SECTION A

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

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

(ii) actual uncertainty $= \pm 70\,\Omega$;

percentage uncertainty $= \left(\frac{70}{2600}\right) \times 100 = 3\%$; *(do not allow 2.7%)* **[2]**

Do not apply SD–1 here since the question asks specifically for an estimate.

(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** $\pm 2\,\Omega\,^{\circ}C^{-1}$)*
<u>negative</u> 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 °C used instead of K.*

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

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

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__ left of the lamp); ***[2]***

A3. (a) the force exerted per unit mass;
on a point (small) mass; ***[2]***

(b) (i) use of $g = \frac{F}{m}$ and $F = G\frac{Mm}{R^2}$;
combine to get $g = G\frac{M}{R^2}$; ***[2]***

(ii) $M = \frac{gR^2}{G}$;
substitute to get $M = 1.9 \times 10^{27}$ kg; ***[2]***

SECTION B

B1. Part 1 Momentum

(a) (i) momentum is mass $\times$ velocity; ***[1]***

(ii) impulse is force $\times$ 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;
$m = \frac{2250}{19} = 118\,\text{kg}\,(\approx 120\,\text{kg})$; ***[2]***

(iii) time of trolley in tank $= \frac{9.3}{15.5} = 0.60\,\text{s}$;

$a = \frac{(18-13)}{0.60}$ ***or*** *force* $= \frac{2250}{0.60}(= 3750\,\text{N})$;

$a = 8.3\,\text{m s}^{-2}$ $a = \frac{3750}{450} = 8.3\,\text{m s}^{-2}$; ***[3]***

or

$v^2 = u^2 + 2as$;

$a = \frac{13^2 - 18^2}{2 \times 9.3}$;

$a = 8.3\,\text{m s}^{-2}$;

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

SECTION B

B1. Part 1 Simple harmonic motion and the greenhouse effect

(a) the force acting/accelerating (on the body) is directed towards equilibrium (position);
and is proportional to its/the bodies displacement from equilibrium; ***[2]***

(b) (i) 1.5×10^{-10} m ; ***[1]***

(ii) $T = 1.1\times10^{-12}$ s ;
$f = \left(\frac{1}{1.1\times10^{-12}}\right)$;
$= 9.1\times10^{13}$ Hz ***[2]***

(iii) $\omega = (2\pi f) = 5.7\times10^{14}$ (rad s^{-1});
$E_{\text{max}} = \left(\frac{1}{2}m\omega^2 x_0{}^2\right) = \frac{1}{2}\times1.7\times10^{-27}\times(1.5)^2\times10^{-20}\times(5.7)^2\times10^{28}$;
$= 6.2\times10^{-18}$ J ***[2]***

(c) negative sine;
starting at zero;
with same frequency as displacement; *(allow ± 2 mm square)* ***[3]***

(d) (i) $k = (4\pi^2 f^2 m_{\text{p}}) = 40\times83\times10^{26}\times1.7\times10^{-27}$;
$\approx 560\,\text{N}\,\text{m}^{-1}$ ***[1]***

(ii) use of $F = kx$ and $F = ma$;
to give $a = \frac{560\times1.5\times10^{-10}}{1.7\times10^{-27}} = 5.0\times10^{19}\,\text{m}\,\text{s}^{-2}$; ***[2]***

(e) (i) infra red radiation radiated from Earth will be absorbed by greenhouse gases;
and so increase the temperature of the atmosphere/Earth; ***[2]***

(ii) the natural frequency of oscillation (of a methane molecule) is equal to 9.1×10^{13} Hz ;
because of resonance the molecule will readily absorb radiation of this frequency; ***[2]***

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

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

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

or

in (2×0.80) seconds, distance traveled is $3.2\,\text{m}$;
$a = \frac{2(\Delta s)}{t^2} = \frac{2 \times 3.2}{(1.6)^2} = 2.5\,\text{m}\,\text{s}^{-2}$;
Allow a different choice of appropriate time interval to give correct answer.