SECTION A

A1. (a) equation corresponds to a straight line (and this is a curve); ***[1]***

(b) (i) unit is s/seconds; ***[1]***

(ii) 2.35; *(3 significant digit essential)* ***[1]***
Responses may be given in table. Do not penalize wrong units.

(c) (i) 31.5, 3.10; *(plotted to within* $\pm 1\,mm$*)*
22.5, 2.35; *(plotted to within* $\pm 1\,mm$*) (allow e.c.f. from (b)(ii))* ***[2]***

(ii) reasonable best-fit straight-line; ***[1]***

(d) (i) at $35\,\mathrm{m\,s^{-1}}$, allow $\frac{D}{v}$ in range $3.30 \rightarrow 3.45$ (s);
so *D* within range $116 \rightarrow 121$ m; ***[2]***
Penalize once if $\frac{D}{v}$ *is not in the range* $3.30 \rightarrow 3.45$ *(s) and then use ECF for the second marking point.*

(ii) intercept within range $0.55 \rightarrow 0.70$ (s); ***[1]***

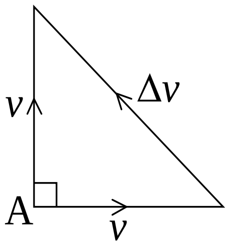
(iii) use of "triangle" with hypotenuse at least half length of graph line; { *Only allow use of data points if the points lie on the graph line.* }
gradient in range $0.074 \rightarrow 0.084$; ***[2]***
Allow candidate's values in (d)(ii) and (d)(iii).

(e) $D = 0.62v + 0.079v^2$; ***[1]***
Accept correct equation or correct statement about the values of a and b.

(f) (i) fractional uncertainty in $\frac{D}{v}$ is $\frac{0.3}{74} + \frac{0.5}{27} = 0.023$;
actual uncertainty $= \pm 0.06$; *(answer must be 1 significant digit)* ***[2]***

(ii) uncertainty in *v* is unaffected;
uncertainty in *D* ***or*** $\frac{D}{v}$ is reduced; ***[2]***
Award ***[1 max]*** *for a general comment that uncertainties will be reduced.*

A2. (a)



arrow drawn (from A) of about correct length;
arrow drawn (from A) at about correct angle;
vector Δv labelled clearly and in correct direction; ***[3]***

Award ***[1 max]*** *if vectors are added and* ***[1 max]*** *if Δv is opposite to correct direction.*

(b) Δv is directed towards the centre of the circle;
force necessary to cause change in velocity/ Δv; ***[2]***
Response must clearly refer to diagram and be consistent with it.

A3. (a) straight-line from origin through to 6.0 V, 150 mA; ***[1]***

(b) (i) potential difference across R = e.m.f. of battery = 4.0 V; ***[1]***

(ii) current in T at 4.0 V = 75 mA; ***[1]***

(iii) use of equation $P = VI$;
power $(= 4.0 \times 0.075) = 0.30\text{ W}$; ***[2]***

(c) (i) idea of same current in both and potential differences summing to 4.0 V;
current is 40 mA (horizontal line through 40 mA shown); ***[2]***
Award ***[2]*** *for a bald answer.*

(ii) for 40 mA, potential difference is 2.4 V;
power dissipation $(= 2.4 \times 0.040) = 96\text{ mW}$; ***[2]***
Award ***[2]*** *for a bald answer.*

A4. (a) (alternate light and dark) concentric rings; *(can be in the form of a diagram)*
with central bright spot; ***[2]***
Accept diagrams with "spots" if these have a discernible circular pattern.

(b) de Broglie wavelength mentioned / use of $\lambda = \frac{h}{p}$;
as v increases, momentum p increases;
so λ decreases causing a change in the pattern; ***[3]***

SECTION B

B1. Part 1 Linear motion

(a) (i) $E_K = \frac{1}{2} \times 72 \times 23^2$;
$= 1.9 \times 10^4$ J ; ***[2]***

(ii) uses area between the *t*-axis and the line;
correctly converts area $\rightarrow$ distance (one $1\text{cm} \times 1\text{cm}$ square $\equiv 5.0$ m);
distance between 90 m and 105 m;
improved accuracy, distance between 95 m and 100 m; ***[4]***
Do not accept kinematic formulas. Distance can only be found from area.

(b) (i) $\Delta E_P = 72 \times 9.8 \times 41$;
$= 2.9 \times 10^4$ J ; ***[2]***
Accept 3.0×10^4 *J for responses using* $g = 10\text{ m s}^{-2}$.

(ii) energy "loss" $= 1.0 \times 10^4$ J ;
average force $= \frac{(1.0 \times 10^4)}{98}$;
$= 100$ N ; ***[3]***
N.B. *follow through working–answer is {(b)(i)–(a)(i)} / (a)(ii).*

(iii) *e.g.* air resistance;
friction between skis and slope;
force to push snow away from skis; ***[2 max]***
To award marks responses must specify where friction is acting.

(c) $1.8 = \frac{1}{2} \times 9.8 \times t^2$;
time of flight $= 0.61$ s ;
horizontal distance travelled $(= 23 \times 0.61) = 14$ m ;
distance CD $(= 14 - 12) = 2.0$ m; ***[4]***
Accept a time of 0.60 s and CD = 1.8 m for responses using $g = 10\text{ m s}^{-2}$.

(d) (i) D is further from the edge C; ***[1]***

(ii) sensible reason *e.g.* velocity not normal to ground;
<u>hence</u> impact is less; *(any other sensible comment)* ***[2]***

Part 2 Nuclear reactions

(a) (i) nucleus emits;
an α-particle / a β-particle / *and/or* γ-ray photon / ionizing radiations; ***[2]***

(ii) cannot tell which nucleus will decay next;
cannot state at what time a nucleus will decay; ***[2]***
*Award **[2]** for constant probability of decay per unit time.*

(b) (i) ${}^{17}_{8}\text{O}$;
${}^{1}_{1}\text{p}$; ***[2]***

(ii) mass difference $= (-)1.29 \times 10^{-3}\, u$;
energy $= (1.29 \times 10^{-3} \times 931) = 1.20\,\text{MeV}$;
indicates in some way that mass defect is on left-hand side of equation / mass defect is negative;
α-particles must <u>provide at least 1.20 MeV</u> of energy; ***[4]***

B2. Part 1 Momentum

(a) the momentum of a system (of interacting particles) is constant;
if no external force acts on system / net force on system is zero / isolated system; ***[2]***
A statement of "momentum before = momentum after" achieves first mark only.

(b) (i) use of volume $= \pi r^2 \times v$;
$= \pi \times (1.4 \times 10^{-3})^2 \times 18$;
$= 1.1 \times 10^{-4}\,\text{m}^3$ ***[2]***

(ii) mass ejected per second $= 1.1 \times 10^{-4} \times 1000 = 0.11\,\text{kg}$;
change in momentum per second $= 0.11 \times 18$;
by Newton's 2nd, this is <u>force on</u> (ejected) <u>water</u>;
by Newton's 3rd, equal <u>force acts upwards on rocket</u>;
so force is $2.0\,\text{N}$ ***[4]***
Do not accept references to momentum conservation.

(iii) weight of rocket (and contents) is greater than the upward force; ***[1]***
Do not accept rocket is heavy/heavier.

Part 2 Temperature, specific heat and latent heat

(a) property measured at two known temperatures (and at unknown temperature);
(temperature calculated) assuming linear change of property with temperature; ***[2]***
*Award **[1]** for descriptions of constructing a thermometer.*

(b) thermometer absorbs (thermal) energy/heat from the body / has a thermal capacity;
so changes temperature of body;

or

time taken for (thermal) energy/heat to be conducted into thermometer;
so may not be able to follow changing temperature; ***[2]***

(c) (i) quantity of (thermal) energy/heat required to raise temperature of unit mass;
by one degree;

or

$c = \frac{\Delta Q}{m\Delta\theta}$;
with ΔQ, m and $\Delta\theta$ explained; ***[2]***

(ii) $m \times 330$;
$+m \times 4.2 \times 8$;
$= 0.45 \times 4.2 \times 16$;
$m = 0.083\,\text{kg}$; ***[4]***
*Award **[2 max]** for an answer $m = 0.092\,\text{kg}$ – ignoring ice-water.*

(d) (i) change is adiabatic;
change is sudden so no heat enters/leaves the gas / there is no time for heat exchange; ***[2]***

(ii) molecules rebound from piston;
with increased speed;
temperature depends on speed and so temperature rises; ***[3]***

(e) (i) substitution into equation for efficiency
$0.15 = \frac{W}{(W + 680)}$;
$W = 120\,\text{J}$; ***[2]***

(ii) gain G when thermal energy transferred to sink/cold reservoir;
loss L when thermal energy transferred from source/hot reservoir;
the overall / total entropy of the universe increases;
law implies $G + S_W > L$; ***[4]***

B3. Part 1 Magnetic and electrical force fields

(a) (i) use of $qV = \frac{1}{2}mv^2$;
$1.6\times10^{-19}\times420 = \frac{1}{2}\times1.67\times10^{-27}\times v^2$
$v = 2.8\times10^5\ \text{m s}^{-1}$; ***[2]***

(ii) arc of circle / continuous curve within region ABCD <u>and</u> deflected upwards *i.e.* towards AB;
straight-line as tangent to arc beyond BC; ***[2]***

(iii) $F = 1.5\times10^{-2}\times1.6\times10^{-19}\times2.8\times10^5$;
$= 6.7\times10^{-16}\ \text{N}$; *(allow 6.8×10^{-16} N)* ***[2]***

(b) (i) arrow pointing down the page; ***[1]***

(ii) $6.7\times10^{-16} = 1.6\times10^{-19}\times E$;
$E = 4.2\times10^3\ \text{V m}^{-1}$; *(allow 4.3×10^3 V m^{-1})* ***[2]***

(c) (i) induced e.m.f. / current acts in such a direction;
to <u>tend/produce effects</u> to oppose the change causing it; ***[2]***

(ii) e.m.f. constitutes electrical energy;
this energy is derived from working against the change causing the e.m.f.; ***[2]***
*Award **[1 max]** for references to forces against the direction of motion <u>if a suitable example</u> has been chosen.*

(d) (i) change in flux (linkage) $= 18\times10^{-6}\times0.32\times0.95$;
$(= 5.5\times10^{-6}\ \text{Wb})$
idea of induced e.m.f $= \frac{\Delta N\phi}{\Delta t}$;
$= \frac{(5.5\times10^{-6})}{0.34}$
$= 16\ \mu\text{V}$; ***[3]***

(ii) side PQ cuts flux but side RS does not cut flux / not move;
so, e.m.f. across QR/PS; ***[2]***

(iii) (as window opens) flux through window would not change;
<u>hence</u> no e.m.f. induced; ***[2]***

Part 2 Gravitational force fields

(a) gravitational force provides/is equal to the centripetal force;

$\frac{GMm}{r^2} = \frac{mv^2}{r}$;

$E_K = \frac{\frac{1}{2}GMm}{r}$ **[2]**

Accept responses that use $E_K = -\frac{1}{2}E_p$ and state what E_p is.

(b) (i) $\Delta E_K = \frac{1}{2} \times 4.00 \times 10^{14} \times 850 \times \left\{(7.18 \times 10^6)^{-1} - (7.26 \times 10^6)^{-1}\right\}$;

$= 2.61 \times 10^8$ J; **[2]**

(ii) $\Delta E_P = (-)4.00 \times 10^{14} \times 850 \times \left\{(7.18 \times 10^6)^{-1} - (7.26 \times 10^6)^{-1}\right\}$;

$= (-)5.22 \times 10^8$ J; **[2]**

*Award **[2]** for statement $\underline{\Delta E_P = (-)2 \times \Delta E_K} = (-)5.22 \times 10^8$ J.*

(iii) change in total energy $= (-)2.61 \times 10^8$ J; **[1]**

(c) change in total energy is negative;
total energy is less;
hence rockets fired to produce force in opposite direction to motion; **[3]**
*Do not accept bald answer without correct explanation. Award **[1]** for statements such as K.E. increases and P.E. decreases or that total energy decreases which may evident from sign in (b)(iii).*

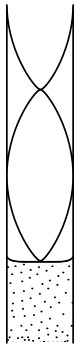
B4. Part 1 Interference of waves

(a) (i) frequency $\left(=\left\{6.0\times10^{-3}\right\}^{-1}\right)=170\,\text{Hz}$; ***[1]***

(ii) at $t=1.0\,\text{ms}$, displacement $(=1.7+0.7)=2.4\,\text{mm}$;
at $t=8.0\,\text{ms}$, displacement $=1.7-0.7$;
$=1.0\,\text{mm}$; ***[3]***

(b) bright fringes are darker/less bright because resultant amplitude is less;
dark fringes are brighter/less dark because summing amplitudes no longer gives zero; ***[2]***
*Award **[1 max]** for descriptions to <u>both</u> situations without explanations. To achieve full marks there must be clear reference to the resultant amplitude.*

(c) (i) wave (travels down tube and) is reflected at (water surface);
incident and reflected waves interfere/superpose; ***[2]***

(ii) 

i.e. $\frac{3}{4}\lambda$, 2 nodes, 2 antinodes;
<u>all</u> nodes marked; ***[2]***

Accept pressure nodes if clearly identified.

(iii) substitution in $v=f\lambda$;
$\frac{1}{2}\lambda=56\,\text{cm}$;
$v=(2\times0.56\times310)=350\,\text{m}\,\text{s}^{-1}$; ***[3]***

(d) (i) <u>observed</u> change in frequency;
when there is relative motion between source and observer; ***[2]***

(ii) f waves emitted in a distance $(c-v)$;

distance between wavefronts (*i.e.* apparent wavelength) $\lambda_o=\dfrac{(c-v)}{f}$;

apparent frequency $=\dfrac{c}{\lambda_o}=\dfrac{cf}{(c-v)}$; ***[3]***

(iii) engine produces many frequencies;
further relevant comment *e.g.* all frequencies are shifted so undetectable / siren frequency higher so Doppler shift more noticeable; ***[2]***

Part 2 X-ray spectra

(a) (i) corresponds to electron losing all its energy to give rise to one photon / max photon energy when photon receives all the energy of the electron; ***[1]***

(ii) electron <u>in target atom</u> moves from ground state to an excited state / atom is ionized;
photon with particular wavelength emitted on de-excitation;
each element has characteristic atomic energy levels; ***[3]***

(b) frequency $= \dfrac{(3.00\times10^{8})}{(0.154\times10^{-9})} = 1.95\times10^{18}\text{ Hz}$;
$1.95\times10^{18} = 2.5\times10^{15}(Z-1.0)^{2}$;
$Z = 29$; ***[3]***

(c) use of $\dfrac{hc}{\lambda} = eV$ ***or*** $hf = eV$;
$6.63\times10^{-34}\times1.95\times10^{18} = 1.6\times10^{-19}\times V$;
$V = 8.1\times10^{3}\text{ V}$; ***[3]***