SECTION A

A1. (a) $\pm 0.5\,^{\circ}\mathrm{C}$; ***[1]***

Do not accept $1\,^{\circ}C$.

(b) (i) *at $20\,^{\circ}C$*: $1800\,\Omega$; ***[1]***

at $5\,^{\circ}C$: within range $3080\,\Omega \rightarrow 3220\,\Omega$;
within $3120\,\Omega \rightarrow 3180\,\Omega$; ***[2]***

(ii) use of tangent at correct position clear;
answer $64\,\Omega\,\mathrm{K}^{-1}$ ***or*** $64\,\Omega\,^{\circ}\mathrm{C}^{-1}$; *(allow $\pm 2\,\Omega\,K^{-1}$ **or** $\pm 2\,\Omega\,^{\circ}C^{-1}$)*
negative sign; ***[3]***

(c) gradient of graph decreases as temperature rises / increases as temperature drops; *accept "gradient not constant".*
so relationship cannot be linear; ***[2]***

or

straight-line joining extreme points;
does not pass through "error boxes" of all points;

(d) product *RT* calculated correctly for two points;
product calculated correctly for third point;
conclusion: not same value so suggestion not correct; ***[3]***
*Award **[2 max]** if $^{\circ}C$ used instead of K.*

A2. (a) (i) $\mathrm{kg\,m\,s^{-2}}$; ***[1]***

(ii) $\mathrm{m\,s^{-1}}$; ***[1]***

(b) $\mathrm{kg\,m^{-1}}$; ***[1]***

ECF if candidate uses Newton for (a)(i) to obtain $N\,m^{-2}\,s^{2}$.

A3. (a) (i) extension $= 4.2\,\mathrm{cm}$; *(stated or shown in the working)*
force $= (4.2 \times 2.5 =)\,10.5\,\mathrm{N}$; ***[2]***

(ii) force $= (1.8 \times 2.5 =)\,4.5\,\mathrm{N}$; ***[1]***

(b) resultant force $= 6.0\,\mathrm{N}$; *(stated or shown in the working)*

acceleration $= \left(\dfrac{6.0}{0.75} =\right) 8.0\,\mathrm{m\,s^{-2}}$; ***[2]***

Accept $F = (k_1 + k_2)s = (2.5 + 2.5) \times 1.2 = 6\,N$.

A4. (a) gold leaf fallen;
negative charge on cap and no charge on gold leaf; ***[2]***

(b) gold leaf raised;
negative charge over gold leaf and cap; ***[2]***

(c) it would (give a measure of the charge) in diagram 4 but not in diagram 3; ***[1]***
Answer to be consistent with the candidate's diagrams 3 and 4.

SECTION B

B1. Part 1 Momentum

(a) (i) momentum is mass × velocity; ***[1]***

(ii) impulse is force × time / change in momentum; ***[1]***
In each case allow an equation, with symbols explained.

(b) (i) $\Delta p = 450\ (18-13)$;
$= 2250\,\text{kg m s}^{-1}$ ***[1]***

(ii) idea of equating Δp to change in momentum of water;
$m = \dfrac{2250}{19} = 118\,\text{kg}\ (\approx 120\,\text{kg})$; ***[2]***

(iii) time of trolley in tank $= \dfrac{9.3}{15.5} = 0.60\,\text{s}$;
$a = \dfrac{(18-13)}{0.60}$ ***or*** $force = \dfrac{2250}{0.60}\ (= 3750\,\text{N})$;
$a = 8.3\,\text{m s}^{-2}$ $a = \dfrac{3750}{450} = 8.3\,\text{m s}^{-2}$; ***[3]***

or

$v^2 = u^2 + 2as$;
$a = \dfrac{13^2 - 18^2}{2 \times 9.3}$;
$a = 8.3\,\text{m s}^{-2}$;

(c) (i) $E_K = \frac{1}{2}mv^2$;
$= \frac{1}{2} \times 450 \times (18^2 - 13^2)$;
$= 35\,000\,\text{J}$; ***[3]***

(ii) $E_K = \frac{1}{2} \times 118 \times 19^2$
$= 21000\,\text{J}$; *(allow 22 000 J for use of m = 120 kg)* ***[1]***

(d) some water will be thrown "sideways";
this will account for the difference in the kinetic energies;
this will not have any momentum in the forward direction / equal masses of water to left and right; ***[3]***

B1. Part 2 Force fields

(a) (i) *at A*: constant;
at B: decreasing; ***[2]***

(ii) field line gives the direction of the force (on mass or charge);
if lines touched (or crossed), particle would move in two directions at the same time and this is impossible; ***[2]***

(b) (i) must be a force normal to direction of motion / some reference to circular motion;
so field is magnetic; { *Do not award if there is no reasoning or reasoning is fallacious or misleading.* } ***[2]***

(ii) particles are oppositely charged; ***[1]***

(iii) $r = \frac{mv}{Bq}$;
speed is decreasing / particle losing energy;
hence radius is decreasing; { *Do not award if there is no reasoning or reasoning is fallacious or misleading.* } ***[3]***

B2. Part 1 Latent heat and specific heat

(a) (i) quantity of thermal energy/heat required to convert unit mass / mass of 1 kg of liquid to vapour/gas;
with no change of temperature / at its boiling point; ***[2]***

(ii) on vaporizing, potential energy of molecules/atoms increases;
on vaporizing, kinetic energy of molecules/atoms does not change;
only change in kinetic energy seen as change in temperature; ***[3]***
The term "vaporizing" or "phase change" should be present at least once to award full marks.

(b) (i) heater, variable resistor and power supply in series;
ammeter in series with heater, voltmeter in parallel with heater; ***[2]***

(ii) $P = VI$ used – not merely quoted;
$I = \frac{80}{9} = 8.9\,\text{A}$; ***[2]***

(iii) idea of $power \times time = mass \times latent\ heat$;
allowance made in equation for heat loss to atmosphere;
$(80 - 35) \times 60 = (1.89 - 0.70) \times L$;
$L = 2300\,\text{J g}^{-1}$; ***[4]***
*Award **[3 max]** for use of two powers and a reference to heat loss to atmosphere/environment to explain the difference in numerical values of L.*
*Award **[2 max]** for use of two powers and taking an average.*
*Award **[1 max]** for use of one power only.*

(c) (i) $\text{mass} = (650 - 350) \times 6 \times 1 = 1800\,\text{g}$; ***[1]***

(ii) $\text{energy} = 1.8 \times 4.2 \times 10^3 \times (100 - 18)$;
$= 6.2 \times 10^5\,\text{J}$ ***[1]***
Award mark for the substitution, not the final answer.

(iii) $\text{cost} = \frac{6.2 \times 10^5 \times 365 \times 3.5}{1.0 \times 10^6}$;
$= 790$ cents; ***[2]***

B2. Part 2 Linear and circular motion

(a) (i) spacing of the dots is increasing / *OWTTE*; ***[1]***

(ii) three further dots;
spacing increases by two squares between any two dots; ***[2]***

(iii) distance $= 37.6\,\text{m}$; ***[1]***

(b) (i) travels $(2.2 \times 4 =) 8.8\,\text{m}$ between drops;
$\text{speed} = \left(\frac{8.8}{0.80} =\right) 11\,\text{m s}^{-1}$; ***[2]***

(ii) in each $0.80\,\text{s}$, speed increases by $\frac{(0.4 \times 4)}{0.80} = 2.0\,\text{m s}^{-1}$;
$\text{acceleration} = \left(\frac{2.0}{0.80} =\right) 2.5\,\text{m s}^{-2}$; ***[2]***

or

in (2×0.80) seconds, distance traveled is $3.2\,\text{m}$;
$a = \frac{2(\Delta s)}{t^2} = \frac{2 \times 3.2}{(1.6)^2} = 2.5\,\text{m s}^{-2}$;

Allow a different choice of appropriate time interval to give correct answer.

B3. Part 1 Waves

(a) (i) C shown where graph line cuts *x*-axis; ***[1]***

(ii) amplitude $= 0.20\,\text{mm}$; ***[1]***

(iii) time period $= 0.30\,\text{ms}$;
use of $v = f\lambda$ and $f = \frac{1}{T}$ ***or*** $v = \frac{\lambda}{T}$;
$\lambda = 380 \times 0.30 \times 10^{-3} = 0.11\,\text{m}$; ***[3]***
ECF if time period misread.

(b) (i) superposition of two waves / *OWTTE*;
of same frequency and amplitude travelling in opposite directions; ***[2]***

(ii) stationary/standing wave is set up in the tube;
heaps form at the (displacement) nodes / powder pushed away from antinodes; ***[2]***

(iii) wavelength $= (2 \times 9.3 =)\ 18.6\,\text{cm}$;
speed $= (1800 \times 0.186 =)\ 330\,\text{m s}^{-1}$; ***[2]***
ECF if value of wavelength wrong.

(c) heaps further apart means longer wavelength;
hence speed increases (as temperature rises); { *Do not award if there is no reasoning or reasoning is fallacious or misleading.* } ***[2]***

B3. Part 2 Nuclear decay

(a) (i) emission of particles and/or e.m. radiation from unstable nucleus;
not affected by temperature/environment / is spontaneous process;
constant probability of decay (per unit time) / is random process;
activity/number of unstable nuclei in sample reduces exponentially;
daughter nucleus is (energetically) more stable; ***[3 max]***

(ii) electron(s) ejected from (neutral) atoms;
to form positively and negatively charged particles; *(do not allow "ions")* ***[2]***

(b) (i) fission; ***[1]***

(ii) **N.B.** *positions may be marked on line or on x-axis.*
U shown near right-hand end of line;
Sr and Xe shown between U and the peak with Sr to the left of Xe; ***[2]***

(iii) total binding energy of uranium $= 1189 + 784.8 - 187.9$;
$= 1785.9\,\text{MeV}$;
binding energy per nucleon $= \left(\frac{1785.9}{235} =\right) 7.60\,\text{MeV}$; ***[3]***
Allow unit as MeV or MeV per nucleon.
Accept answer in Joules e.g. $1.22 \times 10^{-12}\ J$.

(iv) binding energy is zero because neutrons are separate particles; ***[1]***