MARKSCHEME

May 2005

PHYSICS

Higher Level

Paper 2

17 pages

Subject Details: Physics HL Paper 2 Markscheme

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in (…) in the markscheme are not necessary to gain the mark.
- The order of points does not have to be as written (unless stated otherwise).
- If the candidate's answer has the same "meaning" or can be clearly interpreted as being the same as that in the markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalising them for what they have not achieved or what they have got wrong.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded.
- Units should always be given where appropriate. Omission of units should only be penalized once. Ignore this, if marks for units are already specified in the markscheme.
- Deduct **1 mark in the paper** for gross sig dig error *i.e.* for an **error of 2 or more digits**.

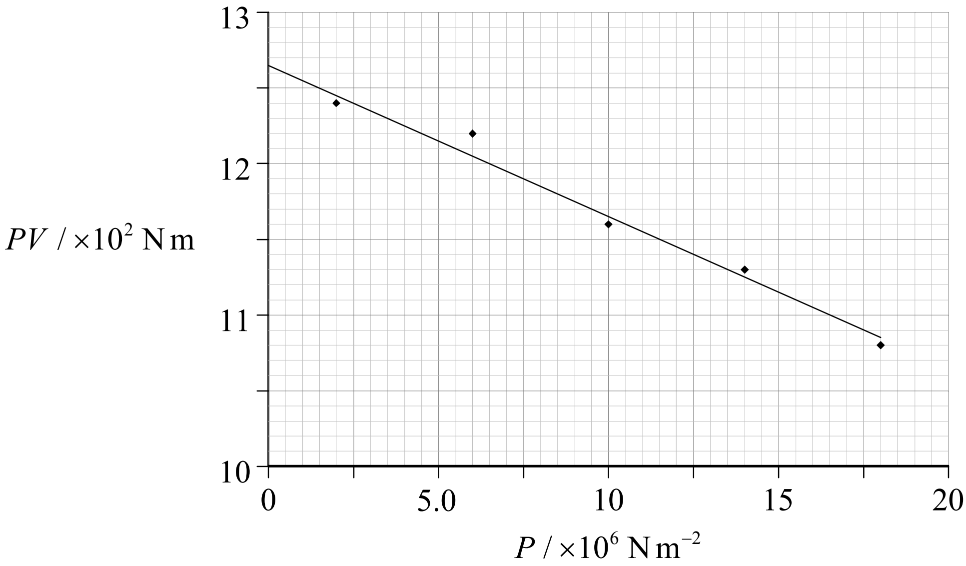
  e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

  However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

SECTION A

A1.



(a) suitable straight-line of best fit; ***[1]***

(b) A is the intercept on the y-axis consistent with line drawn (or by implication);
$= 12.6 = 1.3 \times 10^3$ N m - the best fit line should give a 2 SD value of 1.3×10^3 N m;
B is the gradient;
some evidence that reasonable values have been used $(y_2 - y_1 > 0.9, x_2 - x_1 > 8)$;
$= -1.0(\pm 0.1) \times 10^{-5}$; ***[5]***
*Accept answers based on using two data points on line. Award **[3 max]** if points not on line. Ignore any missing units and do not penalize if minus sign is omitted. Award **[1]** for determination of B if only one data point is used.*

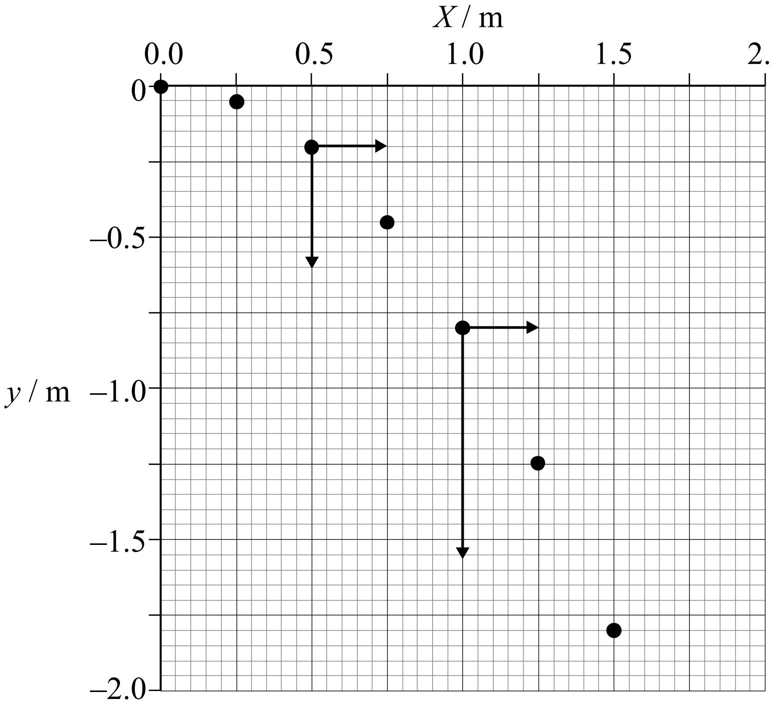
(c) $B = 0$; ***[1]***

(d) (i) substitute into $PV = A + BP$
$PV = 1300 - (1.0 \times 10^{-5} \times 6.0 \times 10^7)$;
$= 700(640 \to 760)$ N m; ***[2]***
$= 1.9(\pm 0.5) \times 10^3$ N m *if BP is added instead of subtracted.*
*Award **[1]** for ECF.*

(ii) recognize that the ideal gas value is the intercept on the y-axis;
or
from $PV = RT$;
or
= constant A;
difference $600(540 \to 660)$ N m; ***[2]***

(e) error bars constructed on two well separated points;
attempt to draw reasonable extreme graph line/lines;
reasonable estimate of uncertainty;
Accept alternative approach.
total % error for $PV = 7\%$;
7 % of $12.6\times10^2 = 0.9\times10^2$;
so absolute error $= (\pm0.9)\times10^2$ N m; ***[3]***

A2. (a)



Mark both together.

V_H : horizontal arrows equal in length;

V_V : two vertical arrows, the one at 1.0 m noticeably longer than the one at 0.5 m; ***[2]***

*If arrows correct but wrong point(s) award **[1]**.*

(b) curve that goes through all data points;
stops at $y = 1.8\,\text{m}$ as this is the height of the wall;
from graph $d = 1.5\,(\pm 0.1)\,\text{m}$; ***[3]***

(c) travels vertically $1.8\,\text{m}$ in $0.6\,\text{s} / 1.25\,\text{m}$ in $0.5\,\text{s}$;

$g = \dfrac{2s}{t^2}$;

to give $g = 10\,(\pm 1)\,\text{m}\,\text{s}^{-2}$; ***[3]***

*Award **[2 max]** for any time shorter than 0.5 s.*

A3. (a) the amount of energy / heat required to raise the temperature of a substance / object through $1\text{K} / {}^{\circ}\text{C}$; ***[1]***

(b) (i) to ensure that the temperature of the metal does not change during the transfer / negligible thermal energy / heat is lost during the transfer; ***[1]***
Do not accept metal and water at same temperature.

(ii) to ensure that all parts of the water reach the same temperature; ***[1]***

(c) energy lost by metal $= 82.7 \times (T - 353)\,\text{J}$;
energy gained by water $= 5.46 \times 10^2 \times 65\,\text{J}$;
energy gained by calorimeter $= 54.6 \times 65\,\text{J}$;
equate energy lost to energy gained to get $T = 825\,\text{K}$; ***[4]***
*Award **[2 max]** if any energy term is missed.*

A4. *Answers will be open-ended but look for these main points.*

Observation I:
energy is needed to eject the electrons from the surface;
according to the wave model, the energy of a wave depends on its amplitude / intensity;
so one would expect emission to depend on intensity not frequency;

Observation II:
according to the wave model, energy is delivered continuously to the surface;
so with a very low intensity wave;
one would expect the electrons to need a certain amount of time to gain sufficient energy to leave the surface; ***[6 max]***
*Award up to **[4]** for a very good understanding of one of the observations such that the marking could go 2+4, 4+2, 3+3.*

SECTION B

B1. Part

(a) if the total external force acting upon a system is zero / for an isolated system;
the momentum of the system is constant; ***[2]***
*Award **[1 max]** if the answer is in terms of collisions.*

(b) 131 g of xenon contains 6.02×10^{23} / N_A atoms;

mass of 1 atom $=\dfrac{131}{6.02\times10^{23}}=2.2\times10^{-22}\,\text{g}=2.2\times10^{-25}\,\text{kg}$;

or

mass of nucleon 1.66×10^{-27} kg;

mass of xenon atom $=131\times1.66\times10^{-27}\,\text{kg}=2.2\times10^{-25}\,\text{kg}$; ***[2]***

(c) time $=1.5\times3.2\times10^{7}=4.8\times10^{7}$ s;

no of atoms per second $=\dfrac{81}{2.2\times10^{-25}\times4.8\times10^{7}}=7.7\times10^{18}\,\text{s}^{-1}$;

or

no of atoms in original mass $=\dfrac{81}{2.2\times10^{-25}}=3.7\times10^{26}$;

time $=\dfrac{3.7\times10^{26}}{7.7\times10^{18}}=4.8\times10^{7}\,\text{s}=1.5$ years; ***[2]***

(d) rate of change of momentum of the xenon atoms
$=7.7\times10^{18}\times2.2\times10^{-25}\times3.0\times10^{4}$;
$=5.1\times10^{-2}\,\text{N}$;
$=$ mass $\times$ acceleration;
where mass $=(540+81)$ kg;

to give acceleration of spaceship $=\dfrac{5.1\times10^{-2}}{6.2\times10^{2}}$;

$=(8.2\times10^{-5}\,\text{m s}^{-2})$ ***[5]***

Accept if mass of fuel omitted $\left(=9.4\times10^{-5}\,\text{m s}^{-2}\right)$.

(e) $a=\dfrac{F}{m}$;

since m is <u>decreasing</u> with time, then a will be <u>increasing</u> with time; ***[2]***

(f) change in speed $=$ area under graph;
$= (8.2 \times 4.8) \times 10^2 + \frac{1}{2}(4.8 \times 1.3) \times 10^2$;
final speed $= (8.2 \times 4.8) \times 10^2 + \frac{1}{2}(4.8 \times 1.3) \times 10^2 + 1.2 \times 10^3$;
$5.4 \times 10^3\,\mathrm{m\,s^{-1}}$;
or
use of $v = u + at$
$u = 1.2 \times 10^3\,\mathrm{m\,s^{-1}}$;
average acceleration from the graph $= \frac{1}{2}(8.2 + 9.45) \times 10^{-5}$;
$= 8.8 \times 10^{-5}\,\mathrm{m\,s^{-2}}$;
final speed $= 4.8 \times 10^7 \times 8.8 \times 10^{-5} + 1.2 \times 10^3 = 5.4 \times 10^3\,\mathrm{m\,s^{-1}}$; ***[4]***

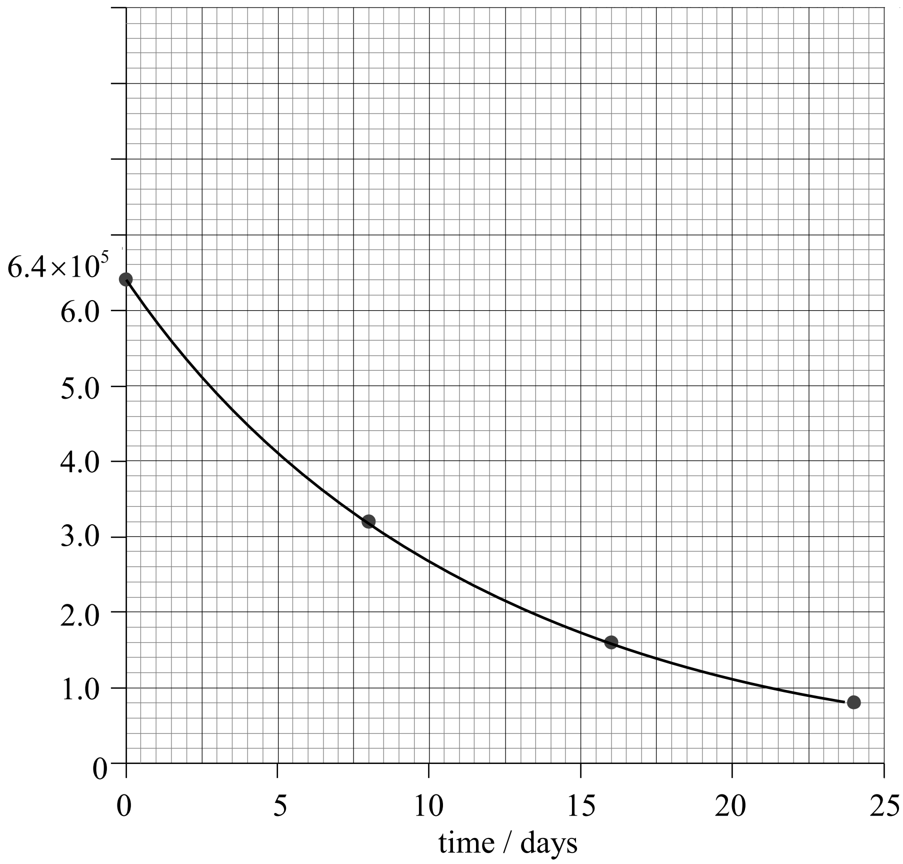
(g) $t = \frac{s}{v} = \frac{4.7 \times 10^{11}}{5.4 \times 10^3} = 8.7 \times 10^7\,\mathrm{s}$;
so total time $4.8 \times 10^7 + 8.7 \times 10^7\,\mathrm{s} \approx 4.2\,\mathrm{y}$; ***[2]***

B1. Part 2

(a) the nuclei of different isotopes of an element have the same number of protons;
but different numbers of neutrons; ***[2]***
Look for a little more detail than say just "same atomic (proton) number, different mass (nucleon) number".

(b) Z for iodine = 53;
+ antineutrino; *(accept symbol)* ***[2]***
Do not accept neutrino or gamma or energy, etc.

(c)



shown on graph at least the 0, 8 and 16 day data points;
exponential shape;
scale on y-axis / goes through 24 day point; ***[3]***

(d) $\lambda = \frac{0.69}{T}$; *(accept ln 2 for 0.69)*
$= 0.086\,\mathrm{d}^{-1}$ / $0.87\,\mathrm{d}^{-1}$ / $1.0\times10^{-6}\,\mathrm{s}^{-1}$; ***[2]***

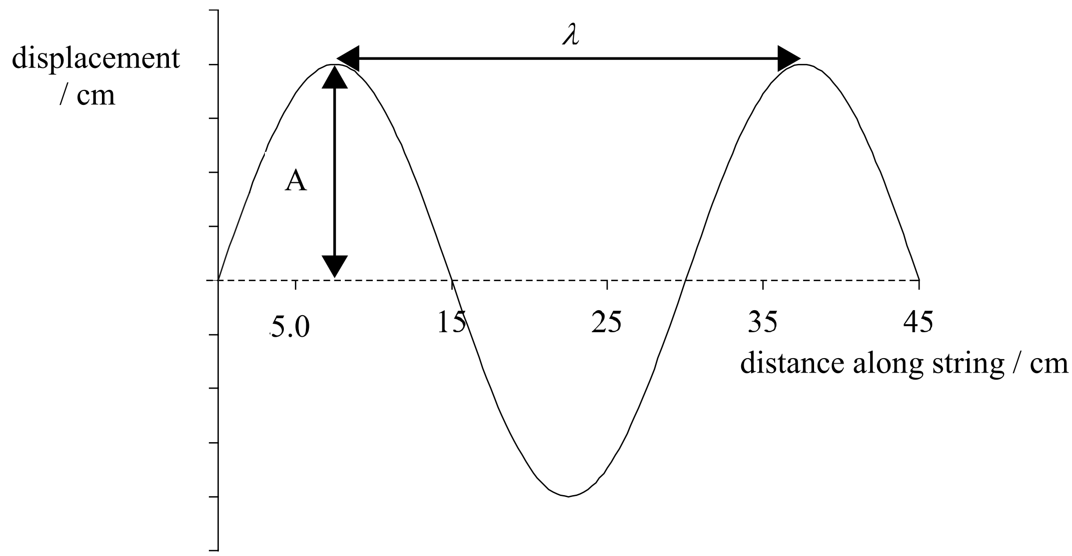
(e) $0.5 = 6.4\,\mathrm{e}^{-0.086t}$;
to give $t = 30\mathrm{d} / 2.6\times10^{6}\,\mathrm{s} / 29\mathrm{d} / 2.5\times10^{6}\,\mathrm{s}$; ***[2]***

B2. Part 1

(a) a wave in which the direction of energy propagation;
is at right angles to the direction of vibration of the particles of the medium through which the wave is travelling / *OWTTE*; ***[2]***
or
suitable labelled diagram e.g.

(b) any em wave / elastic waves in solids / accept water; ***[1]***

(c)



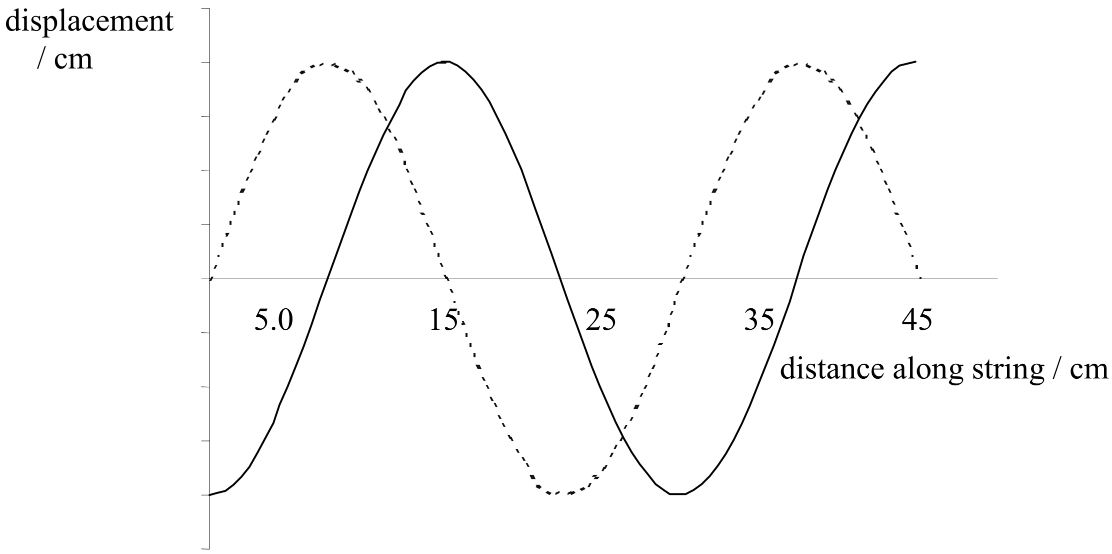
correct annotation

(i) A (4.0 cm); ***[1]***

(ii) λ (30.0 cm); ***[1]***

(d) $f = \dfrac{1}{T} = \dfrac{1}{1.2\times10^{-3}} = 830\,\text{Hz}$;
$c = f\lambda = 830\times0.30 = 250\,\text{m}\,\text{s}^{-1}$; ***[2]***

(e)



troughs / peaks moved to the right;
by $\lambda/4\,(7.5\,\text{cm})$; *(judge by eye)*
wave continuous between $x = 0$ and $x = 45\,\text{cm}$; ***[3]***

(f) a system resonates when a periodic force is applied to it;
and the frequency of the force is equal to the natural frequency of vibration of the system / *OWTTE*; ***[2]***

(g) the string could be clamped at one end and vibrated at the other end by a signal generator / tuning fork;
whose frequency is adjusted until one loop of vibration is observed / *OWTTE*;
or
string is clamped at both ends;
and plucked in the middle; ***[2]***

(h) $\lambda = 0.90\,\text{m}$;
$$f = \frac{c}{\lambda} = \frac{250}{0.90} = 280\,\text{Hz};$$ ***[2]***

B2. Part 2

(a) force exerted per unit mass;
on a small / point mass; ***[2]***

(b) from the law of gravitation, the field strength $\frac{F}{m} = G\frac{M}{R^2}$;

$= g_0$ to give $GM = g_0 R^2$; ***[2]***

***N.B**. To achieve full marks, candidates need to state that* $\frac{F}{m} = g_0$.

(c) downwards; *(accept 90° to B field or down the wire)* ***[1]***

(d) $F = Bev\cos\theta$; ***[1]***

(e) work done in moving an electron the length of the wire is
$W = FL = BevL\cos\theta$;
e.m.f. = work done per unit charge;
therefore, $E = BLv\cos\theta$;
or
electric field $= \frac{F}{e} = Bv\cos\theta$;
e.m.f. $E =$ electric field $\times L$;
to give $E = BLv\cos\theta$; ***[3]***
*Award **[2 max]** if flux linkage argument is used.*

(f) $F = G\frac{Mm}{r^2} = \frac{mv^2}{r}$;

such that $v^2 = \frac{GM}{r} = \frac{g_0 R^2}{r}$;

$v^2 = \frac{10 \times (6.4)^2 \times 10^{12}}{6.7 \times 10^6}$ to give $v = 7.8 \times 10^3\ \mathrm{m\,s^{-1}}$; ***[3]***

(g) $L = \frac{E}{Bv\cos\theta}$;

$= \frac{10^3}{6.3 \times 10^{-6} \times 7.8 \times 10^3 \times 0.93} = 2.2 \times 10^4\ \mathrm{m}$; ***[2]***

B3. Part 1

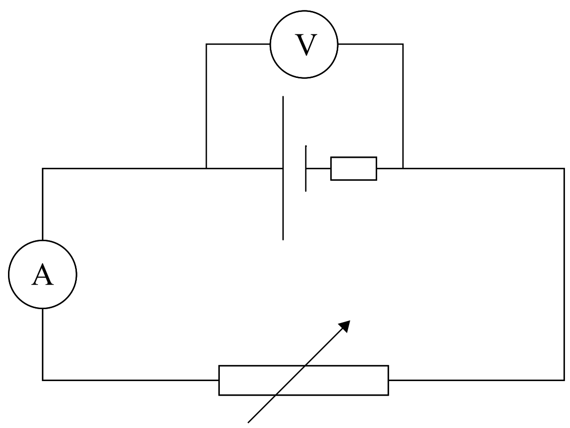
(a) (i) EI; ***[1]***

(ii) I^2r; ***[1]***

(iii) VI; ***[1]***

(b) (from the conservation of energy), $EI = I^2r + VI$;
therefore, $V = E - Ir$ / $E = V + Ir$; ***[2]***

(c)



correct position of voltmeter;
correct position of ammeter;
correct position of variable resistor; ***[3]***

(d) (i) $E = V$ when $I = 0$;
so $E = 1.5\,\text{V}$; ***[2]***

(ii) recognize this is when $V = 0$;
intercept on the x-axis $= 1.3\,(\pm 0.1)\,\text{A}$; ***[2]***

(iii) r is the slope of the graph;
sensible choice of triangle, at least half the line as hypotenuse;
$= \dfrac{0.7}{0.6}$;
$= 1.2\,(\pm 0.1)\,\Omega$
or
when $V = 0$ $E = Ir$;
$r = \dfrac{E}{I}$;
$= \dfrac{1.5}{1.3}$;
$= 1.2\,\Omega$ ***[3]***

(e) $R = 1.2\,\Omega$;
$I = \dfrac{1.5}{1.2 + 1.2} = 0.63\,\text{A}$;
$P = I^2R = (0.63)^2 \times 1.2 = 0.48\,\text{W}$ / $0.47\,\text{W}$; ***[3]***

B3. Part 2

(a) light from a tungsten filament lamp is not coherent;
this means that the phase difference between the light from the slits will be continuously changing / some other relevant detail; ***[2]***
*The action verb is "explain" so more than just a statement is required to award **[2]**.*

(b) "fringes" of equal thickness and spacing and equal height; *(judge by eye)*
with a maximum at X; ***[2]***
*Award **[1]** only if not touching the x-axis.*

(c) $d = \frac{\lambda D}{s}$;

$= \frac{\lambda}{\vartheta}$;

$= \frac{6.33\times10^{-7}}{4.00\times10^{-4}} = 1.58 \text{ mm}$;

or

accept use of $d\sin\theta = n\lambda$ with $n=1$;

$\sin\theta = \theta$;

$d = \frac{6.33\times10^{-7}}{4.00\times10^{-4}} = 1.58 \text{ mm}$; ***[3]***

(d) $Ve = \frac{p^2}{2m}$;

$= \frac{h^2}{2\lambda^2 m_e}$;

so $\lambda^2 = \frac{h^2}{2Vem_e}$ to give $\lambda = \frac{h}{\sqrt{2m_eVe}}$;

or

$v = \sqrt{\frac{2V_e}{m}}$;

$p = mv = \sqrt{2V_em}$;

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_eVe}}$; ***[3]***

(e) $\lambda = \frac{6.6\times10^{-34}}{(2\times9.1\times10^{-31}\times400\times1.6\times10^{-19})^{½}} = 6.1\times10^{-11} \text{ m}$;

$d = \frac{\lambda}{\theta} = \frac{6.1\times10^{-11}}{4.00\times10^{-4}} = 1.50\times10^{-7} \text{ m}$; ***[2]***

B4. Part 1

(a) momentum of object $= 2\times10^3\times6.0$;
momentum after collision $= 2.4\times10^3\times v$;
use conservation of momentum, $2\times10^3\times6.0 = 2.4\times10^3\times v$;
to get $v = 5.0\,\text{m s}^{-1}$; ***[4]***
*Award **[2 max]** for mass after collision $= 400\,kg$ and $v = 30\,m\,s^{-1}$.*

(b) KE of object and bar + change in PE $= 1.2\times10^3\times25 + 2.4\times10^3\times10\times0.75$;
use $\Delta E = Fd, 4.8\times10^4 = F\times0.75$;
to give $F = 64\,\text{kN}$;
*Award **[2 max]** if PE missed,* $F = 40\,\text{kN}$.
or
$a = \frac{v2}{2s}$;
$F - mg = ma$;
to give $F = 64\,\text{kN}$; ***[3]***
*Award **[2 max]** if mg missed.*

(c) recognize that the height is given by $mgh = \frac{1}{2}mv^2$;
$\text{KE} = \frac{1}{2}mv^2 = \frac{1}{2}\times2.0\times10^3\times36 = 3.6\times10^4\ \text{J}$;
$t = \frac{E}{P}$;
$= \frac{3.6\times10^4}{7.2\times10^3} = 5.0\ \text{s}$;
or
calculation of $PE = mgh$ using $v^2 = u^2 + 2as$
$h = 1.8\,\text{m}$;
$mgh = 2.0\times10^3\times10\times1.8$;
$t = \frac{E}{P}$;
$= \frac{3.6\times10^4}{7.2\times10^3} = 5.0\ \text{s}$; ***[4]***

(d) (i) a process in which there is no energy (heat) exchange;
between system and surrounding;
or
all the work done;
either increases or decreases the internal energy of the system; ***[2]***

(ii) a process that takes place at constant volume; ***[1]***

(iii) a process that takes place at constant pressure; ***[1]***

(e) (i) adiabatics: $C \to D$, $A \to B$; ***[1]***

(ii) isochoric: $D \to A$; ***[1]***

(iii) isobaric: $B \to C$; ***[1]***

(f) work done in one cycle; ***[1]***

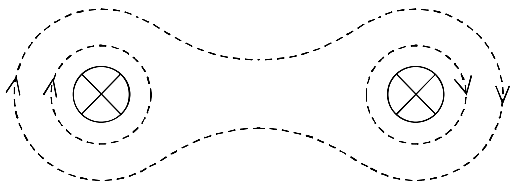
(g) $\dfrac{8400}{40} = 210 \text{ J}$; ***[1]***

(h) $Eff = \dfrac{W}{Q_H}$;

therefore, $Q_H = \dfrac{210}{0.4} = 525 \text{ J}$; ***[2]***

B4. Part 2

(a)



general shape: at least one circle around each wire and one loop around both wires;
appropriate spacing of lines: increasing separation with distance from wires;
correct direction of field; ***[3]***

(b) constant separation / parallel;
current measured in terms of force per unit length of the wires;
or
accept complete definition:
wires 1 m apart;
force between them is 2×10^{-7} N per metre length when current is 1 A; ***[2]***

(c) velocity increases;
acceleration increases;
because the force is getting larger the closer the wires get together; ***[3]***
If answered in terms of a repulsion force then ***[2 max]***.