SECTION A

A1. (a) both error bars of $\pm 5\,\text{m s}^{-1}$ drawn correctly; ***[1]***

(b) a straight line cannot be drawn through the error bars; *Accept the error bar comment with a straight line drawn on graph.*
that goes through the origin; ***[2]***

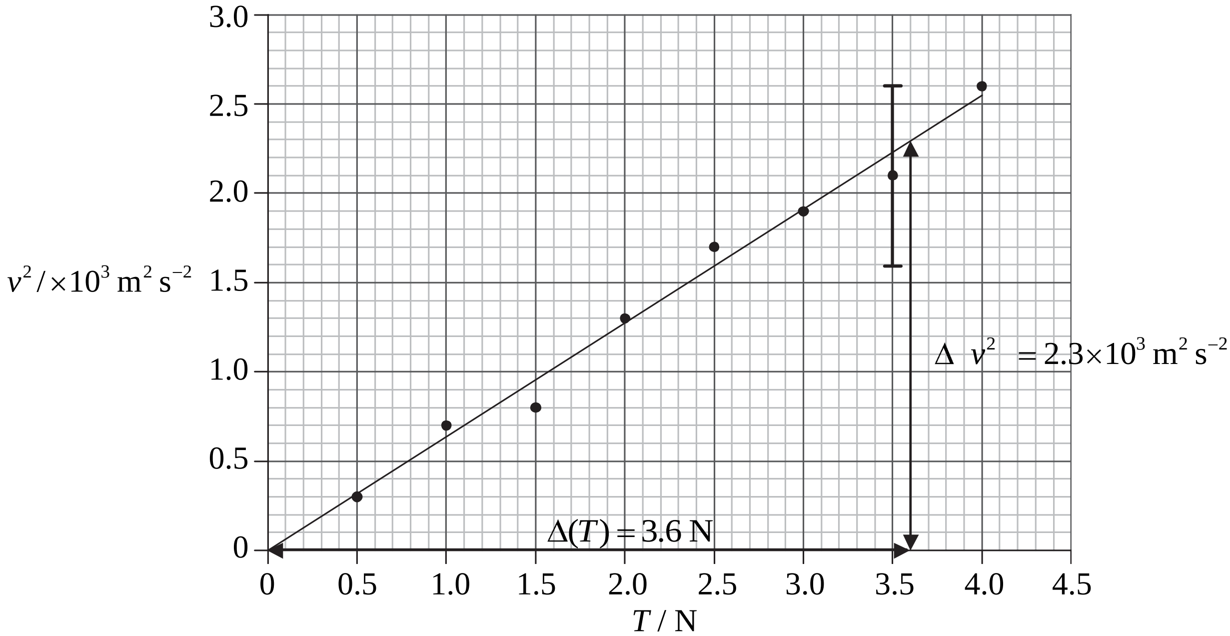
(c) (i) $\pm 500\,(\text{m}^2\,\text{s}^{-2})$; ***[1]***

(ii) $\frac{\Delta v^2}{v^2} = 2\frac{\Delta v}{v}$;
$\Delta v^2 = 27^2 \times 2 \times \frac{5}{27}$;
$\Delta v^2 \approx (\pm)300\,(\text{m}^2\,\text{s}^{-2})$ ***or*** $\approx (\pm)270\,(\text{m}^2\,\text{s}^{-2})$; ***[3]***

or

percentage error/uncertainty in $v = (18.5 =)\,19\%$;
percentage of error/uncertainty in $v^2 = 37\%$;
absolute error $\approx (\pm)300\,(\text{m}^2\,\text{s}^{-2})$ ***or*** $\approx (\pm)270\,(\text{m}^2\,\text{s}^{-2})$;
Answer must be to one or two significant figures.

(d)



use of gradient triangle over at least half of line;
gradient $= 640(\pm 40)$;
$= k^2$ to give $k = \sqrt{640} = 25(\pm 1)$;
unit of k is $\text{kg}^{-\frac{1}{2}}\,\text{m}^{\frac{1}{2}}$ ***or*** $\text{m s}^{-1}\,\text{N}^{-\frac{1}{2}}$; ***[4]***
Do not penalize omission of factor of 1000 for missing y-axis label if already penalized in (c). Treat as ecf.

SECTION A

A1. (a) $\pm 0.5\,^{\circ}\mathrm{C}$; ***[1]***
Do not accept $1^{\circ}C$.

(b) (i) *at 20°C*: $1800\,\Omega$; ***[1]***

at 5°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.*

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 $= \left(\frac{6.0}{0.75} =\right) 8.0\,\mathrm{m\,s^{-2}}$; ***[2]***
Accept $F = (k_1 + k_2)s = (2.5 + 2.5) \times 1.2 = 6\,N$.

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 $v = f\lambda$ <u>and</u> $f = \frac{1}{T}$ ***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 $= (1800 \times 0.186 =)\ 330\,\text{m}\,\text{s}^{-1}$; ***[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]***

B2. Part 1 Simple harmonic motion and waves

(a) is proportional to the displacement/distance (of the particle) from its equilibrium position;
is directed towards the equilibrium position; ***[2]***

(b) (i) overall correct shape;
with max of 0.06 J at $x = \pm 0.05$ and zero at $x = 0$; ***[2]***

(ii) $E_{K_{max}} = \frac{1}{2} 4\pi^2 m f^2 x_0^2$;
from the graph $E_{K_{max}} = 0.06\,(\text{J})$;
and $x_0 = 0.050\,(\text{m})$;
$f = \sqrt{\frac{2E_{K_{max}}}{4\pi^2 m x_0^2}}$;
to give $f = 2.0\,\text{Hz}$ ***[4]***

or

$k = \frac{2E_{K_{max}}}{x_0^2}$;
$= \frac{2 \times 0.06}{0.05^2}$;
= 48;
use of $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$;
= 2.0 Hz

(c) (i) the energy of the wave is propagated in a direction at right angles;
to the direction of oscillation of the particles; ***[2]***

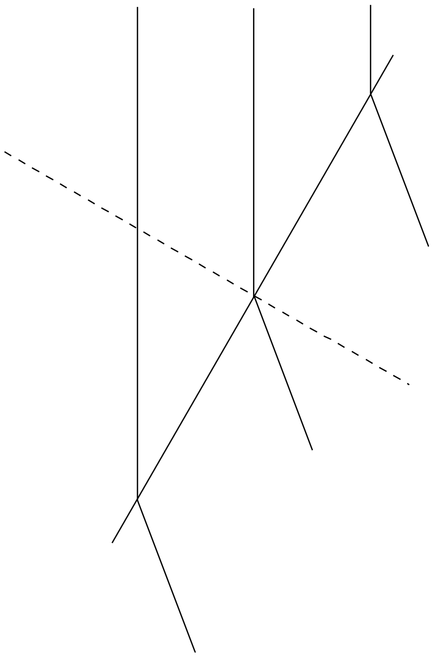
(ii) $\lambda = 0.40\,\text{m}$; ***[1]***

(d) (i) use of $\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$;

$\frac{v_2}{v_1} = 1.5$; } *this marking point is not necessary to award full credit.*

$\theta_2 = \left[\sin^{-1} 0.75\right] = 49^\circ$; ***[3]***

(ii)



any two lines as shown bending in the correct direction; ***[1]***

B2. Part 1 Simple harmonic motion and waves

(a) displacement is proportional to acceleration / *vice versa*;
because graph is straight-line through origin;
displacement and acceleration in opposite directions / acceleration always directed towards origin;
because negative gradient; ***[4]***

(b) use of $\omega^2 = (-)\frac{a}{x}$;

$\omega^2 = \frac{2900}{0.60 \times 10^{-3}}$;

$\omega = 2\pi f$;

$f = \frac{1}{2\pi}\sqrt{\frac{2900}{0.60 \times 10^{-3}}}$;

(to give $f = 350\,\text{Hz}$) ***[4]***

(c) $0.60\,\text{mm}$; ***[1]***

(d) (i) transfer of energy by means of vibrations/oscillations;
vibrations all in one direction parallel to direction of energy transfer; ***[2]***

(ii) $\frac{330}{350}$ ***or*** use of $c = f\lambda$;
$0.94\,\text{m}$; ***[2]***
Award ***[2]*** *for bald correct answer.*

SECTION B

B1. Part 1 Wave motion

(a) (i) 1.5 mm; ***[1]***

(ii) 8.0 cm; ***[1]***

(iii) distance travelled in 0.20 s is 3.2 cm;

so speed is $\left(\frac{3.2\times10^{-2}}{0.20}\right)=0.16\,\text{m s}^{-1}$; ***[2]***

(iv) $f=\frac{0.16}{8.0\times10^{-2}}=2.0\,\text{Hz}$; ***[1]***

(b) travelling waves transfer energy (standing waves do not);
travelling waves have a constant amplitude (standing waves do not);
standing waves have points that always have zero displacement (travelling waves do not);
the phase of a travelling wave constantly changes (but in standing waves points in between consecutive nodes have constant phase); ***[2 max]***

(c) (i) it is the speed of energy transfer/rate/speed at which wavefronts move forward; ***[1]***

(ii) a standing wave is formed from the superposition of two travelling waves;
wave speed refers to the speed of the travelling waves; ***[2]***

(d) (i) the oscillating string collides with the air molecules surrounding it;
creating a pressure/longitudinal wave; ***[2]***

(ii) wavelength of wave on string is $2\times0.80=1.6\,\text{m}$;

frequency is then $\left(\frac{240}{1.6}\right)=150\,\text{Hz}$;

sound has the same frequency and so wavelength is $\left(\frac{340}{150}\right)=2.3\,\text{m}$; ***[3]***

*Award **[1 max]** for those using a wavelength of 0.80 m obtaining a wavelength of 1.1 m in air. Accept alternative derivations that use a ratio and do not calculate the frequency explicitly.*

B2. Part 1 Simple harmonic motion

(a) 1. acceleration proportional to displacement from equilibrium/centre (of motion) /mean position;
2. acceleration directed to equilibrium/centre/mean position; ***[2]***

(b) (i) $\frac{d}{2}$; ***[1]***

(ii) sine/cosine curve shape reasonable; ***[1]***
Do not allow semi-circle for half sine curve.

(iii) period labelled;
amplitude labelled; ***[2]***

(c) (i) $v = a2\pi f$ seen/used;
$3.3\,\text{m s}^{-1}$; ***[2]***

(ii) $\text{acceleration} = a4\pi^2 f^2$ seen/used;
$9.2\times10^3\,\text{m s}^{-2}$; ***[2]***