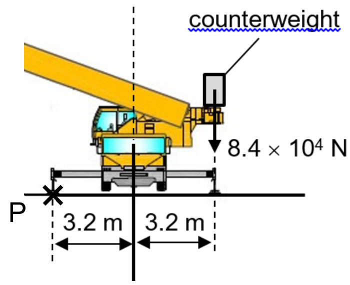
2019 Preliminary Examinations H2 Physics Paper 3 Solutions

1 (a) The moment of a force about a point is defined as <u>the product of the force and the perpendicular distance</u> from <u>the point to the line of action of the force.</u> B1 B1

(b) (i) B1



(ii) The <u>weight of the load produces an anti-clockwise moment about P</u>. B1
The counterweight produces <u>an additional clockwise moment</u> that can balance the moment due to heavier loads. B1

(iii) Taking moments about P,
$W \times (20 - 3.2) + 5.0 \times 10^4 \times (7.6 - 3.2)$ M1
$= 3.5 \times 10^5 \times 3.2 + 8.4 \times 10^4 \times (3.2 + 3.2)$ A1
$W = 8.56 \times 10^4$ N

Marker's Comments:
1 (b) (iii) The normal contact force acting on the crane at P is unknown. Students who apply the principle of moments about any other position needs to include this normal contact force in their equation to obtain the correct answer.

2 (a) The gravitational potential at a point is the <u>work done per unit mass</u> by an external force in bringing a small test mass from <u>infinity to that point</u>. B1 B1

*B1 is not awarded if student wrote:
- energy instead of work done
- object instead of mass

(b) *There are a few ways to get x, the easiest way is to equate the gravitational field strengths due to Earth and Moon because at Q, the resultant gravitational field strength is zero.

$$g_{\text{Earth}} = g_{\text{Moon}}$$

$$\frac{GM_E}{x^2} = \frac{GM_M}{\left(3.8\times10^8 - x\right)^2}$$ M1

$$\frac{3.8\times10^8 - x}{x} = \sqrt{\frac{M_M}{M_E}}$$

$$3.8\times10^8 - x = \sqrt{\frac{7.4\times10^{22}}{6.0\times10^{24}}}x$$ M1

$$x = 3.4\times10^8 \text{ m}$$

OR

$$\phi_Q = \phi_M + \phi_E$$

$$-1.3\times10^{6} = -\frac{GM_M}{3.8\times10^{8}-x} + \left(-\frac{GM_E}{x}\right)$$ M1

$$-1.3\times10^{6} = -\frac{(6.67\times10^{-11})(7.4\times10^{22})}{3.8\times10^{8}-x} + \left(-\frac{(6.67\times10^{-11})(6.0\times10^{24})}{x}\right)$$ M1

$$x = 3.4\times10^{8}\text{ m}$$

(c) **(i)** The resultant force due to Earth and Moon on the satellite provides the centripetal force.

$$F_{\text{net}} = F_C$$

$$1.22 = mr\omega^2$$ M1

$$1.22 = (520)(d)\left(\frac{2\pi}{27\times24\times60\times60}\right)^2$$ M1

$$d = 3.2\times10^{8}\text{ m}$$

Or (this method is too time consuming to solve)

$$F_{net} = F_{\text{Earth}} - F_{\text{Moon}}$$ M1

$$1.22 = \frac{GM_E m}{d^2} - \frac{GM_M m}{(3.8\times10^{8}-d)^2}$$

$$1.22 = (6.67\times10^{-11})(520)\left(\frac{6.0\times10^{24}}{d^2} - \frac{7.4\times10^{22}}{(3.8\times10^{8}-d)^2}\right)$$ M1

$$d = 3.2\times10^{8}\text{ m}$$

(ii) $\phi_{total} = \phi_E + \phi_S$

$$= -\frac{GM_E}{d_E} + \left(-\frac{GM_M}{d_M}\right)$$ C1

$$= -\frac{(6.67\times10^{-11})(6.0\times10^{24})}{(3.2\times10^{8})} - \frac{(6.67\times10^{-11})(7.4\times10^{22})}{(3.8\times10^{8}-3.2\times10^{8})}$$ M1

$$= -1.33\times10^{6}\text{ J kg}^{-1}$$ A1

*1 mark if student only found the potential due to the Earth or the Moon.

(c) The minimum energy required should be the difference in potential energy between Q and **(c)(ii)**. Or the energy required should be just enough to reach Q. B1

Marker's Comments:

2 **(b)** As this is a show question, you just need to show the expression followed by the proper substitution. After that, you can use your calculator to get the final answer. You do not need to show the mathematical steps on how you arrive at your final answer.

Do note that for show questions, you need to show all substitution values instead of leaving them in notations e.g. for mass of Earth, you need to show 7.4 × 10^{22} instead of leaving it as M_E.

You are not advised to prove by substituting the value that you are supposed to show and conclude that the left hand side of the equation is equal to the right hand side.

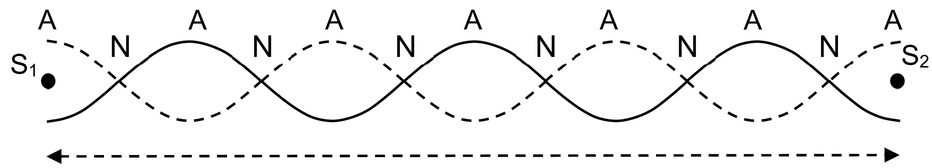
(c) **(i)** Similar comments as **2(b)**.

(ii) There are several students who did not know that gravitational potential is ALWAYS negative and left out the negative sign in their calculations.

The total gravitational potential due to Earth and Moon at the location of the satellite is the additional of the gravitational potential due to Earth alone and the potential due to Moon alone. Many students found the difference instead.

3 **(a)** **(i)** A stationary wave is formed when two progressive waves of the same frequency (wavelength), speed and amplitude, moving along the same line towards each other, meet and superpose. B1 B1

(ii) **1.**

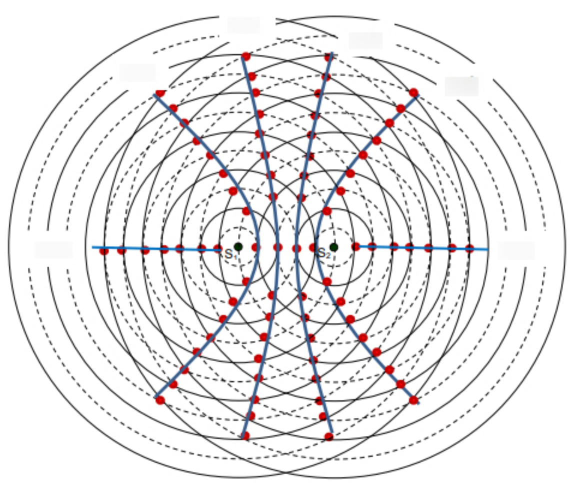


shape of wave M1 (antinode at S_1 and S_2)
correct label M1

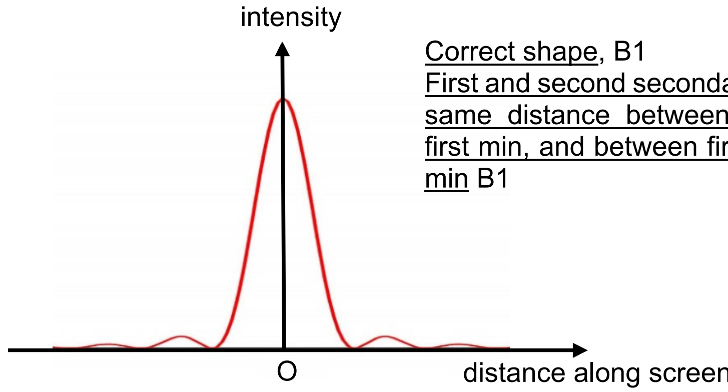
2. **(i)** At M, the path difference between the two microwaves reaching M is the separation between S_1 and S_2, which is equal to 0.12/0.040 = 3 wavelengths. Hence the waves will produce a constructive interference and an intensity maximum is formed at M. M1 A1

*in fact, M is at the position of 3rd order maximum.

(ii) Either (2× 4) + 4 (due to two 0th orders and two 3rd orders) = 12 B1
OR (5 × 2) + 2 = 12
*5 Antinodes correspond to 5 antinodal lines, and 2 more along S_1S_2 line



(b) (i)



Correct shape, B1
First and second secondary maxima shown; same distance between central max and first min, and between first min and second min B1

(ii) $\sin\theta = \dfrac{\lambda}{d}$

for very small angles $\sin\theta \approx \tan\theta$

$$\tan\theta = \frac{\left(\dfrac{2.3\times10^{-3}}{2}\right)}{1.2} \approx \frac{\lambda}{d} = \frac{550\times10^{-9}}{d}$$ B1

$\therefore d = 5.74\times10^{-4}$ m

Marker's comments:

3 (a) (i) Conditions required to form a stationary wave were generally not well stated. Quite a few students gave the conditions to form an observable interference pattern instead.

(ii) 1. Very very few students scored 2/2 for this part.
Common mistakes were:
- Majority drew nodes at S_1 and S_2 instead of antinodes.
- Quite a few students did not draw the stationary wave correctly (that is, one solid curve, and one dotted curve of opposite phase).
- Forgot to label A and N for antinodes and nodes.
- Labelled A and N wrongly
- Wrong number of half-wavelength segments between the two sources.

2. (i) Generally well done for this part. Some students took 0.18 m as the path difference, and deduced a minimum instead (no ecf for this.)

(ii) Very few students got the correct answer of 12 maxima.

3 (b) (i) Very few well-drawn curves.
Should include the two secondary maxima as well, with equal spacing between the centre and the 1st minimum, and between the 1st and 2nd minimum. The intensities of the secondary maxima should be much lower than the central maximum.
(Do refer to your lecture notes for the correct drawing.)

(ii) Not many showed clear working using correct equations.

On the whole, this question was not well scored.

4 **(a)** The First Law of Thermodynamics states that the increase in the internal energy of a system is equal to the sum of the heat supplied to the system and the work done on the system, B1
and the internal energy of a system depends only on its state. B1

(b) **(i)** Work done by gas = $p \times \Delta V = 1.00 \times 10^5 \times (4.00 - 2.00) \times 10^{-3}$ M1
$= 200$ J A1

(ii)

change	work done on gas / J	heat supplied to gas / J	Increase in internal energy / J	
A to B	310	0	**310**	B1
B to C	**0**	– 610	– **610**	B1
C to A	– **200**	**500**	**300**	B1

Marker's Comments:

4 **(a)** This part was not very well-answered. If "change in internal energy" is used, then "the change in internal energy is equal to the sum of the heat transfer to/from the system and the work done on/by the system". So its easier to just say "increase in internal energy".
Some students forgot to include the 2nd part "the internal energy of a system depends only on its state".

(b) **(i)** Some students forgot to write "work done = $p\Delta V$"
(ii) This part was generally alright.

5 **(a)** The resistance of a resistor is defined as the ratio of the potential difference across it to the current flowing through it. B1

(b) **(i)** Since the value of *R* is **comparable** to the resistance of the voltmeter, only a fraction of 1.50 mA flows through it. A1

(ii) $R_{eff} = \dfrac{3.00}{1.5 \times 10^{-3}} = 2000\ \Omega$ M1

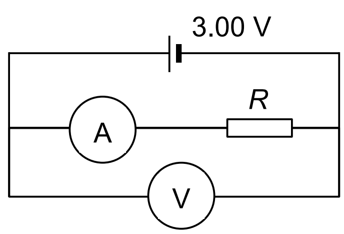
Therefore,

$$2000 = \frac{R \times 6000}{R + 6000}$$ M1

$$2000R + 1.2 \times 10^6 = 6000R$$

$$R = 3000\ \Omega$$ A1

(iii)



A1

(c) **(i)** $V_{AB} = \dfrac{10}{10+5} \times 3.00$ M1

$V_{AB} = 2.00$ V A1

(ii) $\dfrac{AJ}{AB} = \dfrac{V_{AJ}}{V_{AB}}$

$$\frac{AJ}{100} = \frac{\dfrac{3000}{3000+2000} \times 1.5}{2.0}$$ M1

A1

$AJ = 45$ cm

Or:

Current flowing through $R = \dfrac{1.50}{5000} = 3.00 \times 10^{-4}$ A

Hence, p.d. across $R = 3.00 \times 10^{-4} \times 3000 = 0.900$ V M1

Therefore,

$$\frac{AJ}{AB} = \frac{0.900}{2.0}$$ A1

$AJ = 45$ cm

Marker's Comments:

5 **(a)** Students should note that that when they use the word "ratio" it should followed by "of A to B" and **not** "of A over B" or any other way of expressing it.

We accepted "ratio between A and B" but this is a more layman way of putting it.

Do note that you should not use "voltage" instead of "potential difference" in the explanation.

(b) **(i)** It is important to note that a voltmeter can have finite resistance and yet gives off accurate reading as long as its resistance is much higher than the resistance of the resistor that it is measuring. Hence students who stated that the voltmeter is not ideal or has finite resistance are not awarded 1 mark.

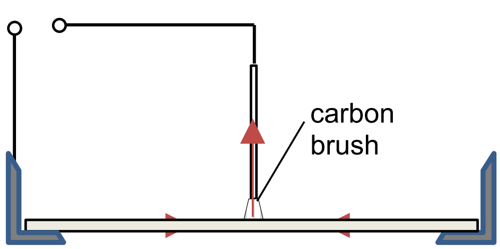
Many students stated that the resistance of the voltmeter is not negligible. This is wrong as the statement infers that an ideal voltmeter should have zero resistance.

(ii) Generally well done.

(c) Generally well done.

6 **(a)** One tesla is the uniform magnetic flux density which when acting normally to a long straight wire carrying a current of one ampere, B1
causes a force per unit length of one newton per metre. B1

(b) **(i)**



Arrow upward through the brush, and each arrow on the rod pointing radially inwards towards the brush. B1

(ii) Using Flemings' left hand rule, and referring to Fig 6.1, the rod to the left of the brush will experience a magnetic force upwards, B1
while the rod to the right of the brush experiences a force of equal magnitude downwards. M1
This causes a turning effect/torque about the carbon brush and hence the rod rotates in a clockwise direction. A1

(iii) Current flows radially from the guide towards the brush.
Current in one half section of the rod = 1.5 A

$F = BIL$

$\frac{F}{L} = BI = (0.56)(1.5)$ M1

$= 0.84 \text{ N m}^{-1}$ A1

Use 3.0 A, obtain one mark

(iv) When the field is rotated, the force per unit length on the wire decreases and is given by F/L = $BI\cos\theta$, where θ is the angle between B and the vertical axis, and the force is unable to overcome the friction between the edges of the rod and the guide. B1

Marker's Comments:

6 (a) Answers that implied that one Tesla is a force or force per unit length is a wrong concept and hence was not awarded any marks.

The force per unit length is induced/produced by having a current carrying conductor at an angle with the magnetic field.

(b) (i) Many students did not read the question properly and hence drew arrows at the wrong parts of the diagram or even on the wrong diagram.
Many also neglected the right side of the rod, implying that there was no current on that end despite it also being connected to the metal rail.

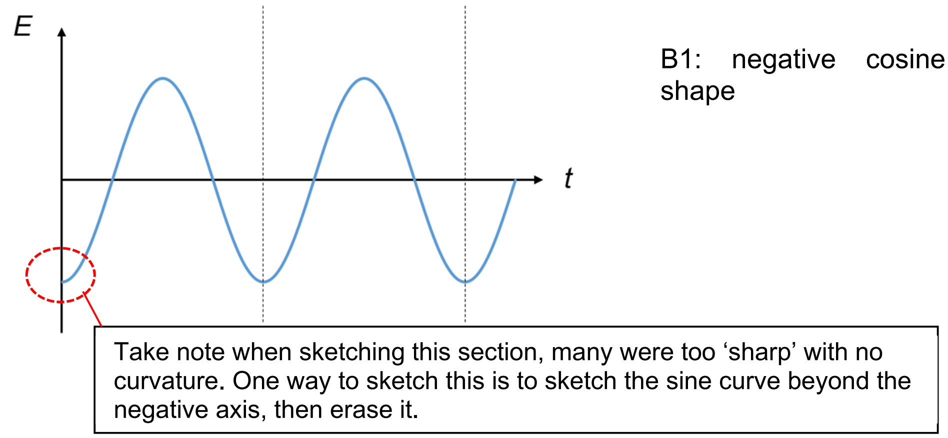
(ii) Many students managed to explain that there was an upward force on the left side of the rail but neglected to mention the opposite for the right side.
A resultant force acting on the object will cause the object to accelerate in the direction of the force, hence it is insufficient to conclude that the rod will rotate just because it experiences an upward force.
The carbon brush is not an axle and does not restrict the center of the metal rod to a fixed position.
Another common misconception was that the clockwise rotation was due to Lenz' Law, but this would cause an anti-clockwise moment to counter the change in flux.
There is also no such thing as a "clockwise" force or a "clockwise current in the rod". The rod is straight, not circular.

(iii) The current provided in the question is the combined current from the metal rail, through the rod and then up the brush. This means that the current through the rod is 1.5 A.

(iv) There was a common misconception that once the field is not perpendicular to the rod (or current), there will be no force.
Many students correctly pointed out the the magnetic force reduces to zero once the field is parallel with the rod and assumed that only then will the rod stop rotating but forgot to think about external forces like friction.

7 **(a)** **(i)** As the coil rotates, the perpendicular component of the magnetic flux density to its area changes which results in a changing magnetic flux linkage. A1
By Faraday's law, this results in an induced e.m.f..

(ii)



B1: negative cosine shape

(b) **(i)** The root-mean-square voltage is the value of the steady/constant/direct voltage that produces thermal energy at the same rate / same power dissipation in a resistor. B1 B1

(ii)
$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$
$$V_S = \left(\frac{600}{12}\right)(2.3) \quad \text{M1}$$
$$= 115 \text{ kV} \quad \text{A1}$$

(iii) Stepping up the voltage will reduce the current in the transmission wires.
This reduces the power loss in the transmission lines since $P = I^2R$ / due to joule heating. B1

Markers' Comments

(a) **(i)** Well done. Students are to note that it there are any contradictory/incorrect statements with in their answers, no credit will be awarded.

(ii) Many students sketched a positive cosine graph instead, and also did not sketch a full graph, stopping after 2 waveforms. Please be reminded that the graph has to curve properly close to the axis (refer to comment in diagram above).

(b) **(i)** Generally well done. Note that "rate of power dissipation" is incorrect.

(ii) Very well done, with some making calculation errors or errors in units. A fair number do not realise that the values provided are already r.m.s. values and go on to multiply/divide by $\sqrt{2}$. Some students end up wasting time by converting V_{rms} to V_0 to subsequently converting back to r.m.s. values.

(iii) Generally well done. Many students did not explain the advantage, but only 'stated' that it was to 'reduce power loss'. "Power loss" alone was not accepted. Power loss via joule heating or dissipation of heat in wires, as well as current is being reduced in transmission wires, is required for full credit.
Note: Current is reduced as P = VI, with power being constant. (no credit awarded for wrong physics if student stated that current is reduced due to V=IR).

8 **(a)** The rate of change of momentum of a body is proportional to the resultant force acting on it and occurs in the direction of the force. B1 B1
(Do not accept "equal" instead of "proportional".)

(b) **(i)** impulse $= F_{net}\Delta t = 0.0050 \times 30 = 0.15$ N s B1

(ii)
$p_{ini} = p_{ini}^{truck} + p_{ini}^{rain} = mu + 0 = 1.0 \times 0.20 = 0.20$ N s
$p_{fin} = p_{ini} + \Delta p = 0.20 + 0.15 = 0.35$ N s B1

(iii) **1.** $m_{fin} = m_{ini} + \Delta m = 1.0 + 0.0325 \times 30 = 1.975 = 1.98$ kg B1

2. $v = \dfrac{p_{fin}}{m_{fin}} = \dfrac{0.35}{1.975} = 0.1772 = 0.177 \text{ m s}^{-1}$ B1

3. The velocity (to the right) is decreasing. M1
Hence, the average acceleration is to the left (opposite to the direction of the velocity). (accept backwards) A1

4. When the rain drops are collected in the cargo compartment, a forward force (to the right) acts on them by the truck. C1
By Newton's Third Law, an equal and opposite force (to the left) acts on the truck by the rain drops. M1
This force is larger than the driving force. Hence, the net force acting on the truck is to the left. By Newton's Second Law, the acceleration of the toy truck is also to the left. A1

(c) **(i)** **1.** $F_{net} = -kx$ (accept $F_{net} = kx$) B1

2. According to Newton's Second Law,
$F_{net} = ma = -kx$
$a = -\dfrac{k}{m}x \equiv -\omega^2 x$ with $\omega = \sqrt{\dfrac{k}{m}}$ B1

3. The negative sign indicates that the acceleration and the displacement are opposite in direction. B1
(accept – acceleration is always directed to the equilibrium position)

(ii)
$\omega = \sqrt{\dfrac{k}{m}} = \sqrt{\dfrac{2.0}{0.10}} = 4.47 \text{ rad s}^{-1}$ M1

$f = \dfrac{\omega}{2\pi} = \dfrac{4.47}{2\pi} = 0.712$ Hz A1

(iii) The sphere will oscillate with the maximum amplitude when the frequency of the driving force is equal to that of the natural frequency of the system (i.e. at resonance):

$$\text{frequency} = \frac{\text{speed}}{\text{distance between two nearby obstacles}}$$ C1

$$\Rightarrow \text{distance between two nearby obstacles} = \frac{\text{speed}}{\text{frequency}} = \frac{5.0}{0.712} = 7.02 \text{ m}$$ A1

(iv) The rain absorbed changes the mass m of the sphere, hence the natural frequency of the sphere-spring system, given by $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, is changed. M1

Hence the system is no longer in resonance, and the system will oscillate with a smaller amplitude. A1

Markers' Comments

(a) Many answers missed the keyword 'net' or 'result'. Some switched the order by saying force is proportional to rate of change of momentum. Some left out the part on the direction of the change of momentum.

(b) **(iii)** **4.** Many answers referred to the resistive force between the wheels and the surface, or that between parts of the toy truck, or even the air resistance, which the question had specified as negligible. If such forces existed, calculations on momentum and speed in the previous parts would all be wrong. One of the assumptions of this question is precisely that such resistive forces are negligible.

The toy truck will slow down in the absence of those resistive forces, because of the force between the toy truck and the raindrops. One characteristic of this force is that it is not accumulative, i.e. the force between the raindrops and the truck will not increase simply because more raindrops are collected. This is because once the raindrops have been accelerated to the same speed as the truck, no horizontal force exists between them and the truck. Instead, this force depends on the rate at which the raindrops are collected, and their eventual change in velocity, but not on the total mass collected.

(c) **(i)** **2.** One has to understand that the negative sign between the acceleration and the displacement is not due to a sign convention. (In other words, the negative sign exists regardless of sign convention chosen.) Instead, it indicates that the two vectors, namely the acceleration and the displacement, are always opposite in direction.

3. Please refer to the comments in **(c)(i)(2)**.

(iii) Some used the formula $v = f\lambda$, which does not apply here, because there are no waves in this question, hence no wavelength to talk about.

(iv) There is no damping here. A damping force (such as air resistance) must resist (be in the opposite direction of) the motion of the oscillating object at all times. This is not true of the additional weight due to the raindrops absorbed.

Some students confused the natural frequency of oscillation and the actual frequency of forced oscillation. In forced oscillation, the frequency, hence the period, are those of the driving force. In this question, the natural frequency of the system decreases, but the actual frequency and period remain unchanged, because the driving force remain unchanged.

9 **(a)** A photon is a quantum/packet of electromagnetic energy (radiation). B1

(b) **(i)** The line emission spectrum has discrete coloured (bright) lines on a dark background. B1 B1

(ii) When an electron de-excites, a photon is emitted with energy ΔE, where ΔE is the difference in energy of the 2 energy levels, B1

where $\Delta E = hf = \frac{hc}{\lambda}$. B1

As only light of specific wavelengths/frequencies are emitted, it shows that energy levels are discrete. B1

(c) **(i)** 10 B1

(ii) ultraviolet B1

(iii)
$$\Delta E = E_4 - E_1 = \frac{hc}{\lambda}$$
$$= \frac{(6.63 \times 10^{-34} \times 3.0 \times 10^8)}{97.5 \times 10^{-9}}$$ M1
$$= 2.04 \times 10^{-18} \text{ J}$$
$$= \frac{2.04 \times 10^{-18}}{1.6 \times 10^{-19}}$$
$$= 12.75 \text{ eV}$$
$$E_4 = E_1 + \Delta E = -0.85 \text{ eV}$$ A1

(iv)
$$E_\infty - E_1 = \frac{hc}{\lambda}$$
$$[0 - (-13.6)] \times 1.6 \times 10^{-19}$$ B1
$$= \frac{(6.63 \times 10^{-34} \times 3.0 \times 10^8)}{\lambda}$$ B1
$$\lambda = 91.4 \text{ nm}$$

(d) **(i)**
$$13.6 \text{ eV} = \text{work function} + eV_s$$
$$\text{work function} = 13.6 - 8.13$$ M1
$$= 5.47 \text{ eV}$$ A1

(ii) max kinetic energy of photoelectrons $= 8.13$ eV
$$8.13 \times 1.6 \times 10^{-19} = \frac{p^2}{2 \times 9.11 \times 10^{-31}}$$ M1 A1
$$p = 1.5395 \times 10^{-24} = 1.54 \times 10^{-24} \text{ N s}$$

(iii)
$$p = \frac{h}{\lambda}$$ M1
$$1.5395 \times 10^{-24} = \frac{6.63 \times 10^{-34}}{\lambda}$$
$$\lambda = 4.31 \times 10^{-10} \text{ m}$$ A1

(v) $\Delta p \Delta x \geq h$

$$9.11\times10^{-31}\times1.2\times10^{6}\times\frac{0.0025}{100}\times\Delta x \geq 6.63\times10^{-34}$$ M1

$\Delta x \geq 2.43\times10^{-5}$ m A1

Markers' Comments

(a) Many candidates did not mention the keyword "electromagnetic" in their answers.

(b) (i) Some candidates mentioned "bright white lines" which is incorrect.

(b) (ii) Most candidates failed to mention the relationship between energy of photon to the wavelength or frequency of the photon.

(c) (iv) Many candidates failed to realise the most energetic photon is emitted due to the transition from E_∞ to E_0.

(d) This part was generally well answered.