SECTION A

A1. (a) correct positioning of all three error bars;
correct length of error bars – at least 3 mm long, even if only two are shown; ***[2]***

(b) a smooth curve through the data points within 2 mm of each data point; ***[1]***
*Award **[0]** for points joined by straight-line segments.*

(c) line of best-fit must be a curve;
in order to pass through the error bars; ***[2]***
*Award **[0]** for plain "curve" without attempt at an explanation.*

(d) (i) $20(\pm 2)\ ^\circ\text{C}$; ***[1]***

(ii) large enough triangle-hypotenuse 6 cm, from which to get slope;
correct calculation of slope at $x = 50\,\text{cm}$ to give $(-)1.05 \pm 0.25\ ^\circ\text{C cm}^{-1}$;
for a more accurate calculation in the range $(-)1.05 \pm 0.15\ ^\circ\text{C cm}^{-1}$; ***[3]***

(e) realization that $\dfrac{R_{50}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{50}} = \dfrac{R_{10}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{10}}$ if rate is proportional to temperature gradient;

substitution to get $R_{50} = \left(\dfrac{R_{10}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{10}}\left(\dfrac{\Delta\theta}{\Delta x}\right)_{50}\right) = \dfrac{43}{1.81} \times 1.05 = 25\ \text{W}$;

with a comment about the agreement of the result with the given value of R_{50}; ***[3]***

A2. (a) (i) initial momentum $= 500 \times 6 = 3000\ \text{N s}$;
final momentum $= 500 \times (-1) + 700 \times 5 = 3000\ \text{N s}$; ***[2]***
(working must be shown to award marks)
Allow approach that shows equal and opposite momentum changes.

(ii) initial kinetic energy $= \frac{1}{2} 500 \times 36 = 9000\ \text{J}$;
final kinetic energy $= \frac{1}{2} 500 \times 1 + \frac{1}{2} 700 \times 25 = 9000\ \text{J}$; ***[2]***
(working must be shown to award marks)

(b) impulse $=$ change of momentum $= 700 \times 5 = 3500\ \text{N s}$;
duration of collision $= 2.0\ \text{s}$;
to give $F = \dfrac{3500}{2.0} = 1800\ \text{N}$; ***[3]***
Accept force in the range 1700 N to 1800 N even with three significant figures.

A3. (a) (i) **two** arrows directed towards the centre of the circular path, within $\pm 0.5\,\text{cm}$ of the centre. ***[1]***

(b) (i) negative by stating any rule for the direction of the magnetic force; ***[1]***

(ii) the work done is zero;
since the force is at all times normal to the velocity; ***[2]***

(c) a curved path starting at X and in the right direction i.e. counterclockwise;
circular path of radius $\frac{R}{2}$; ***[2]***
Allow diameter 3-4 cm and be generous with how round the circle is.

SECTION B

B1. Part 1 Motion of a ball

(a) the maximum height reached by the ball/the displacement in the first 2 s /the distance travelled; ***[1]***

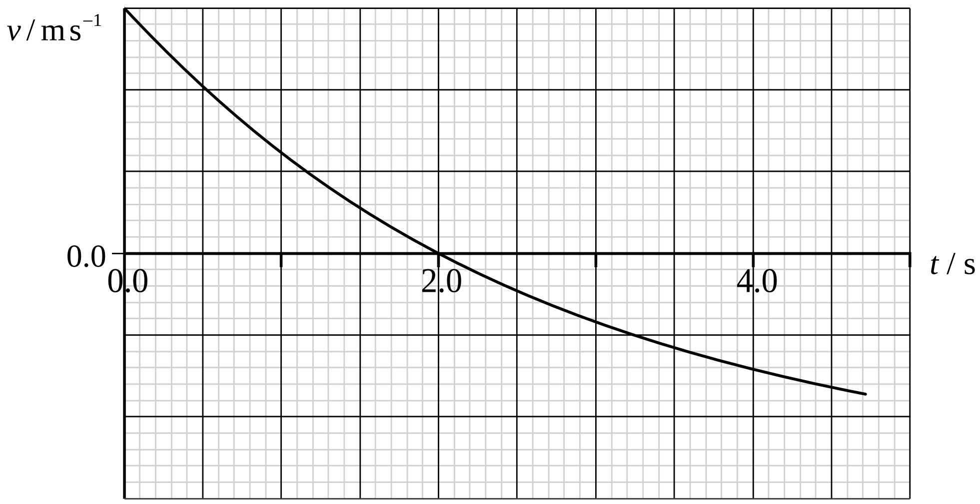
(b) 30 m; ***[1]***
Accept answers in the range 25 m to 30 m.

(c) (i) drawing tangent at $t = 1.0\,\text{s}$;
using a sufficiently large triangle – at least 6 cm hypotenuse;
to get $a = 15\,\text{m s}^{-2}$; ***[3]***
Accept acceleration in the range $14.5 - 15.5\,\text{m s}^{-2}$.

(ii) $R + mg = ma$;
$R = 3.75 - 2.50 = 1.2\,\text{N}$; ***[2]***
(Watch ECF from (i))

(d) slope of the graph is decreasing;
the force of air resistance must decrease as well; ***[2]***

(e)



smooth curve at t = 2.0 s ;
terminating between 4.25 s and 4.50 s ; ***[2]***
(Award second marking point only if first is correct)

(f) it will be less;
because mechanical energy/kinetic energy is being transformed into thermal energy (in the particle and air); ***[2]***
*Award **[0]** for an answer without justification.*

(g) the areas under the graph for the upward and downward motion must be the same;
from the way the <u>curve slopes</u> it follows that the time must be longer than 2.0 s ; ***[2]***

or

the average speed on the way down is less;
and so the time taken is longer;

Part 2 Nuclear decay

(a) the nucleus of He-4 / helium nucleus / two protons and two neutrons (bound together); ***[1]***

(b) electrons would be deflected by the electrons in the gold atoms;
without being able to approach (and hence probe) the nucleus; ***[2]***

(c) (i) the time that must elapse for the initial activity of the radioactive sample;
to be reduced by a factor of 2;

or

the time that must elapse for the initial number of <u>radioactive</u> nuclei;
to be reduced by a factor of 2; ***[2]***

(ii) ${}^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\alpha + {}^{234}_{90}\text{Th}$; ***[2]***
*Award **[1]** for correct numbers on the alpha and **[1]** for thorium.*
No ECF on thorium if alpha wrong and other way around.

(d) (i) realization that three half-lives have gone by;
to give an age of $3\times 4.5\times 10^{9} = 1.4\times 10^{10}$ years; ***[2]***
*Award **[2]** for bald answer of* 1.4×10^{10} *years.*

(ii) that no lead was lost from the rocks/none of the intervening daughters was lost from the rocks; ***[1]***

B2. Part 1 Waves on a string

(a) (i) wavelength $= 3.0\,\text{cm}$; **[1]**

(ii) period $= 0.25\,\text{ms}$;
hence frequency $= 4000\,\text{Hz}$; **[2]**
(Bald answer 4000 Hz scores ***[2]****)*

(iii) $c = \left(\dfrac{0.03}{0.25\times10^{-3}}\right) = 0.03\times4000 = 120\,\text{m}\,\text{s}^{-1}$; **[1]**
Watch ECF from (i) and (ii)

(b) (i) correct labelling of amplitude of 2.0 mm; **[1]**
(Any line from equilibrium to crest or trough)

(ii) cosine wave <u>from $x = 0$</u> ;
period constant throughout ; **[2]**

(c) (i) pulse of similar shape and size;
and inverted; **[2]**
Accept pulse that is of similar width but smaller amplitude.

(ii) the string pulls on the wall and so the wall pulls in the opposite direction on the string by Newton's third law;
the wall pushes on the string creating an inverted pulse; **[2]**

(d) (i) the oscillating left end creates a travelling wave to the right ;
which gets reflected by the fixed end;
at any one time there are two waves on the string travelling in opposite directions whose displacements/amplitudes are added (creating the standing wave); **[3]**

(ii) $c = f\lambda$

$\lambda = \dfrac{4L}{3} = 4.0\,\text{m}$;

hence $f = \dfrac{120}{4.0} = 30\,\text{Hz}$; **[2]**
Use ECF for wave speed from (a)(iii).

Part 2 Specific latent heat

(a) the amount of (thermal) energy needed to convert a unit mass of a solid substance into a liquid at the melting temperature of the substance / at constant temperature; ***[1]***

(b) (i) $V = 12 \times 3 \times 10^{-2} = 0.36\,\text{m}^3$;
$m = \rho \times V = 900 \times 0.36 = 324$;
$\approx 320\,\text{kg}$ ***[2]***

(ii) $E = PtA = 340 \times 12 \times 6 \times 60 \times 60$;
$= 8.8 \times 10^7$ J (*no marks for answer*) ***[1]***

(iii) mass that can melt with this available energy is
$\frac{8.8 \times 10^7}{330 \times 10^3} = 270\,\text{kg}$;
and so not all the ice will melt;

or

energy required to melt ice = $320 \times 330 \times 10^3 = 1.1 \times 10^8$ J;
so not all the ice melts (as this is more than the available energy); ***[2]***
Do not accept answers without justification.

(iv) that all the energy incident on the ice gets absorbed / that no energy gets reflected / no energy gets conducted to the water below; ***[1]***

(c) *Accept any reasonable discussion based on any method of heat transfer e.g.*
the air in contact with the ice is warmer than the rest and so rises;
leaving its place to colder air which in turns warms up as well carrying energy away from the ice;

or

the water/ice surface is warmer than the surroundings;
and so radiates electromagnetic waves losing thermal energy/net transfer by radiation losses;

or

the molecules of ice/water in contact with the air molecules;
transfer energy to them through collisions thus losing thermal energy; ***[2]***

B3. **Part 1** Electrical conduction

(a) (delocalized/valence/free) electrons that are not bound to any one particular atom of the metal/electrons loosely bound to atoms; ***[1]***

(b) (i) the mass of $1.0\,\text{m}^3$ is $8.93\times10^3\,\text{kg}$;

and therefore number of moles is $\dfrac{8.93\times10^6}{64}$;

$=1.4\times10^5\,\text{mol}$ (*no marks for answer*) ***[2]***

(ii) $1.4\times10^5\times6.02\times10^{23}=8.4\times10^{28}$; ***[1]***

(c) there is no net transfer of electric charge to the right or left;
because on the average as much charge moves to the right as to the left;

or

random velocities means no net motion in any direction;
hence no transfer of charge; ***[2]***

(d) arrow to the right; ***[1]***

(e) (i) $\dfrac{0.50}{10^{-3}}=5\times10^2\,\text{s}$ ***or*** $\approx 8\,\text{min}$; ***[1]***

Accept answer in seconds or minutes up to 2 significant figures.

(ii) all electrons in the wire start drifting at the same time/the electric field is established in the wire almost instantaneously;
the lamp will light as soon as the electrons <u>already</u> in the lamp filament begin to move; ***[2]***

(iii) the electrons gain kinetic energy as they are accelerated by the potential difference across the filament;
they collide with the filament atoms transferring energy to them;
the average kinetic energy of the filament atoms thus increases;
which implies that the temperature of the filament increases (since temperature is a measure of the average kinetic energy of the molecules); ***[4]***

Part 2 Block on an incline plane

(a) (i) *Award* ***[2]*** *if all three directions are correct.*
Award ***[1]*** *for showing that the weight arrow is longer than the other two.* ***[3]***

(ii) taking components to find the component of the weight as $mg\sin\theta$;
and hence tension $= mg\sin\theta = 11\,\text{N}$; ***[2]***
Accept 3 s.f. as 10.8 *N*

(b) (i) since the velocity is constant the acceleration is zero/body is in equilibrium as before;
and hence the net force is zero leading to the same tension; ***[2]***
Award ***[2]*** *for answers where it is clear that the candidate understands that this is an equilibrium situation.*

(ii) $P = Fv$
so $P = mg\sin\theta v$;
$P = 9.4$ W; ***[2]***
Accept 9.2 W. Bald answer gains ***[2]****.*

(iii) it will be equal to 9.4 W (*ECF from (ii)*);
because the net force is zero and so power by tension equals rate of change of potential energy / rate of change of potential energy is $\frac{mg\Delta h}{\Delta t} = \frac{mg\sin\theta\Delta s}{\Delta t} = mg\sin\theta\, v$;

or

no energy/power loss to friction ;
all energy increases potential energy so 9.4 W ; ***[2]***