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MARKSCHEME

May 2012

PHYSICS

Higher Level

Paper 2

18 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) through Scoris™, by e-mail or telephone – if through Scoris™ or by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through Scoris™ or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of Scoris™, please contact emarking@ibo.org.

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1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use Scoris™ annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

5. Personal codes/notations are unacceptable.

6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, enter a zero in the mark panel on the right-hand side of the screen. Where an answer to a part question is worth no marks because the candidate has not attempted the part question, enter an "NR" in the mark panel on the right-hand side of the screen.

7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. Scoris™ will only award the highest mark or marks in line with the rubric.

8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp "seen" on any page that contains no other annotation.

9. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the "CON" stamp.

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[45 marks]** and **TWO** questions in Section B **[2 % 25 marks]**. Maximum total = **[95 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional.

2. Each marking point has a separate line and the end is shown by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect).

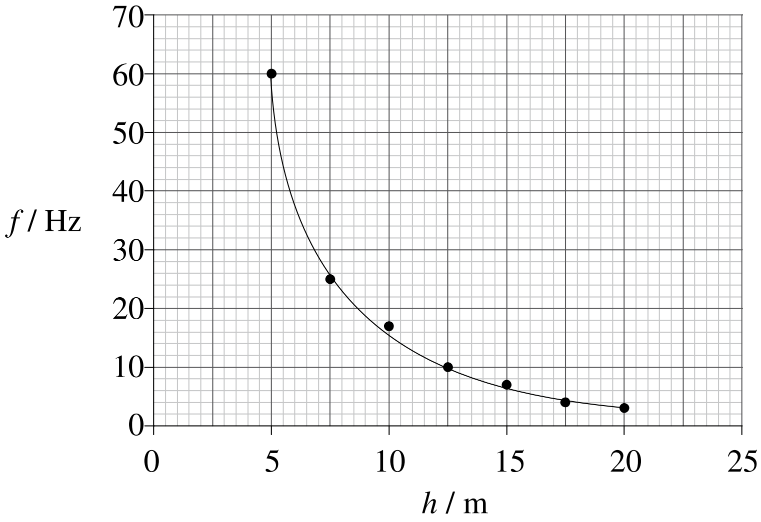
8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

SECTION A

A1. (a)



smooth curve as above; *(judge by eye)* ***[1]***
Do not allow point-to-point curve.
Do not allow curve to "curl round" at low or high h.
Single "non-hairy" line only is acceptable.

(b) choice of points separated by $(\Delta h \geq 7.5)$ *e.g.* [6.0, 37] [15, 6.0];
recognize $fh=$constant for an inverse relation;
calculates fh correctly for both points;
state that two calculated numbers are not equal (therefore not inverse); ***[4]***
Award ***[3 max]*** *if data points are not on line.*
Award ***[3 max]*** *if data points are too close together* $(\Delta h \geq 7.5)$.
Award ***[2 max]*** *if both of above.*

(c) (i) a straight-line that goes through all the error bars;
and drawn through the origin; *(allow* $\pm\frac{1}{2}$ *square)* ***[2]***

(ii) read-off of suitable point(s) on line separated by at least half of drawn line; *(allow implicit use of origin)*
calculation of gradient to give $1.5(\pm 0.2)\times 10^{3}$;
$\text{s}^{-1}\,\text{m}^2$ ***or*** $\text{Hz}\,\text{m}^2$; ***[3]***

(d) the relation might not hold/extrapolate for larger values of h / outside range of experiment / values would be close to origin and with large (percentage experimental) error / girders of this height could buckle under their own weight / *OWTTE*; ***[1]***

A2. (a) average speed is the speed over a period of time/distance;
instantaneous speed is the speed at a particular instant in time/point in space; ***[2]***

(b) (i) speed = (area under graph =) $\frac{1}{2} \times 7.5 \times 3$;
$= 10$ ***or*** 11 ***or*** $11.3\ \mathrm{m\,s^{-1}}$; ***[2]***

(ii) suitable curve approximating to $v = kt^2$; ***[1]***

A3. (a) (i) *nuclide*:
(a species of atom that is characterized by) the constitution of its nucleus / the number of protons and neutrons in the nucleus *OWTTE*;

isotope:
nuclides with the same proton number but different nucleon/neutron numbers; ***[2]***

or

atoms of the same element that have different numbers of neutrons/neutron number;

(ii) alpha particle / helium nucleus / $^{4}_{2}\mathrm{He}$; ***[1]***

(b) protons repel/break nucleus apart;
binding energy/strong force holds nucleus together;
neutron excess / n : p ratio is greater in lead therefore overall balance of forces is more attractive / (magnitude of) binding energy per nucleon is greater in lead / binding energy per nucleon more negative in lead than uranium; ***[3]***

A4. (a) point molecules / negligible volume;
no forces between molecules except during contact;
motion/distribution is random;
elastic collisions / no energy lost;
obey Newton's laws of motion;
collision in zero time;
gravity is ignored; ***[2 max]***

(b) (i) the molecular weight of argon in grams / 6.02×10^{23} argon atoms / same number of particles as in 12 g of C-12; *(allow atoms or molecules for particles)* ***[1]***

(ii) mass of gas $= 0.040\,\text{kg}$;

specific heat $= \dfrac{Q}{m\Delta T}$ ***or*** $620 = 0.04\times c\times 50$; *(i.e. correctly aligns substitution with equation)*

$= \left(\dfrac{620}{0.040\times 50} = \right) 310\,\text{J kg}^{-1}\,\text{K}^{-1}$; ***[3]***

A5. (a) the work done per unit charge;
when a small/test/point positive charge; *(charge sign is essential)*
is moved from infinity to the point; ***[3]***

(b) (i) perpendicular / at right angles / at 90° / normal; ***[1]***

(ii) $V = \frac{8.99\times10^9 \times 4.00\times10^{-6}}{2.78}$ ***or*** $1.2935\times10^4\,\text{V}$; *(use of* $\frac{1}{4\pi\varepsilon_0}$ *gives* *1.29378×10^4)*

$(\approx 1.29\times10^4\,\text{V})$ ***[1]***

(iii) difference in potential $=\left(7.20\times10^4 - 1.29\times10^4 =\right) 5.91\times10^4$;
required loss in kinetic energy/minimum kinetic energy to reach sphere $=\left(0.032\times10^{-6}\times5.91\times10^4 =\right)1.89\times10^{-3}\,\text{J}$;
available kinetic energy $=\left(\frac{1}{2}\times1.20\times10^{-4}\times3.50^2 =\right)7.35\times10^{-4}\,\text{J}$;
not enough (initial) kinetic energy to reach sphere; ***[4]***
Response needs some statement of conclusion, e.g. so it does not reach sphere.
Allow answer in terms of minimum speed to reach sphere $5.61\,\text{m s}^{-1}$.

A6. (a) (i) electrons are moving at right angles to the magnetic field;
electrons experience a force directed along the rod / charge is separated in the rod;
the work done by this force to achieve this separation leads to an induced emf; ***[3]***

(ii) the product of magnitude of field strength and the rate at which the area is swept out by the rod is changing / the rate at which the rod cuts through field lines; ***[1]***

(b) (i) $B = \frac{\varepsilon}{vl}$; *(must see the data book equation re-arranged or correctly aligning substitution with equation)*

$=\left(\frac{15\times10^{-3}}{6.2\times1.2} =\right)2.0\,\text{mT}$; *(accept 2+ sf)* ***[2]***
*To award **[2]** both steps must be seen.*

(ii) Lenz's law states that the direction of the induced emf/current is such as to oppose the change producing it;
there is a current in the rod due to the induced emf;
the force on the current/rod due to the magnetic field is in the opposite direction to the force producing the motion of the rod; ***[2 max]***

SECTION B

B1. Part 1 Fields, electric potential difference and electric circuits

(a) (i) the force exerted on a small/test/point mass; ***[1]***
Do not allow bald "gravitational force".

(ii) the force exerted on a small/point/test positive charge; ***[1]***
*To award **[1]** "positive" is required.*
Do not allow bald "electric force".

(iii) the size/magnitude/value of the small/point mass; ***[1]***
Do not accept bald "mass".

(iv) the magnitude/size/value of the small/point/test (positive) charge; ***[1]***
Do not accept bald "charge".

In part (a) only penalize lack of "small/test/point" once, annotate as ECF.
It must be clear that the mass/charge in (iii) & (iv) refer to the object in (i) and (ii).

(b) $E_{\text{p}} = \dfrac{e}{4\pi\varepsilon_0 r^2}$ and $g_{\text{p}} = \dfrac{Gm_{\text{p}}}{r^2}$; *(both needed)*

$\dfrac{e}{4\pi\varepsilon_0 Gm_{\text{p}}}\left(= \dfrac{9\times10^{9}\times1.6\times10^{-19}}{6.7\times10^{-11}\times1.7\times10^{-27}}\right)$;

$\approx 10^{28}$; ***[3]***

*Award **[2 max]** if response calculates ratio of force as this is an ECF from the first marking point* $\left(10^{39}\right)$.

*Award **[3]** for solution that correctly evaluates field strengths separately and then divides.*

(c) $V = \dfrac{1.9\times10^{-18}}{1.6\times10^{-19}}$;

$= 12\,\text{V}$; ***[2]***

(d) (i) ratio potential difference/voltage (across resistor) to current (in resistor) / $\frac{V}{I}$ with symbols defined; ***[1]***

(ii) pd across $R = \frac{1.44\times10^{-18}}{1.6\times10^{-19}} = 9.00\,\text{V}$;
pd across internal resistance $= 12.0 - 9.00\,(= 3.00\,\text{V})$;
current in circuit $= \left(\frac{3.00}{5.00} =\right) 0.600\,\text{A}$;
$R = \frac{9.00}{0.600}$;
$(= 15.0\,\Omega)$ ***[4]***

(iii) $7.20\,\text{W}$; ***[1]***

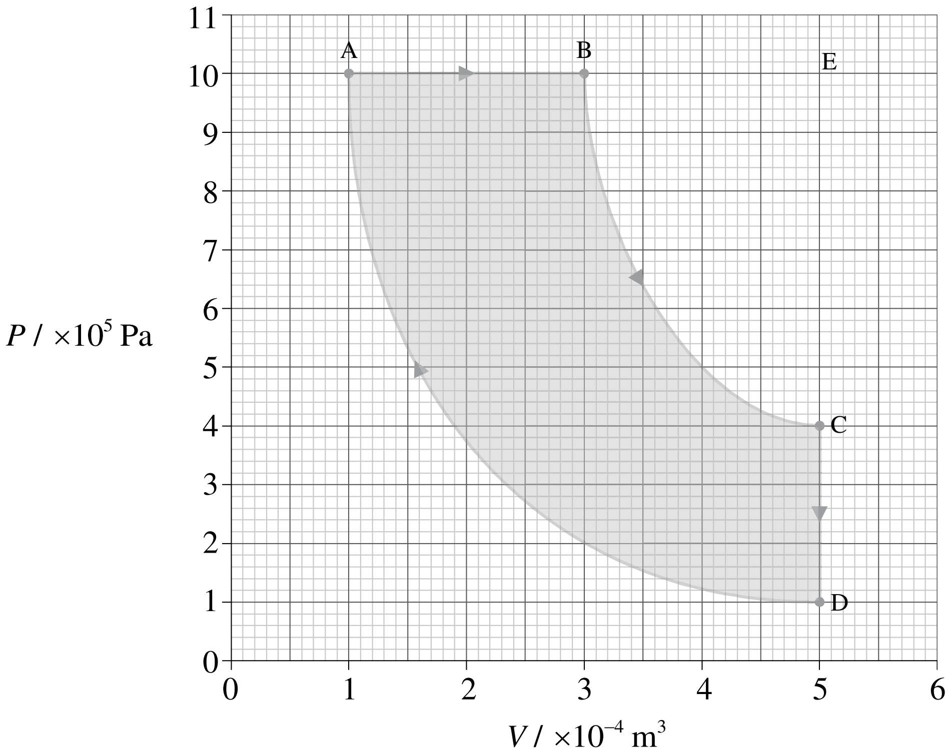
Part 2 Thermodynamic cycles

(a) (i) low pressure;
high temperature; *[2]*

(ii) no thermal/heat energy is transferred (in change of state); *[1]*
Allow "heat energy" but not "heat".

(b) work is done (by the gas) because there is an increase in volume/gas expands;
so W is positive;
ΔU is greater than zero (because P is constant and V increases);
from first law $Q = \Delta U + W$ means that Q is positive which means energy transferred into gas; *[4]*

(c)



total work done = enclosed area / number of large squares ~ 40 (±5);
1 square = 5 J;
work done = 200 J (±25) J; *[3]*

B2. Part 1 Solar power and climate models

(a) a solar heating panel converts the (radiation) energy of the Sun into thermal/heat energy; *(allow "solar energy" but do not allow "heat")*

a photovoltaic cell converts the (radiation) energy of the Sun into electrical energy; ***[2]***

(b) (i) water heater / any specific use such as swimming pool/bath; ***[1]***

(ii) powering TV/radio/lighting/any domestic electrical appliance; ***[1]***

(c) surface area of sphere at 1.5×10^{11} m from Sun $= 4\pi\times1.50^2\times10^{22}$;

power per $\text{m}^2 = \dfrac{3.90\times10^{26}}{4\times3.14\times1.50^2\times10^{22}} = 1.38\times10^3$; *(presence of the substitution allows inference of first marking point)*

power per m^2 at surface $= 0.7\times1.38\times10^3\,\text{W m}^{-2}$;

$\left(=966\,\text{W m}^{-2}\right)$ ***[3]***

*To award the first two marking points, look for the candidate clearly identifying the meaning of the equation or substitution. Award **[2 max]** if it is not clear about the quantity being evaluated in either or both of the first two marking points.*

(d) Earth appears, to the Sun, like a disc of radius R; *(must be explicit)*
intensity = power incident per unit area; *(must be explicit in words or equation)*

(power incident per unit area) $= \dfrac{966\pi R^2}{4\pi R^2}$;

$\left(=242\,\text{W m}^{-2}\right)$ ***[3]***

(e) (power absorbed) 242 = (power emitted) σT^4;

$T = \left[\dfrac{242}{5.67\times10^{-8}}\right]^{\frac{1}{4}}$ ***or*** 255.5;

$(= 256\,\text{K})$ ***[2]***

(f) gases such as carbon dioxide/methane/water vapour in the atmosphere;
trap/absorb the (infrared) radiation emitted from the surface;
the radiation is reradiated in all directions;
some of the reradiated radiation reaches the surface of Earth so increasing the surface temperature; ***[4]***

Part 2 Digital storage of data

(a) bookshops could disappear;
lack of privacy / interference by the State into personal life;
better medical diagnosis;
any other sensible implication; ***[2 max]***
Do not allow comments regarding transfer or conversion or speed of conversion of data.

(b) (i) a (small) area of the CCD which behaves as a capacitor / which stores charge; ***[1]***
Treat reference to photoelectric emission as neutral whether correct or incorrect.

(ii) a potential difference is developed across each pixel;
the potential difference is converted into a digital signal/binary number; ***[2]***

(c) area of pixel $= \left(\frac{7.4\times10^{-5}}{10^{7}} =\right) 7.4\times10^{-12}\ \text{m}^2$;

length of side of pixel $= \left(\sqrt{7.4\times10^{-12}} =\right) 2.72\times10^{-6}\ \text{m}$;

separation of dots on CCD $= (7.0\times10^{-3}\times2.0\times10^{-4} =)\ 1.4\times10^{-6}\ \text{m}$;

separation less than length of two pixels so not resolved; ***[4]***
*Award **[0]** for bald correct answer.*

B3. Part 1 Kinematics and mechanics

(a) mass $\times$ velocity; *(allow mv with symbols defined)* ***[1]***

(b) the rate of change of momentum of a body is equal to/directly proportional to the force acting on the body; ***[1]***

Accept $F = \frac{\Delta p}{\Delta t}$ *only if all symbols are defined.*

(c) $\left(F = \frac{\Delta p}{\Delta t}\right)$

therefore impulse $F\Delta t = \Delta p$; *(accept t for* Δt*)* ***[1]***

(d) (i) (impulse $=$) change in momentum $= 2.2\times10^3 \times 4.3 \left(= 9.46\times10^3 \text{ N s}\right)$;

impulse $=$ area under graph $= \frac{1}{2} F_{max} \Delta t$;

$\frac{1}{2} F_{max} \times 0.54 = 9.46\times10^3$;

$F_{max} = 35 \text{ kN}$ ***or*** $3.5\times10^4 \text{ N}$; ***[4]***

(ii) (magnitude of) acceleration $= \left(\frac{u^2 - v^2}{2s} = \frac{4.3^2 - 2.8^2}{30} = \right) 0.355 (\text{m s}^{-2})$;

time $= \left(\frac{u - v}{a} = \frac{1.5}{0.355} = \right) 4.2 \text{ s}$; ***[2]***

*Award **[1 max]** if an additional 0.54 s is added to answer.*

(iii) $\Delta KE = \left(\frac{1}{2} \times 2.2\times10^3 \left[4.3^2 - 2.8^2\right] = \right) 1.17\times10^4 \text{ J}$;

rate of change of $\Delta KE = \frac{1.17\times10^4}{4.2} = 2.8 \text{ kW}$; *(mark is for division by 4.2 <u>and</u> correct calculation)* ***[2]***

(iv) *statement of momentum conservation*:

e.g. momentum of the truck before collision $=$ momentum of both trucks after collision; *(allow clear symbolism instead of words)*

$2.2\times10^3 \times 2.8 = 5.2\times10^3 V$ ***or*** $V = \frac{2.2}{5.2} \times 2.8$;

to give $V = 1.2 \text{ m s}^{-1}$ ***[2]***

(v) the first truck loses kinetic energy that is transferred to internal energy in the links between the trucks (and as sound);
and to kinetic energy of the stationary truck; ***[2]***
Award ***[0]*** *for "lost as heat, light and sound", or "in air resistance".*

Part 2 Resolution and the Doppler effect

(a) (i) diffraction; ***[1]***

(ii) the (central) maximum of the diffraction pattern of one image coincides with the first minimum of the diffraction pattern of the other image; ***[1]***
Allow mark for clear diagram.

(iii) angular separation of G_1 and $G_2 = \frac{d}{2.2\times10^{25}}$;
$\frac{d}{2.2\times10^{25}} = \left(1.22\frac{\lambda}{D} =\right)\frac{1.22\times0.14}{4.0\times10^{3}}$;
$d = 9.4\times10^{20}\,\text{m}$; ***[3]***

(b) (i) if there is relative motion between source/galaxy and observer/Earth;
the observed frequency/wavelength will differ from the source frequency/wavelength;
the observed frequency will be lower / the observed wavelength will be greater if the direction of relative motion is away from the source; *(to award the mark it must be clear in which direction a red-shift occurs)* ***[3]***
Award ***[3]*** *for a good description that mentions all of the above.*
Award ***[3]*** *for a clear annotated diagram that shows all of the above points.*

(ii) $\frac{\Delta f}{f} = \frac{v}{3\times10^{8}} = \left(\frac{6.40\times10^{11}}{4.57\times10^{14}} =\right)1.40\times10^{-3}$;
$v = \left(3\times10^{8}\times1.40\times10^{-3} =\right)4.20\times10^{5}\,\text{m s}^{-1}$; ***[2]***

B4. Part 1 Simple harmonic motion and waves

(a) (i) the acceleration of (force acting on) W is proportional to its displacement from equilibrium;
and directed towards equilibrium; ***[2]***

(ii) $F = (18 \times 0.04 =) 0.72\,\text{N}$;

$\text{acceleration} = \frac{0.72}{0.15} = 4.8\,\text{m s}^{-2}$; ***[2]***

(iii) $\omega = \sqrt{\frac{a}{x}}$;

$= 10.95\,\text{rad s}^{-2}$;

$T = \left(\frac{2\pi}{\omega} =\right)\frac{6.28}{10.95} = 0.57\,\text{s}$; ***[3]***

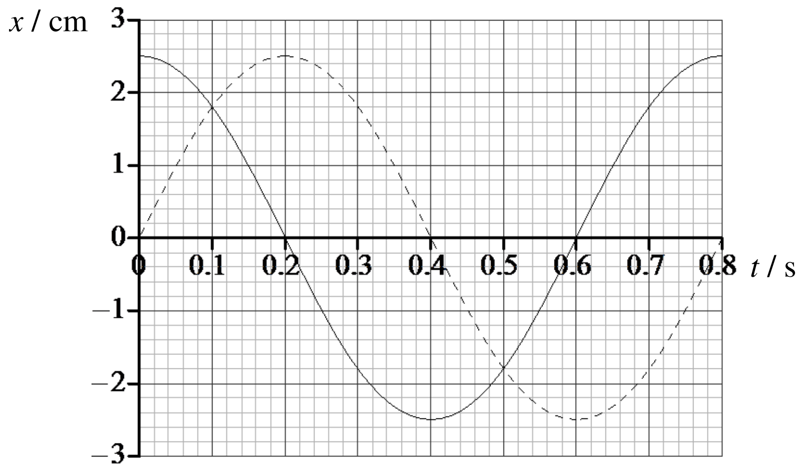
(b) (the frictional force on W is such that) motion rapidly dies away/rapidly stops/stops in the minimum time;
without completing an oscillation / without overshooting (equilibrium position); ***[2]***

(c) (i) the direction of oscillation of the particles of the medium; *(must see "particles")*
is in the direction of energy propagation; ***[2]***
Accept answer in terms of coils of spring in place of particles of medium.

(ii) $\text{frequency} = \left(\frac{1}{T} = \frac{1}{0.80} =\right) 1.25\,\text{Hz}$;

$\text{wavelength} = \frac{v}{f} = \frac{3.0}{1.25} = 2.4\text{ cm}$ ***or*** $2.4 \times 10^{-2}\text{ m}$; ***[2]***

(iii)



graph: positive cosine; *(line must cross axis at 0.2 and 0.6 as shown)*
explanation: 1.8 cm is $\frac{3}{4}$ of a wavelength; ***[2]***

Part 2 Energy levels of the hydrogen atom

(a) (i) spectral lines are discrete;
therefore energy of photon is discrete/quantized;
photon energy is equivalent to difference in energy that electron has in each (discrete) level / $\Delta E = hf$ / *OWTTE*;
(so electron levels are themselves discrete) ***[3]***

(ii) difference in energy $= hc\left[\frac{1}{\lambda_\gamma} - \frac{1}{\lambda_\alpha}\right]$;

$= 6.6\times10^{-34}\times3\times10^{8}\times10^{7}\times0.0780 = 1.54\times10^{-19}$ J; ***[2]***

or

$E_\alpha = \left[\frac{hc}{\lambda_\alpha}\right] = \frac{6.6\times10^{-34}\times3\times10^{8}}{6.56\times10^{-7}} = 3.02\times10^{-19}$ J ***or*** 1.89 eV

$E_\gamma = \left[\frac{hc}{\lambda_\gamma}\right] = \frac{6.6\times10^{-34}\times3\times10^{8}}{4.34\times10^{-7}} = 4.56\times10^{-19}$ J ***or*** 2.85 eV;

(both needed for the mark)

difference in energy $= 1.54\times10^{-19}$ J ***or*** 0.963 eV;

(b) (i) the electron has an associated wavelength λ given by $\lambda = \frac{h}{p}$ where p is its momentum; ***[1]***

(ii) (allowed wavelengths of electron) $\lambda_n = \frac{2L}{n}$;

$E_n = \left(\frac{p^2}{2m_e} = \right)\frac{h^2}{2\lambda_n^{\,2} m_e}$;

substitute for λ_n; *(substitution must be explicit)*

$\left(\text{to get } E_n = \frac{n^2h^2}{8m_eL^2}\right)$ ***[3]***

(c) 1.7×10^{-10} m; ***[1]***