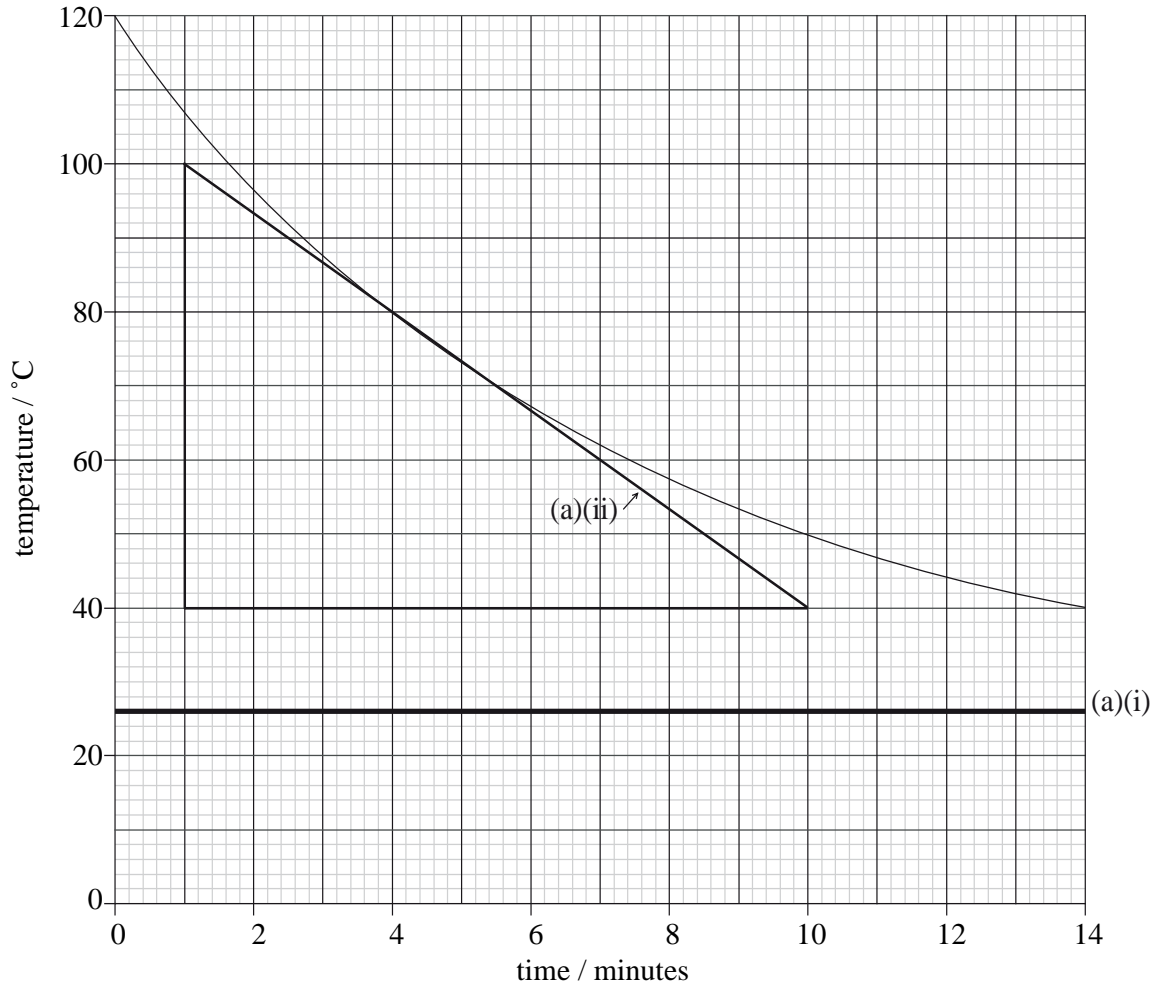


SECTION A

A1.

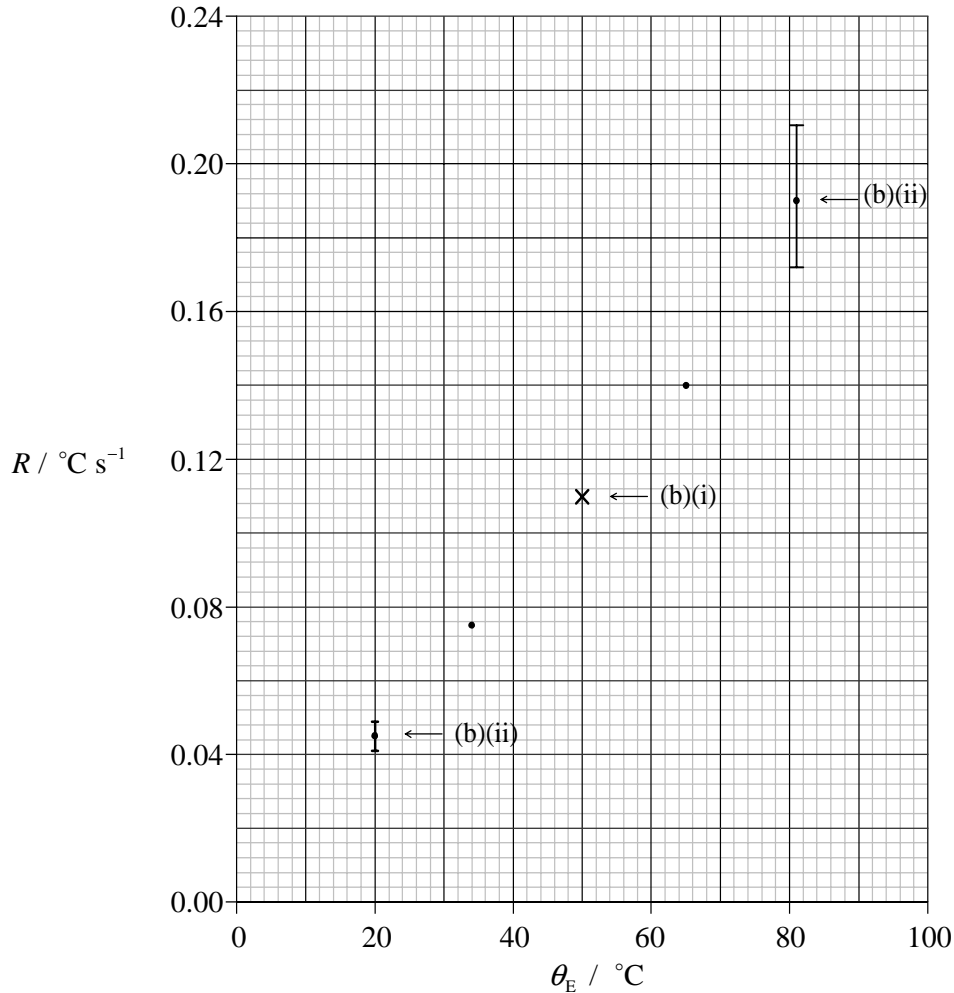


(a) (i) line in correct position from $t = 0$ to $t = 14$ min ; [1]
 Allow $\pm \frac{1}{2}$ square.

(ii) reasonable tangent drawn at correct position *i.e.* at 76°C but allow $70^\circ\text{C} \rightarrow 85^\circ\text{C}$;
 If tangent position is not acceptable, award [1 max] in this section for length of tangent.
 line length used for tangent at least 8 cm;
 value $0.09 \rightarrow 0.13$;
 accuracy – value within $0.10 \rightarrow 0.12$; [4]
 Award [1] for value between $\pm 10\%$ and $\pm 20\%$ of 0.11 and [2] for value $0.11 \pm 10\%$.

Unit of answer is not required. If the candidate fails to convert to s^{-1} , then award one of the last two marks for answer in range $6.0 \rightarrow 7.2^\circ\text{C min}^{-1}$.

(b)



(i) point plotted correctly; (allow ECF from (b)) [1]

(ii) error bar at $\theta_E = 20^\circ\text{C}$: $4(\pm 2)$ mm long;
 error bar at $\theta_E = 81^\circ\text{C}$: $20(\pm 4)$ mm long; [2]
 Ignore any horizontal error bars.

(c) (i) allowing for uncertainties in readings;
 points lie on straight-line;
 and line passes through origin; [3]
 Award [1] for "last point off line, so not obeyed".

(ii) points between $\theta_E = 20^\circ\text{C}$ and 65°C all lie close to straight-line;
 point at 81°C is at limit of uncertainty bar; [2]
 Award [1 max] if the candidate states straight-line deviates from the points at high temperatures.

(d) (i) straight-line with (+)ve intercept on $\lg R$ axis; [1]

(ii) gradient is 1.0;
 take antilog of value of intercept on $\lg R$ axis; [2]

- A2.** (a) *Labelled schematic/block diagram showing:*
 ion source and collimator;
 velocity selector and B-field (Bainbridge-type) / E-field and B-field (Aston-type);
 evacuated region in which ions travel;
 means of detection; **[3 max]**
- (b) correct paths through spectrometer shown for ions of two masses;
 peaks/lines close to one another and not $\times 2m$; **[2]**
- (c) (i) gluons; **[1]**
- (ii) vector bosons; (*allow Z or W*) **[1]**
- (iii) mesons; **[1]**
- A3.** (a) mention of change in internal energy depends on mass;
 mention of change in internal energy depends on specific heat capacity;
 same if product of mass and specific heat capacity are same; **[3]**
- (b) (i) total entropy of universe is increasing; **[1]**
- (ii) freezing causes release of latent heat;
 entropy of surroundings increases;
 more than the decrease when water freezes; **[3]**
- (c) (i) adiabatic; **[1]**
- (ii) ΔQ is zero;
 ΔU is negative *or* U decreases;
 this ΔU is transferred to do external work W ; **[3]**
Accept points in any logical order.

SECTION B

B1. Part 1 Linear motion

- (a) change in velocity / rate of change of velocity;
per unit time / with time; (*ratio idea essential to award this mark*) [2]
- (b) (i) acceleration is constant/uniform; [1]
- (ii) $t = \frac{2s}{(u+v)}$ and $t = \frac{(v-u)}{a}$;
clear working to obtain $v^2 = u^2 + 2as$; [2]
- (c) (i) $1.96 = \frac{1}{2} \times 9.81 \times t^2$;
 $t = 0.632 \text{ s}$; [2]
- (ii) time to fall (1.96 + 0.12) m is 0.651 s ;
shutter open for 0.019 s ; [2]
If the candidate gives a one significant digit answer treat it as an SD-1.
Award [0] if the candidate uses $s = \frac{1}{2}at^2$ and $s = 12 \text{ cm}$.
- (iii) greater distance means higher speed for ball;
so distance moved whilst shutter is open is greater;
so (fractional) error in measuring distance is smaller; $\left\{ \begin{array}{l} \text{(do not allow} \\ \text{"more accurate")} \end{array} \right.$ [3]

B2. Part 1 Gravitation

- (a) centripetal force is provided by the gravitational force; (*do not allow "equals" or "is"*)

$$\frac{mv^2}{R} = \frac{GMm}{R^2}; \quad [2]$$

to give $GM = Rv^2$ (*no mark for the answer*)

- (b) (i) $6.67 \times 10^{-11} \times 5.69 \times 10^{26} = (1.36 \times 10^8) \times v^2$

$$v = 1.67 \times 10^4 \text{ m s}^{-1};$$

$$T = \frac{2\pi r}{v};$$

$$T = 5.1 \times 10^4 \text{ s}; \quad [3]$$

Award [2 max] for use of diameter, answer $7.24 \times 10^4 \text{ s}$.

- (c) (i) $E_p = \frac{-GMm}{r}; \quad [1]$

- (ii) if E_p decreases, then r decreases;

because rv^2 constant, then speed increases; [2]

Award [0] in (ii) if answer states r increases.

Award [0] if argument is based on p . e decreases so k . e increases, v increases.

- (d) speed (of object) at surface (of planet) / specified starting point;
so that object may move to infinity / escape gravitational field of planet; [2]

- (e) loss in kinetic energy = gain in (gravitational) potential energy;

$$\frac{1}{2}mv^2 = \frac{GMm}{R};$$

$$\text{but } g = \frac{GM}{R^2};$$

hence $v = \sqrt{(2gR)}$ (*no mark for answer*)

assumption: *e.g.* planet is isolated / no friction / no atmosphere *etc.*; [4]

- (f) $v_{\text{es}} = \sqrt{(2 \times 1.6 \times 1.7 \times 10^6)};$
 $= 2.3 \times 10^3 \text{ m s}^{-1}; \quad [2]$

- (g) $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times (2.3 \times 10^3)^2 = 2.1 \times 10^{-23} \times T;$
 $T = 840 \text{ K}; \quad [2]$

- (h) atoms have a distribution of speeds / atoms may collide in upper atmosphere; [1]

Part 2 Electromagnetic induction

- (a) (i) $3.3 \times 10^{-2} \text{ T}$; [1]
- (ii) flux linkage = $3.3 \times 10^{-2} \times 1.7 \times 10^{-4} \times 250$;
 $= 1.4 \times 10^{-3} \text{ Wb (turns)}$; [2]
Award [0] if answer given as flux in (a)(ii) but allow full credit in (b)(i).
- (b) (i) new flux linkage = $7.23 \times 10^{-4} \text{ Wb turns}$ *or* $\Delta B = 1.6 \times 10^{-2} \text{ T}$;
change = $(1.4 - 0.7) \times 10^{-3}$ *or* change = $1.6 \times 10^{-2} \times 1.7 \times 10^{-4} \times 250$; [2]
change = $7 \times 10^{-4} \text{ Wb turns}$ (*no mark for answer*)
- (ii) e.m.f. is proportional/equal to rate of change of flux } (*do not allow*
(linkage); } "*induced current*")
- e.m.f. = $\frac{(7 \times 10^{-4})}{0.35} = 2 \times 10^{-3} \text{ V}$; [2]
- (c) (i) e.m.f./induced current acts in such a direction to (produce effects to) oppose
the change causing it; [1]
- (ii) induced current produces a magnetic field in the coil / induced current is in
field of magnet;
this produces a force; (*award only if the first marking point is correct*)
the force acts to oppose the motion of the coil; [3]

- B3.** (a) (i) wave that transfers energy; [1]
- (ii) amplitude = 4.0 mm; [1]
wavelength = 2.4 cm; [1]
frequency = $\frac{1}{0.3}$;
= 3.3 Hz; [1 max]
speed = 3.3×2.4 ;
= 8.0 cm s^{-1} ; [1 max]
- (b) (i) angle of incidence = 40° ;
 $\sin r = \frac{\sin 40}{1.4}$
 $r = 27^\circ$;
angle = 63° ; [3]
Award [1 max] for angle of incidence = 50° , $r = 33^\circ$.
- (ii) construction: wavefronts equally spaced;
separation less in medium B;
angle in medium B correct – by eye; [3]
- (c) e.g. coherent; (do not allow “same frequency / monochromatic / crest meets crest”)
(approximately) same amplitude/intensity;
polarised in same plane;
waves from source meet at a point; [2 max]
- (d) (i) wavelength is shorter;
hence fringes are closer together; [2]
Award [1 max] for wavelength longer hence fringes further apart.
- (ii) centre fringe is white;
because all wavelengths give constructive interference here;
fringes are coloured;
with blue “inner” edge / with red “outer” edge;
because constructive interference occurs at different positions;
far from centre position, no fringes observed; [4 max]
- (e) frequency determines maximum kinetic energy of photo-electron;
instantaneous;
intensity determines rate of production of photo-electrons;
intensity does not determine maximum kinetic energy of photo-electron; [2 max]

(f) idea of $eV = \frac{hc}{\lambda}$;

$$1.6 \times 10^{-19} \times 2.4 = \frac{(6.63 \times 10^{-34} \times 3.0 \times 10^8)}{\lambda};$$

$$\lambda = 5.2 \times 10^{-7} \text{ m};$$

[3]

Award [2 max] if factor 1.6×10^{-19} is missing.

- (g) (i) current is $2i_p$ / doubled;
because photon flux is doubled;
photon energy is unchanged;

[3]

- (ii) current is less than i_p ;
because photon flux is reduced;
since photon energy is increased;

[3]

B4. Part 1 Electricity

- (a) metal conductor: positive charges fixed;
mobile electrons;
plastic insulator: (positive charges and) electrons fixed; [3]
- (b) (i) moving charge from Earth to electroscope;
would require work to be done; [2]
- (ii) electric field causes movement of electrons (in metal);
and charges are not moving; [2]
- (iii) electrons move;
from Earth to the electroscope; [2]
- (c) (i) e.m.f. is the p.d. across cell when current is zero;
find intercept on V -axis; [2]
- (ii) r is (-) gradient of graph *or* $r = \text{e.m.f./current when } V = 0$ *or* value of R
quoted at a given voltage;
relevant working shown on graph $\left(\text{e.g. } \frac{4.5}{3.8} = 1.2 \Omega \right)$ *or* use of $E = Ir + IR$; [2]
- (d) diagram showing resistor in series with device;
from graph, at 1.5 A, p.d. is 2.7 V *or* use of $E = I(R + r)$
to give total external resistance as 1.8Ω ;
p.d. across $R = 2.7 - 0.8 = 1.9 \text{ V}$ resistance of device $= \frac{0.8}{1.5} = 0.53 \Omega$;
resistance $= \frac{1.9}{1.5} = 1.27 \Omega$ resistance $= 1.8 - 0.53 = 1.27 \Omega$; [4]
- (e) $2P$;
 P ;
 $\frac{1}{2}P$; [3]

Part 2 Radioactivity

- (a) (i) different forms of same element / nuclei having same proton number;
with different nucleon / mass numbers; [2]
- (ii) probability of decay (of nucleus) per unit time (ratio must be clear);
or
 $\frac{dN}{dt} = -\lambda N$ with $\frac{dN}{dt}$, λ and N explained; [1 max]
- (b) ${}_{20}^{42}\text{Ca}$;
 ${}_{-1}^0\text{e}$ *or* ${}_{-1}^0\beta$; (*do not accept* e^-). [2]
Award [1 max] if any extra particle e.g. neutron is included in equation.
- (c) (i) evidence that half-life is 12.5 hours;
correct labelling of t -axis; (*at least three values required*) [2]
- (ii) line as “inverse” of given line, *i.e.* starts at zero, curves correct direction and
flattens out reasonably; [1]
- (d) for this ratio, number of potassium atoms is $0.2N_0$;
time = 29 hours; [2]
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