# MARKSCHEME

## May 2006

## PHYSICS

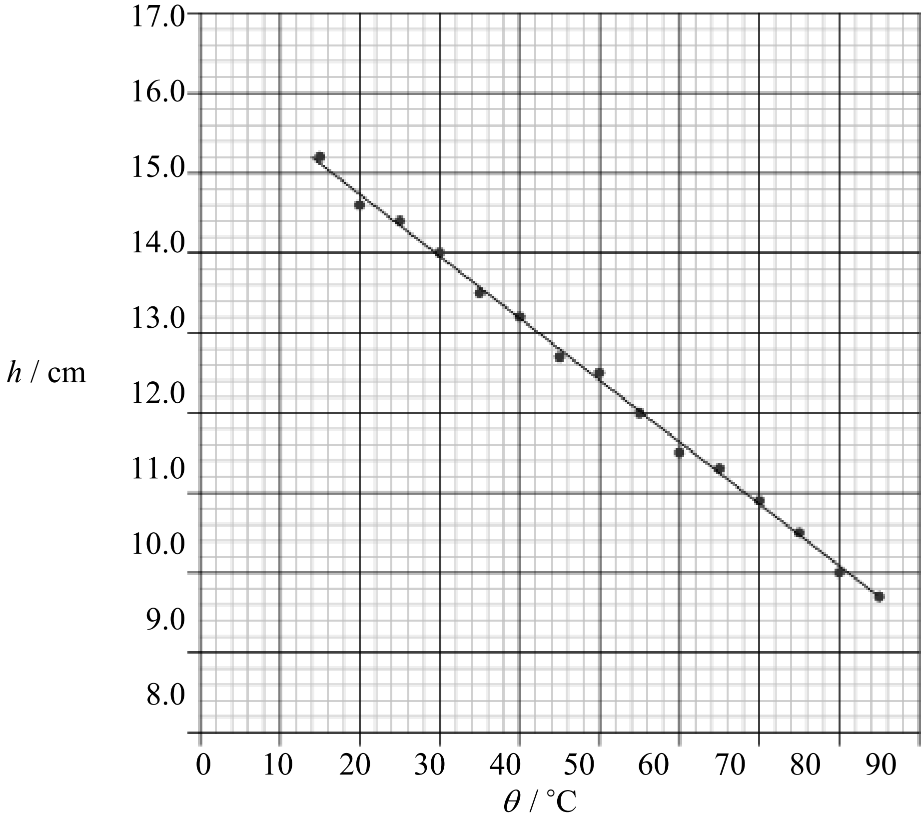
## Higher Level

## Paper 2

22 pages

**SECTION A**

**A1.** (a)




(i) sensible line of fit with reasonable distribution of points either side of line; ***[1]***

(ii) $h_0 = 16.2\,(\pm 0.2)\,\text{cm}$; ***[1]***

(b) this is a straight-line graph so has equation of the form $y = mx + c$;
$h = h_0(1 - k\theta)$ gives $h = h_0 - h_0 k\theta$;
$m = -h_0 k$;
$c = h_0$; ***[4]***
*essentially look for*:
*stating equation of a straight-line graph, showing that* $h = h_0(1 - k\theta)$ *can be written in this form, identifying m and c.*

(c) $k = \dfrac{\text{gradient}}{h_0}$; $\left.\begin{array}{l} \textit{If credit for } m = -h_0 k \textit{ has not been given in } (b) \\ \textit{then it can be given if this statement is correct.} \end{array}\right\}$

gradient $= 0.077\ (\pm 0.003)$;

therefore, $k = \dfrac{0.077}{16.2}$;

$\approx 4.8 \times 10^{-3}\ \text{deg}\,\text{C}^{-1}$

***Or***

Allow use of a point <u>on line of best fit</u> i.e. choice of data point from line of best fit;
correct substitution into $h = h_0(1 - k\theta)$;
correct rearrangement essentially showing that $k = \dfrac{1}{\theta}(1 - \dfrac{h}{h_0})$; ***[3]***

*Accept range of answers for the gradient between $4.9 \times 10^{-3}$ and $4.6 \times 10^{-3}$.*

(d) *estimate*:

$h = \dfrac{\text{gradient}}{r}$;

gradient $= 1.5\,(\pm 0.2) \times 10^{-5}$;

$r = \dfrac{1.5 \times 10^{-5}}{25} = 6.0\,(\pm 0.8) \times 10^{-7}\ \text{m}$;

*comment*:
this is very small so it is unlikely that capillary action is the only mechanism / *OWTTE* / this assumes that the direct proportion holds for values of $h$ up to $25\ \text{m}$ / *OWTTE*; ***[4]***

*Accept ECF based on estimate only if comment is reasonable and consistent. If numerical value is correct, then award the mark for a plausible explanation (e.g. reference to molecular forces) as to why this is a reasonable value.*

**A2.** (a) translational equilibrium: sum of the (net) forces acting is zero;
rotational equilibrium: sum of the (net) torques / moments of the forces is zero; ***[2]***

(b) (i) 5.00 kN; ***[1]***

(ii) appreciate to take moments;
moments about A: $N_B \times 8.80 = 1.50 \times 2.00 + 3.50 \times 3.80$;
to give $N_B = 1.85\,\text{kN}$;
therefore, $N_A = 5.00 - 1.85 = 3.15\,\text{kN}$;

***Or***

appreciate to take moments;
by moments about B : $N_A \times 8.80 = 1.50 \times 6.80 + 3.50 \times 5.00$;
to give $N_A = 3.15\,\text{kN}$;
therefore, $N_B = 1.85\,\text{kN}$; ***[4]***

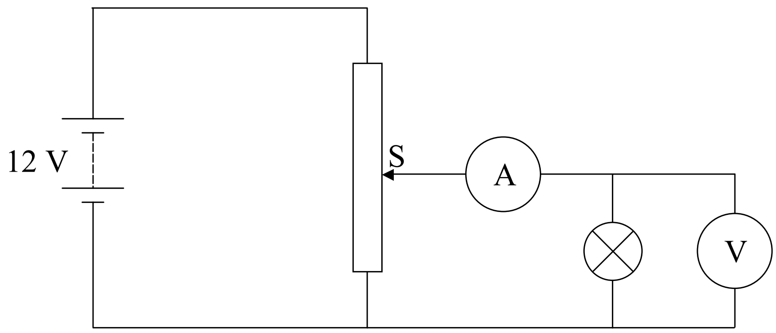
**A3.** (a) there are no positions;
the lamp is effectively in series with $100\,\mathrm{k}\Omega$ no matter what the position of S;
this means that the pd across it will always be close to zero (very small) / never reach 6 V;

***Or***

there are no positions;
the resistance of the filament is much smaller that $100\,\mathrm{k}\Omega$;
so (nearly) all the potential of the battery appears across the variable resistance; ***[3]***
*Award **[1]** max for correct answer with no argument or incorrect argument. Anthropomorphic answers such "battery has a lot of resistance to overcome" score **[1]** max. Must mention that voltmeter is effectively in series with battery to get full marks.*

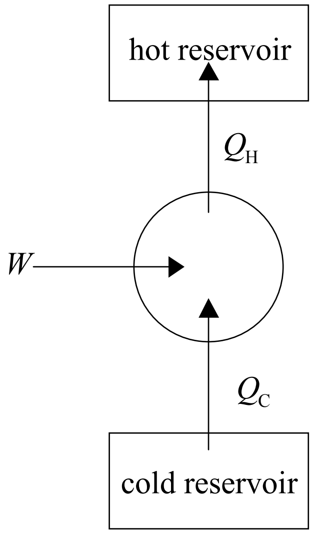
(b) $I = \dfrac{V}{R}$;
$= \dfrac{12}{15} = 0.80\,\mathrm{A}$; ***[2]***

(c)




correct position of ammeter;
correct position of voltmeter (either to the right <u>or</u> left of the lamp); ***[2]***

**A4.** (a)




***[3]***

*Award **[1]** for the correct direction and labelling of each arrow.*

(b) (i) $C \rightarrow D$ vaporization / change of phase to gas (vapour);
$A \rightarrow B$ condensation / change of phase to liquid; ***[2]***
*Do not accept answers explaining just the isobaric nature of the change. Explaining the isothermal nature of the changes by using $Q = W$ is not sufficient.*

(ii) absorbed $C \rightarrow D$ / $C \rightarrow D$ and $B \rightarrow C$;
ejected $A \rightarrow B$ / $A \rightarrow B$ and $A \rightarrow D$; ***[2]***

(iii) the area enclosed by ABCD; ***[1]***

**SECTION B**

**B1. Part 1 Kepler's third law**

(a) (i) the orbits are elliptical / not circular; ***[1]***
*Do not accept "because R changes".*

(ii) gravity / gravitational; ***[1]***

(iii) $F = G\dfrac{M_s m}{R^2}$; ***[1]***
*Same symbols as in question must be used to receive the mark.*

(iv) let $v =$ the speed of planet, the acceleration is then $= \dfrac{v^2}{R}$

from Newton 2, $F = G\dfrac{M_s m}{R^2} = \dfrac{mv^2}{R}$; $\left\{ \begin{array}{l} \textit{Some reference to Newton 2} \\ \textit{is required to receive this mark.} \end{array} \right.$

$v = \dfrac{2\pi R}{T}$;

therefore, $= G\dfrac{M_s m}{R} = \dfrac{4\pi^2 m R^2}{T^2}$;

therefore, $T^2 = \dfrac{4\pi^2}{GM_s}R^3$ ; ***[4]***

so $K = \dfrac{4\pi^2}{GM_s}$

*Be aware of the many simple variants of this e.g. using* $a = \omega^2 R = \dfrac{4\pi^2 R}{T^2}$.

(b) (i) recognize that gravitational field strength $= \dfrac{v^2}{R} = \dfrac{4\pi^2 R}{T^2}$;

$= \dfrac{40 \times 1.1 \times 10^9}{(6.2 \times 10^5)^2}$;

$= 0.1\,\text{N kg}^{-1}$ ***[2]***

(ii) $T^2 = \dfrac{4\pi^2}{GM_s}R^3$ therefore, $M_{jup} = \dfrac{4\pi^2 R^3}{GT^2}$;

$M_{jup} = \dfrac{4\pi^2 \times (1.1)^3 \times 10^{27}}{6.7 \times 10^{-11} \times (6.2 \times 10^5)^2}$;

$\approx 2.0 \times 10^{27}$ kg ;

***Or***

$$0.1 = \frac{GM}{R^2};$$
$$M = \frac{0.1R^2}{G};$$
$$= \frac{0.1\times(1.1\times10^9)^2}{6.7\times10^{-11}}$$
$$\approx 2.0\times10^{27}\text{ kg};$$ ***[3]***

**Part 2 Heating water electrically**

(a) (energy is transferred) by conduction through the insulation of the element / *OWTTE*;
(energy is then transferred) by the bulk motion of the water / convection through the water / *OWTTE*;
the element will also radiate some energy which will be absorbed by the water / *OWTTE*; ***[3]***

(b) energy supplied by heater in $1\text{s} = 7.2\times10^3$ J ;
energy per second = mass per second × sp ht × rise in temperature;
$7.2\times10^4$ = mass per second $\times 4.2\times10^3\times 26$;
to give mass per second = 0.066 kg / flow rate = 0.066kg $\text{s}^{-1}$ ; ***[4]***

(c) energy is lost to the surroundings;
flow rate is not uniform; ***[2]***
*Do not allow "the heating element is not in contact with all the water flowing in the unit". Accept answers that imply that there will be a temperature gradient between element and wall of pipe. Do not accept answers such as "element will not heat water uniformly".*

(d) $P = VI, I = \frac{P}{V}$;
$$= \frac{7.2\times10^3}{240} = 30\text{ A};$$ ***[2]***

(e) when operating at 7.2 kW the element is at a higher temperature / hotter than when first switched on;
therefore, resistance is greater (and so current is smaller) / *OWTTE*;

***Or***

element is cold / *OWTTE* when first switched on;
therefore, smaller resistance than when hot (and so current is larger); ***[2]***

(f) (i) $P = \dfrac{V^2}{R}$;

$\dfrac{240^2}{R_{240}} = \dfrac{110^2}{R_{110}}$;

$\dfrac{R_{110}}{R_{240}} = \left(\dfrac{110}{240}\right)^2$;

$= 0.21$

***Or***

from $P = VI$

$240I_2 = 110I_1$ to give $I_2 = \dfrac{11}{24}I_1$;

$I_2^{\,2}\ R_2 = I_1^{\,2}R_1$;

$\dfrac{R_1}{R_2} = \dfrac{I_2^{\,2}}{I_1^{\,2}} = \left(\dfrac{11}{24}\right)^2$;

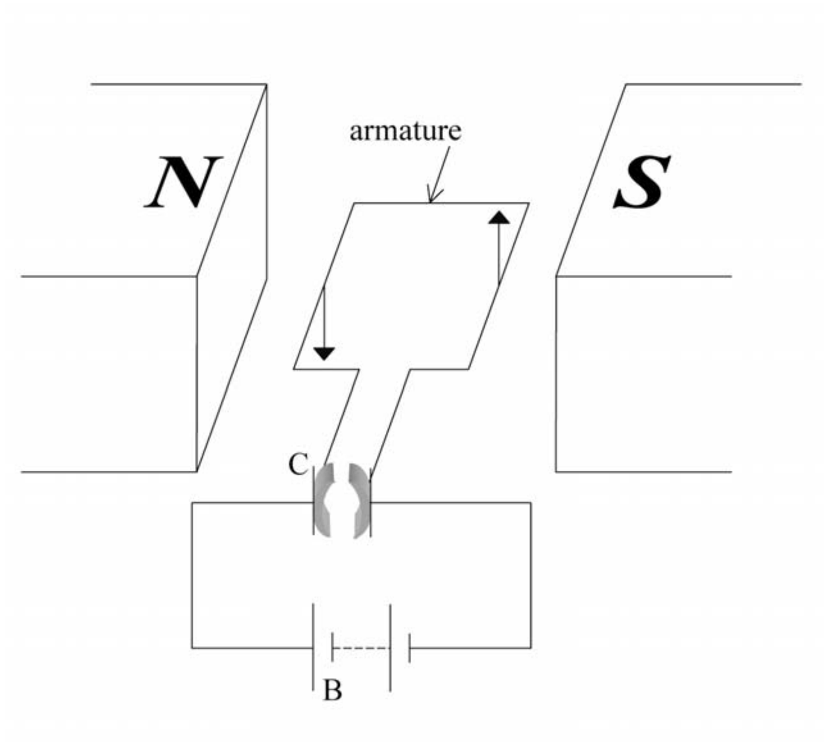
$= 0.21$ ***[3]***

(ii) to get equivalent power, heating elements must have lower resistance;
therefore, they have to be physically larger so more expensive / take up more space;

***Or***

smaller voltage supply needs larger current;
so thicker cables therefore, more expensive / take up more space; ***[2]***

**B2.**

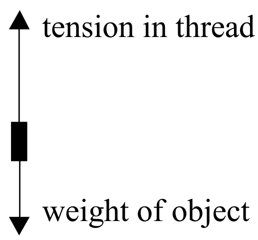



(a) (i) showing connection via brushes, *[1]*

(ii) two correct forces; *[1]*

(iii) when the split ring is in contact with the brushes the current in the coil will always be in the same direction / *OWTTE*;
some statement to the effect that this will be so even after the coil has rotated through $180^{\circ}$ and sides of coil are reversed;
when the split ring is not in contact with the brushes, the momentum of the coil will keep it rotating / *OWTTE*; *[3]*

(b) (i)




tension in thread;
weight (of object) / mg;
tension length $>$ weight length; *[3]*

(ii) $a = \frac{2s}{t^2}$;

$= \frac{2 \times 0.84}{(2.2)^2} = 0.35\,\mathrm{m\,s^{-2}}$;

$T - mg = ma$;

$T = m(g + a) = 0.015 \times 10.35 = 0.16\,\mathrm{N}$; *[4]*

(c) (i) measure the time it takes the object to go successive distances of say 10 cm / any realistic length given or implied;
if the times are equal then speed is constant / *OWTTE*; ***[2]***

(ii) increase in potential energy $= 0.015 \times 10 \times 0.84 = 0.13\,\text{J}$;

rate of working $=$ power input $= \dfrac{0.13}{3.4} = 0.037\,\text{W}$; ***[2]***

(iii) power input to motor $= VI = 6.0 \times 0.045 = 0.27\,\text{W}$;

$Eff = \dfrac{P_{out}}{P_{in}} = \dfrac{0.037}{0.27} = 0.14$ ***or*** $14\%$; ***[2]***

(d) $\lg(E)$ against $\lg(I)$;
$\lg(E) = \lg(k) + n\lg(I)$;
slope/gradient $= n$; ***[3]***

(e) (i) a magnetic flux links the coil;
as the coil rotates the flux linkage changes with time;
therefore, from Faraday's law an e.m.f. will be induced; ***[3]***

(ii) the faster the speed of rotation, the greater the flux change;
Faraday's law states that the e.m.f. is equal/proportional to the rate of change of flux; ***[2]***

(iii) the amount of flux linking the coil changes with the angle that the coil makes with the magnetic field / *OWTTE;* ***[1]***

(f) (i) any maximum/minimum value of $V$; ***[1]***

(ii) from the graph $V_0 = 2.0\,\text{V}$;

therefore, $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}} = 1.4\,\text{V}$; ***[2]***

**B3. Part 1 Sound waves**

**Production of sound waves**

(a) the direction in which energy (of the wave) is propagated;
for a transverse wave it is at right angles to the direction of vibration of the particles (of the medium through which the wave is travelling);
for a longitudinal wave the direction of energy propagation is in the same direction as the vibration of the particles; ***[3]***
*Accept answers based on diagrams for full marks* <u>*provided*</u> *direction of energy transfer and direction of oscillation are clear on the diagram.*

(b) (i) longitudinal;
it is likely that the hammer will set the atoms of the rod to vibrate in the same direction as the direction of the motion of the hammer / *OWTTE*;
*Award* ***[0]*** *if no explanation or poor explanation.*

***Or***

hammer would not experience a rebounding force (if wave were not longitudinal) /OWTTE;
some reference to direction of propagation of energy being along the length of the rod; ***[2]***

(ii) $s = 3.00\,\text{m}$;

$$v = \frac{s}{t} = \frac{3.00}{6.00\times10^{-4}} = 5.00\times10^{3}\ \text{ms}^{-1};$$ ***[2]***

*Watch out for incorrect answers based on* $v = f\lambda$ *and*
$f = \frac{1}{6\times10^{-4}} = 1667$ Hz *! it can give the correct numerical result with a completely wrong argument.*

(iii) the hammer blow/pulse sets the rod vibrating;
the vibration of the rod causes the air molecules in contact with the rod to vibrate;
thereby setting up a longitudinal wave in the air/creates the sound/*OWTTE*; ***[3]***

(iv) $\lambda = \frac{v}{f}$;

$$= \frac{5.00\times10^{3}}{1.67\times10^{3}} = 3.00\,\text{m};$$

some statement to recognize that this wavelength corresponds to the fundamental mode standing wave *e.g.* for the fundamental $\lambda = 2l$; ***[3]***

**Interference of sound waves**

(c) (i) the sound from the two sources undergo interference / some statement that recognizes that interference is occurring;
when the path difference between the sources is an integral number of wavelengths there is maximum interference and minimum when the path difference is an odd integral number of half wavelengths;
some statement that the path difference is altering as $S_1$ moves; ***[3]***

(ii) path difference $= \frac{\lambda}{2}$;
to give $\lambda = 0.16\,\text{m}$; ***[2]***

(iii) $S_1X =$ one wavelength $= 0.082\,\text{m}$;
$v = f\lambda = 0.082 \times 4100 = 340\,\text{ms}^{-1}$; ***[2]***
*Accept ECF for those candidates who use the incorrect wavelength from (ii).*

**Part 2 Radioactive decay**

(a) proton/ ${}^{1}_{1}\mathrm{H}$ / $\mathrm{p}^{+}$ ; ***[1]***

(b) (i) no more C-14 / carbon dioxide is taken in when a tree is dead;
the amount of C-14 determines the activity (of the charcoal);
(since C-14 is radioactive) the amount present (in the charcoal) decreases with time / *OWTTE*; ***[3]***

(ii) $N = N_0 e^{-\lambda t}$

$\lambda = \dfrac{\ln 2}{T}$ ;

$= 1.3 \times 10^{-4}\ \mathrm{yr}^{-1}$ ;

activity $A \propto N$ therefore, $A = A_0 e^{-\lambda t}$ ;

therefore, $e^{-(1.3\times10^{-4})t} = \dfrac{2.1}{9.6} = 0.22$ ;

to give $t = 1.2 \times 10^{4}$ yr ; ***[5]***

*Do not accept answers that use arguments based on proportionality or approximate number of half-lives.*

(iii) so little radioactive carbon left to make detection difficult/inaccurate/ *OWTTE* /
difficult to distinguish activity from background count / *OWTTE*; ***[1]***

**B4. Part 1 Momentum**

(a) if the total (or net) external force acting on a system is zero / for an isolated system;
the momentum of the system is constant/momentum before collision equals momentum after collision; ***[2]***
*Award **[1]** for "momentum before (collision) = momentum after (collision)".*

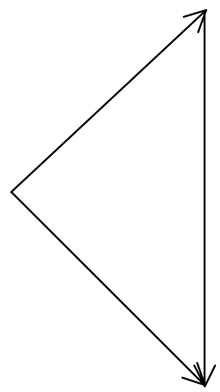
(b) (i) (a collision in which) kinetic energy is not lost / kinetic energy is conserved; ***[1]***

(ii) the momentum of the puck is not conserved since a force acts on it during collision / *OWTTE*;
the rink is attached to the Earth and momentum is given to the Earth such that the change in momentum of the puck is equal to the change in momentum of the Earth / *OWTTE*;

***Or***

the momentum of the Earth and puck are conserved / *OWTTE*;
the change in momentum of the puck is equal and opposite to the change in momentum of the Earth; ***[2]***
*This is a discussion so more than bald statements are required e.g. identification of system and some explanation.*

(c)



vector 5.0 cm long;
at right angles to initial vector as shown;
*By eye is sufficient.*
resultant vector as shown;
stated length $= 7.1(\pm 0.2)\,\text{cm}$ equivalent to $0.71(\pm 0.2)\,\text{N s}$;
*Length should be checked.*

.

***Or***

Second vector at right angles to first;
And of equal length;
Difference shown as a vertical vector;
Of magnitude $\sqrt{0.5^2 + 0.5^2}$ ;
$= 0.71\ \text{N s}$ ***[4]***
*Caution*: *Many students are obtaining instead the <u>sum</u> of the two momenta rather than the difference. In this case the numerical answer is the same for the magnitude so watch out.*

(d) $F = \dfrac{\Delta p}{\Delta t} = \dfrac{0.71}{12 \times 10^{-3}} = 59\ \text{N}$ ;
this is the average force and from the graph it can be seen that $F = 2F_{\text{av}}$ ;
therefore, $F = 120\ \text{N}$ ;

***Or***

area under graph is $\Delta p = 0.71\ \text{N s}$ ;
area is $\dfrac{1}{2} F_{\text{max}} \Delta t$ ;
and so $F_{\text{max}} = \dfrac{2 \times 0.71}{12 \times 10^{-3}} = 120\ \ \text{N}$ ; ***[3]***

**Part 2 The quantum nature of radiation**

**The photoelectric effect**

(a) light consists of photons /photons are incident on the surface;
the energy of each photon $= hf$ where $h$ is the Planck constant;
a certain amount of energy, the work function $\phi$ is required to remove an electron from the metal surface;
if $f < \frac{\phi}{h}$ then no electrons will be emitted; ***[4]***
*In view of the question, these precise points are needed for* ***[4]****, allow* ***[2 max]*** *for a purely qualitative answer.*

(b) (i) $1.1\times10^{15}$ Hz ; ***[1]***

(ii) $e\,E_{\text{K}} = hf - \phi$ ;
slope of graph $= \frac{h}{e}$ ;
slope $= 4.2\,(\pm0.4)\times10^{-15}$ ;
$h = 4.2\,(\pm0.4)\times10^{-15}\times1.6\times10^{-19} = 6.7\times10^{-34}$ J s ; ***[4]***
*Accept answers in the range $6.1\times10^{-34}$ J s and $7.4\times10^{-34}$ J s .*
***Note****: the answer must show that the graph has been used – if not, award* ***[0]*** *as this could have been taken from the data book. Award full points for correct answers using just one point on the line or two points and a system of equations to eliminate the work function.*

(iii) $\phi = hf_0$ ;
$= 1.1\times10^{15}\times6.7\times10^{-34} = 7.4\times10^{-19}$ J ; ***[2]***
*Accept answers in the range $6.7\times10^{-19}$ J and $8.1\times10^{-19}$ J .*
*The value of h from part (ii) must be used.*

**X-rays**

(c) (i) $Ve = \frac{1}{2}mv^2$;

$v = \sqrt{\frac{2Ve}{m}} = \sqrt{\frac{2 \times 25 \times 10^3 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}}$;

$\approx 10^8\ \mathrm{m\,s^{-1}}$ ***[2]***

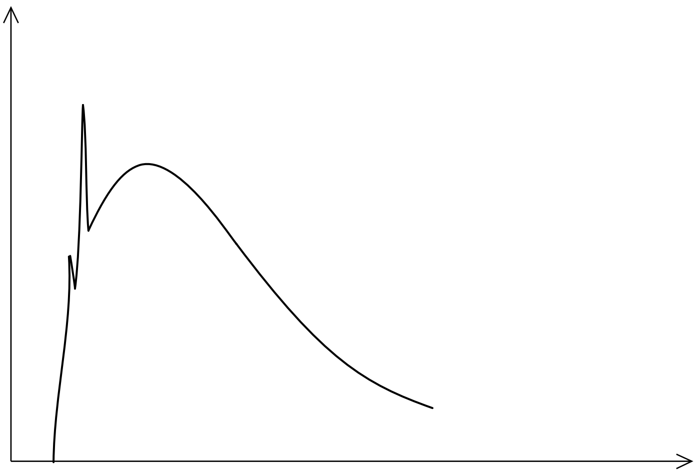
(ii) $Ve = \frac{hc}{\lambda}$;

$\lambda = \frac{hc}{Ve} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{25 \times 10^3 \times 1.6 \times 10^{-19}}$;

$\approx 5 \times 10^{-11}\ \mathrm{m}$; ***[2]***

*Accept $10^{-10}$ m.*

(d)



continuous spectrum with cut off;
and with reasonable tail;
characteristic peak(s); ***[3]***