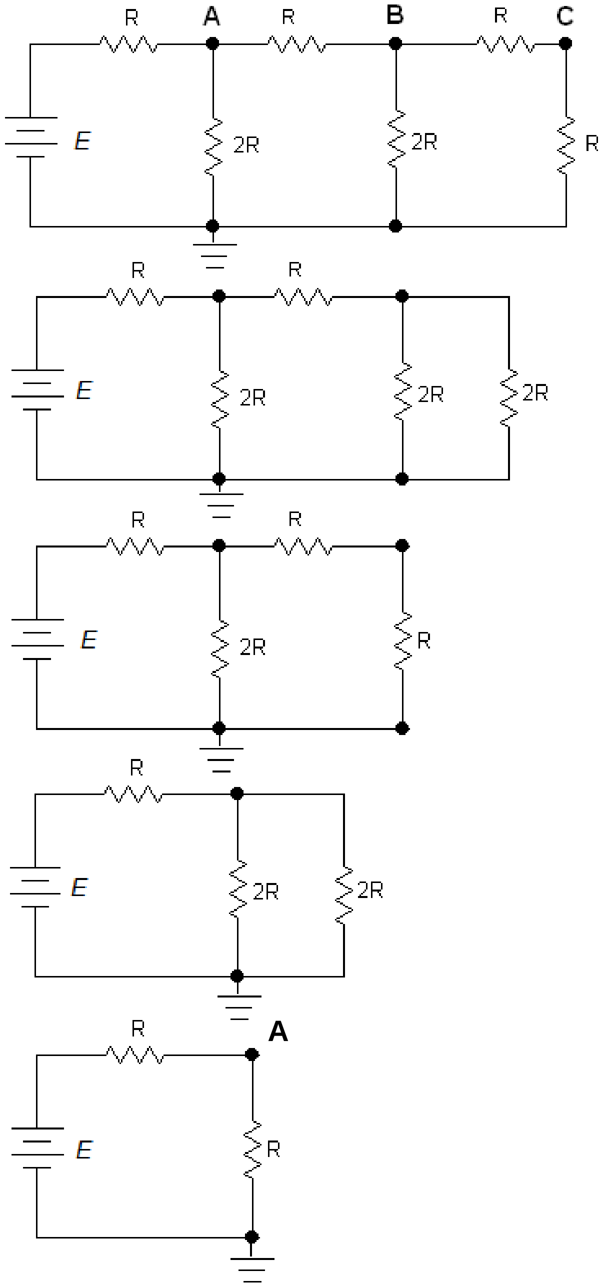
[M1]

$$P_{mean} = I_{mean} \times V_{mean}$$

$$= 2 \times 1 \times 10^5$$

$$= 2 \times 10^5 \text{ W}$$ [A1]

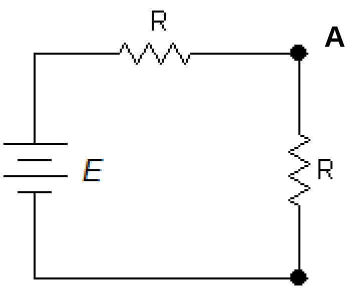
(d) **(i)**



Effective Resistance = 2*R*

[B2]

(ii) Equivalent Circuit



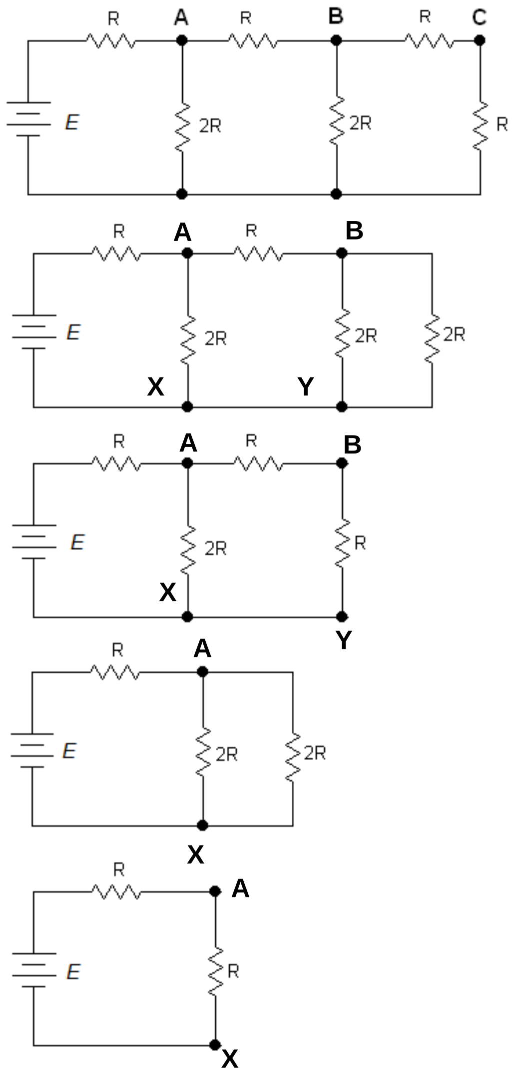
[M1]

Emf *E* is divided equally between the two resistors R.

[M1]

$V_A = E/2$ [A0]

(iii)



Since $V_{AX} = E/2$, [M1]

$V_{AB} = 1/2 \times E/2 = E/4 = V_{BY}$ [A1]

$V_B = E/4$

$V_X = V_y = 0$

Potential difference across point **AX**

$V_{AX} = E/2$

Solution viewed in this direction

(iv)

Recognize the sequence

	E/2,	*E*/4,	*E*/8	*E*/16	*E*/32	*E*/64
At point	**A**	**B**	**C**	**D**	**E**	**F**

[M1]

[A1]

$V_F = E/64$

6 (a) (i) Using Hooke's law, F = k. Δx
300 x g = k (0.01)
k = 294300 N m^{-1} [C1]

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = (\frac{1}{2\pi}\sqrt{\frac{294300}{1800}})$ [M1]

$= 2.035068 = 2.04$ Hz [A1]

(ii) Resonance occurs when the driving frequency of passing over the bumps equals to the natural frequency of the car, [B1]

resulting in the car oscillating at maximum amplitude when there is maximum energy transfer from the driver to the system. [B1]

(iii) When amplitude is maximum, driving frequency = natural frequency,

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

$v = \frac{\text{distance between adjacent humps}}{T}$

$= (\frac{1}{2\pi}\sqrt{\frac{294300}{1800}})(18)$ [M1]

$= 36.6\, m\, s^{-1}$ [A1]

Note: to deduct 1 mark if student write v = fλ

(iv) If passenger is removed from the car, the mass decreases and by $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, the natural frequency of the car increases. The amplitude of vibration also increases for the same power provided. [B1]

(v) Suspension system of a car is designed so that it experiences critical damping so that the car system will return to the equilibrium position in the shortest possible time without oscillating after passing a hump. [M1]

This is to ensure that the passengers experience as little vibrations over as short a period of time. [A1]

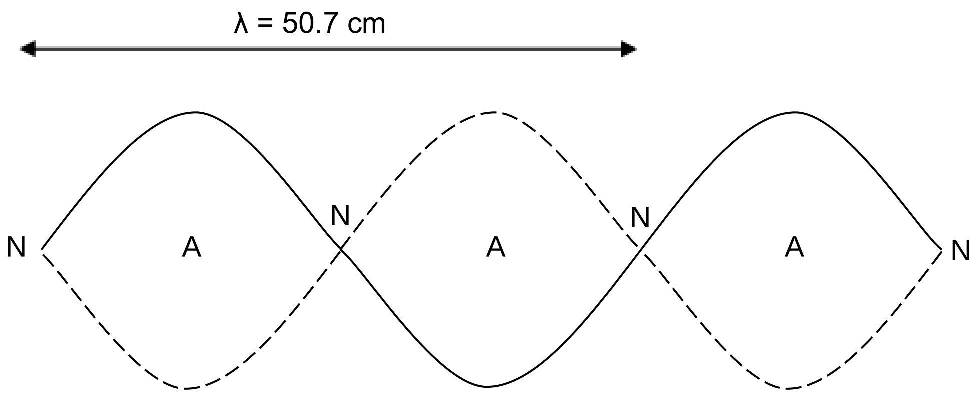
Or

This is for the safety of the passengers as well as their comfort when overcoming road humps.

(b) **(i)** There is a magnetic field acting perpendicular to the current carrying conductor which causes a magnetic force perpendicular both the field and the current. [M1]

As the current alternates, the direction of force also changes with the frequency of the current, setting up an oscillatory motion in the wire [A1]

(ii) 1.



Correct shape (dotted line required) with labelled wavelength at the correct position [B1]

Labelled all positions of all nodes & antinodes [B1]

2.

λ = (76/3)*2 = 50.6666666666

$f\lambda = \sqrt{\frac{T}{m}}$ [M1]

$(50)(50.7x10^{-2}) = \sqrt{\frac{6}{m}}$ [A1]

m = 9.35 x 10^{-3} kg m^{-1}

(c) $\lambda = \frac{xd}{D} = \frac{(2.03x10^{-3})(0.50x10^{-3})}{1.50}$ [M1]

= 6.77 x 10^{-7} m

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta x}{x} + \frac{\Delta d}{d} + \frac{\Delta D}{D}$$

$$\frac{\Delta\lambda}{6.77x10^{-7}} = \frac{0.01}{2.03} + \frac{0.01}{0.50} + \frac{0.01}{1.50}$$ [M1]

Δλ = 0.214 x 10^{-7} m
= 0.2 x 10^{-7} m [M1]

$\lambda = (6.8 \pm 0.2)x10^{-7}$ m (correct s.f and d.p.) [A1]

7 (a) (i) *hf* : Energy of a (one) photon of frequency f incident on the metal surface
Φ : Work function of the metal surface
E_k :Maximum kinetic energy of a (one) photoelectron emitted from the

metal surface

[B2]: All three correct
[B1]: Two of three correct

(ii) Conservation of Energy [B1]

By conservation of energy, the maximum kinetic energy of a photoelectron is equal to the energy gained by absorbing a photon, less the work done for it to escape from the metal surface.

(iii) **1** $\frac{hc}{\lambda} = \phi + eV_s$

$\frac{(6.63\times10^{-34})(3.0\times10^{8})}{(300\times10^{-9})(1.6\times10^{-19})} = 2.03 + V_s$ [M1]

$V_s = 2.11\text{ V}$ [A1]

2 Power of beam, P = (0.500)(4.5 x 10^{-5}) = 2.25 x 10^{-5} W

Number of incident photons per unit time, n_p

$n_p = \frac{P\lambda}{hc}$

$n_p = 3.39\times10^{13}\text{ s}^{-1}$ [M1]

Photoelectic Current $I = \frac{N_e e}{t}$

$= (0.5n_p)e$

$= (0.5)(3.39\times10^{13})(1.6\times10^{-19})$ [M1]

$= 2.71\times10^{-6}\text{ A}$ [A1]

(b) **(i)** Electrons have a wave-like nature. [B1]

(ii) Kinetic energy of electron at wall, E_k = 600 eV = 9.6 x 10^{-17} J [M1]

Momentum of electron at wall, p

$p^2 = 2mE_k$

$p = \sqrt{2(9.11\times10^{-31})(9.6\times10^{-17})}$ [M1]

$= 1.32\times10^{-23}\text{ N s}$ [A0]

(iii) de Broglie wavelength λ of electron at wall

$= \frac{h}{p}$

$= \frac{6.63\times10^{-34}}{1.32\times10^{-23}}$

$= 5.01\times10^{-11}\text{ m}$ [M1]

[M1]

$d = \frac{\lambda D}{a}$ [A1]

$= \frac{(5.01\times10^{-11})(0.240)}{272\times10^{-9}}$

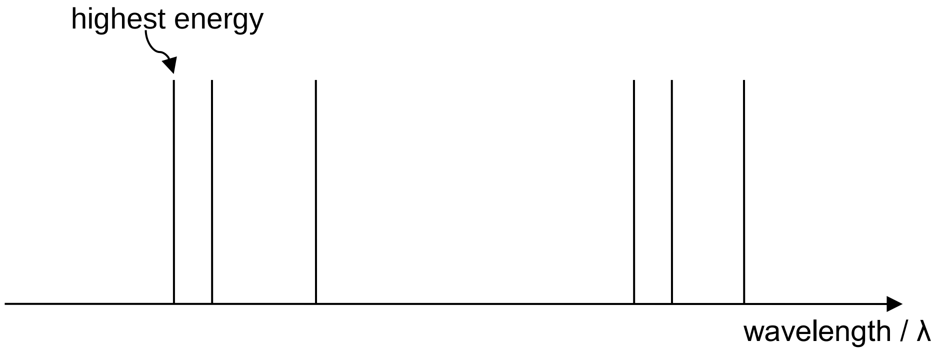
$= 4.42\times10^{-5}$ m

(c) **(i)** ionisation energy = **13.6 eV** [B1]

(ii) Energy levels X can attain ≤ 12.8 – 13.6 = – 0.80 eV
Hence highest energy level that can be attained is – 0.85 eV [M1]

Number of wavelengths = number of discrete transitions
= $^4C_2$
= 6 [A1]

(iii)



- Correctly labels the highest energy line as the leftmost line
- 3 lowest and 3 highest wavelengths clustered as shown.
- Correct relative spacing between wavelengths within each cluster.

[B2] – All three shown
[B1] – Two of three shown
Note': ecf from (ii) can only be given if answer in (ii) is 10, corresponding to highest energy level attained is – 0.54 eV

(iv) Energy of highest energy photon
= – 0.85 – (–13.6)
= 12.75 eV = 2.04 x 10^{-18} J

$E = \frac{hc}{\lambda}$

$2.04\times10^{-18} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{\lambda}$ [M0]

$\lambda = 97.5$ nm [A1]