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| 1 (a) (i) | Change of momentum of football  
\[= 0.44 \times 32 = 14.1 \text{ Ns (or kg m s}^{-1}) \text{ or } 14 \text{ N s}\] | 1 | The ball was at rest before being kicked, so the initial momentum was zero. |
| 1 (a) (ii) | Using \( F = \frac{\Delta (mv)}{\Delta t} \) gives \( F = \frac{14.1}{9.2 \times 10^{-3}} \)  
\[\therefore \text{ average force of impact} = 1.53 \text{ kN or } 1.5 \text{ kN}\] | 1 | The question leads you nicely into this form of solution.  
*Alternatively* you could use \( v = u + at \) and \( F = ma \) |
| 1 (b) (i) | Use of \( v = u + at \) gives  
\[15 = 24 + (9.2 \times 10^{-3})a \]
and \( a = -978 \text{ m s}^{-2} \)  
\[\therefore \text{ deceleration of boot} = 978 \text{ m s}^{-2}\] or 980 m s\(^{-2}\) | 1 | During the impact the boot is subject to two accelerations at right angles to each other. Part (i) considers the linear (negative) acceleration along the line of the impact force. Parts (ii) and (iii) look at the radial acceleration towards the centre of the arc in which the boot travels. |
| 1 (b) (ii) | **Centripetal acceleration of boot at time of impact**  
\[\frac{v^2}{r} = \frac{24^2}{0.62} = 929 \text{ m s}^{-2}\] or 930 m s\(^{-2}\) | 1 |  
| 1 (b) (iii) | **Before impact:** radial pull on knee joint is caused by centripetal acceleration of boot.  
**After impact:** radial pull is reduced because speed of boot is reduced. | 1 |  
| 2 (a) (i) | **Angular speed** \( \omega = 2\pi f = 2\pi \times 6.5 \)  
\[= 40.8 \text{ rad s}^{-1}\]  
**Force exerted by wheel on mass**  
\(F = m\omega^2 r = 0.015 \times 40.8^2 \times 0.25\)  
\[= 6.25 \text{ N or } 6.2 \text{ N or } 6.3 \text{ N}\] | 1 | The centripetal force on the boot acts inwards, towards the knee joint. The knee joint pulls inwards on the boot but is itself pulled outwards by the boot. When the boot slows down this centripetal force is reduced. |
| 2 (a) (ii) | Arrow drawn at a tangent to the circular path, starting on the mass and directed vertically upwards. | 1 | The force exerted by the wheel on the mass is the centripetal force on the mass, which acts towards the centre of the wheel. The mass exerts an equal and opposite force on the wheel. |
| 2 (b) | **Graph drawn to show:**  
• Exactly one cycle of a negative sinusoidal shape.  
• A period of 0.15 s clearly marked on time axis. | 1 | If the mass is no longer fixed to the wheel, it will move in the direction it was travelling at the instant it became detached, **but in a straight line**.  
At \( t = 0 \) the vertical component of \( F \) is zero as \( F \) acts towards the centre of the wheel. It becomes downwards or negative at 90°, and returns to zero at 180°. 0 at 270°, and returns to its original value at 360°. The period of rotation is \(\frac{1}{6.5}\) s. |
### Section 6: Further mechanics and thermal physics

**Answers to practice questions**

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| 2 (c) | Relevant points include:  
- Forced vibrations occur when a body is subjected to a periodic driving force.  
- The frequency of vibrations from the wheel increases as it speeds up.  
- The frequency of the forced vibrations is equal to the frequency of the wheel vibrations.  
- Resonance occurs at the natural frequency of the mirror.  
- At resonance the frequency of the forcing or driving oscillator is the same as the natural frequency of the mirror.  
- The amplitude of vibration reaches a maximum when the wheel rotates at 6.5 rev s$^{-1}$ (or when the frequency of the forcing vibration is 6.5 Hz).  
- At higher frequencies (or speeds) the amplitude decreases again. | Any 5 | The vibrating wheel provides a periodic driving force that sets the mirror in forced vibration. These vibrations are at the frequency of the driving oscillator (the wheel) and they therefore increase in frequency as speed increases. Eventually the resonant frequency is reached, when there is maximum energy transfer from the driving oscillator to the driven oscillator, the mirror. At resonance the amplitude of vibration is greatest, so the mirror shakes violently. At higher frequencies the mirror still vibrates, but with much smaller amplitudes. |
| 3 (a) (i) | Angular speed $\omega = 2\pi f = 2\pi \times 15 = 94.2$ rad s$^{-1}$  
Force on an end cap  
$F = mu^2r = 1.5 \times 94.2^2 \times 0.55$  
$= 7320$ N or 7330 N (about 7 kN) | 1 | The force on each end cap is the centripetal force required to keep it moving in a circular path. This acts inwards, towards the axis about which the rotor is rotating. |
| 3 (a) (ii) | Towards the centre of the rotor | 1 | |
| 3 (a) (iii) | Longitudinal stress in blade  
$\text{force} \quad = \quad \frac{7320}{\text{c.s.area}} = \frac{7320}{3.5 \times 10^{-4}} = 2.09 \times 10^7$ Pa (about 20 MPa) | 1 | This question now brings in a topic covered in AS Physics A Unit 2: the elastic properties of materials. The centripetal force on the end cap puts the whole rotor blade in tension, creating a tensile (longitudinal) stress throughout the blade. This stress will cause the length of the blade to increase slightly. |
| 3 (a) (iv) | Young modulus $E = \frac{\text{tensile stress}}{\text{tensile strain}}$  
$\therefore$ tensile strain = $\frac{2.09 \times 10^7}{6.0 \times 10^{10}} = 3.483 \times 10^{-4}$  
$tensile \text{ strain} = \frac{\Delta L}{L}$  
$\therefore$ change in length of blade $\Delta L = 3.483 \times 10^{-4} \times 0.55 = 1.92 \times 10^{-4}$ m  
(0.192 mm or 0.19 mm) | 1 | |
| 3 (a) (v) | Strain energy stored in one blade  
$= \frac{1}{2} F\Delta L = \frac{1}{2} \times 7320 \times 1.92 \times 10^{-4}$  
$= 0.703$ J or 0.70 J | 1 | Like a stretched spring, a stretched rotor blade stores some potential energy. |
| 3 (b) (i) | In 1 second volume of air passing over blades  
$= \text{area} \times \text{length per second} = Av$  
Mass of air passing over blades = $Av\rho$  
Momentum gained by air  
$= \text{mass} \times v = Apv^2$ | 1 | It is helpful to think about the cylinder of air that is dragged down over the rotor blades. In 1 second this air travels a distance $v$, so the length of the cylinder is $v$. The air was at rest (with momentum = 0) before being pulled down by the blades. |
### Section 6: Further mechanics and thermal physics

#### Answers to practice questions

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<td>3 (b) (ii)</td>
<td><strong>Upward</strong> force on helicopter = weight = 900 N &lt;br&gt;Area swept out by blades $A = \pi r^2$ = $\pi \times 0.55^2 = 0.950 \text{ m}^2$ &lt;br&gt;$A\rho v^2 = 900$ gives speed of air &lt;br&gt;$v = \sqrt{\frac{900}{0.95 \times 1.3}} = 27.0 \text{ m s}^{-1}$ or $27 \text{ m s}^{-1}$</td>
<td>1</td>
<td>The upwards force on the helicopter is equal to the downwards force on the column of air. When the helicopter has no vertical motion, this force is equal to its weight. Force = rate of change of momentum = momentum gained in 1 second.</td>
</tr>
<tr>
<td>4</td>
<td><strong>Relevant points include:</strong></td>
<td>Any 5</td>
<td>Part (a) illustrates another practical example of resonance, where the periodic driving force is caused by the rotation of the pump in a central heating system. This will set all of the connected pipework into forced vibration at the frequency of the driving force. Every part of the pipework will have a natural frequency of vibration. At particular frequencies, resonance could occur in different parts of the pipework. This will cause large amplitude vibrations if the pipes are free to move.</td>
</tr>
<tr>
<td>4 (a)</td>
<td><strong>Why strong vibrations are caused</strong>&lt;br&gt;• The pump creates a periodic driving force which acts on the pipe.&lt;br&gt;• The pipe has a natural frequency of vibration.&lt;br&gt;• The frequency of the periodic driving force increases as the pump speeds up.&lt;br&gt;• At a certain speed, the frequency of the driving force equals the natural frequency of the pipe.&lt;br&gt;• Under this condition resonance occurs.</td>
<td>1</td>
<td>Any 5</td>
</tr>
<tr>
<td>4 (b)</td>
<td><strong>Reduction of vibrations</strong>&lt;br&gt;• Fit extra clamps along pipe.&lt;br&gt;• To eliminate (or change) the resonant frequency.&lt;br&gt;<strong>or</strong>&lt;br&gt;• Change pipe dimensions (or material).&lt;br&gt;• To alter the resonant frequency.</td>
<td>1</td>
<td>Damping, perhaps by fitting padding around a pipe, would also be effective in reducing the amplitude of vibrations produced by this effect. Equivalent credit would be available for an answer which referred to damping and explained its effect.</td>
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<tr>
<td>5 (a)</td>
<td><strong>Centripetal acceleration</strong> $a = \frac{v^2}{r} = \frac{(7.68 \times 10^3)^2}{6750 \times 10^3} = 8.74 \text{ m s}^{-2}$</td>
<td>1</td>
<td>Notice that this question requires the centripetal acceleration, not the centripetal force. The radius $r$ of the orbit is found by adding the height of the orbit (380 km) to the radius of the Earth (6370 km).</td>
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<tr>
<td>5 (b)</td>
<td><strong>Relevant points include:</strong>&lt;br&gt;• The scientist is in free fall.&lt;br&gt;• The weight of the scientist provides the centripetal force.&lt;br&gt;• To give the scientist the same orbit radius and acceleration as the ISS.&lt;br&gt;• The scientist experiences no motion (or force) relative to the ISS.</td>
<td>Any 2</td>
<td>‘Apparent weightlessness’ in a spacecraft is a similar situation to that of somebody in a lift whose supporting cables have snapped. There is no need for contact with the surrounding capsule, because it has the same acceleration towards the Earth as the person inside it.</td>
</tr>
<tr>
<td>5 (c) (i)</td>
<td>$T = 2\pi \sqrt{\frac{m}{k}}$ gives $k = \frac{4\pi^2 M}{T^2}$ &lt;br&gt;$\therefore$ stiffness of spring system &lt;br&gt;$k = \frac{4\pi^2 \times 2.0}{1.2^2} = 54.8 \text{ N m}^{-1}$ (about 55 N m$^{-1}$)</td>
<td>1</td>
<td>The quantity represented by $k$ is usually called the ‘spring constant’, but that is fora single spring. The quantity referred to here as ‘stiffness’ is the effective spring constant for the two springs.</td>
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<td>5 (c) (ii)</td>
<td>For the atom's vibrations, ( T = 2\pi \sqrt{\frac{m}{k}} ) gives period ( T = 2\pi \sqrt{\frac{4.7 \times 10^{-26}}{54.8}} ) ( = 1.84 \times 10^{-13} ) s. Frequency of vibration ( f = \frac{1}{T} = \frac{1}{1.84 \times 10^{-13}} = 5.43 \times 10^{-12} ) Hz or ( 5.4 \times 10^{-12} ) Hz.</td>
<td>1</td>
<td>The whole of part (c) is a good example of scientific modelling. A system that is much too small to be observed directly can be represented by a laboratory model having similar characteristics. Study of the model will provide information about the behaviour of the system represented by it.</td>
</tr>
<tr>
<td>6 (a)</td>
<td>( T/s: 0.35, 0.44, 0.51, 0.57, 0.62 ) (all shown to 2 decimal places) ( T^2/s^2: 0.123, 0.194, 0.260, 0.325, 0.384 ) (all shown to 3 decimal places).</td>
<td>1</td>
<td>It is the normal practice in tables of experimental results to maintain a consistent number of decimal places down a column. In this table an example is set by the first entry, given as 0.25 and 0.63.</td>
</tr>
<tr>
<td>6 (b) (i)</td>
<td>For the mass suspended from the spring, ( Mg = k\Delta L = k(l - l_0) ) Squaring, and substituting in, equation for period ( T^2 = \frac{4\pi^2 m}{k} = \frac{4\pi^2 (l - l_0)}{g} ) ( \therefore g = \frac{4\pi^2}{4\pi^2} = 9.87 ) (( \pm ) 0.15) m/s^2. Intercept on ( l ) axis = ( l_0 = 300 ) (( \pm ) 5) mm</td>
<td>1</td>
<td>The extension ( \Delta L ) of the spring is found by subtracting the original length from the new (measured) length. Hooke's law indicates that the tension in the spring is ( k\Delta L ). When the system is in equilibrium, this tension is equal to the weight of the suspended masses.</td>
</tr>
<tr>
<td>6 (b) (ii)</td>
<td>Graph drawn to have: • Suitable scales • Both axes labelled: ( T^2 / s^2 ) and ( l / \text{mm} ) • At least 5 points plotted correctly • An acceptable straight line.</td>
<td>Any 4</td>
<td>The scales you choose should allow your line to occupy more than half of the area of the graph paper. Use a 300 mm ruler when drawing the straight line, which should be the 'best-fit' line for the experimental points.</td>
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<tr>
<td>6 (b) (iii)</td>
<td>Gradient ( = \frac{4\pi^2}{g} = \frac{0.400}{0.100} ) ( = 4.00 ) (( \pm ) 0.05) ( \text{s}^{-2} ) m^{-1} ( \therefore g = \frac{4\pi^2}{4.00} = 9.87 ) (( \pm ) 0.15) m/s^2. Intercept on ( l ) axis = ( l_0 = 300 ) (( \pm ) 5) mm.</td>
<td>1</td>
<td>When ( T^2 = 0, l = l_0 ). Hence ( l_0 ) is the intercept on the ( l ) axis. Expanding the equation of the line ( T^2 = \frac{4\pi^2 l}{g} - \frac{4\pi^2 l_0}{g} ). Comparison with the straight line equation ( y = mx + c ) shows that the gradient ( (m) ) is ( \frac{4\pi^2}{g} ).</td>
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<tr>
<td>6 (c)</td>
<td>If ( T = 1.00 ) s, ( (l - l_0) = \frac{g}{4\pi^2} = \frac{1}{\text{gradient}} ) ( = 0.250 ) m ( \therefore l = 0.250 + l_0 = 250 + 300 = 550 ) mm. Spring may not obey Hooke's law when large masses are added to it. Beyond limit of proportionality, equal masses produce larger extensions.</td>
<td>1</td>
<td>The largest time period in the experimental results is 0.62 s. The time period increases when a larger mass is placed on the spring. Since ( T \propto \sqrt{m} ), a much larger mass would be needed to give ( T = 1.00 ) s. The extension of the spring would be almost as great as its original length. With such a large extension, the spring would be unlikely to obey Hooke's law.</td>
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<tr>
<td>7 (a) (i)</td>
<td>mass = density ( \times ) volume ( = 1000 \times 1.3 \times 10^{-3} = 0.13 ) kg.</td>
<td>1</td>
<td>Part (i) relies on your retention of very early experiences in science:</td>
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### Section 6: Further mechanics and thermal physics

**Answers to practice questions**

#### AQA Physics

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<td>7 (a) (ii)</td>
<td>Energy to change temperature: $\Delta Q = mc\Delta \theta = 0.13 \times 4200 \times 18$ $= 9.83 \times 10^3 \text{ J}$</td>
<td>1</td>
<td><strong>Guidance:</strong> Changing water at 18°C completely into ice at 0°C is a two-stage process. To find the average rate of removal of energy you must find the total energy removed and then divide by the time. To simplify the calculation, the energy that has to be removed from the beaker is regarded as negligible. In practice the rate of removal of energy is likely to decrease as the temperature of the water falls towards 0°C. Can you explain why?</td>
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<tr>
<td>Energy to turn water to ice: $\Delta Q = ml = 0.13 \times 3.3 \times 10^5$ $= 4.29 \times 10^4 \text{ J}$</td>
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<td>Average energy removed per second $= \frac{(9.83 \times 10^3) + (4.29 \times 10^4)}{1700}$ $= 5.27 \times 10^4 \div 1700 = 31.0 \text{ J s}^{-1}$ (or W)</td>
<td>1</td>
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<tr>
<td>7 (b)</td>
<td>Electrical energy passed to surroundings by the freezer $= Pt = 25 \times 1700 = 4.25 \times 10^4 \text{ J}$</td>
<td>1</td>
<td>All of the electrical energy supplied to the freezer is converted into thermal energy, which is passed to the surroundings together with the energy that is removed from the water.</td>
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<tr>
<td>Total energy passed to surroundings $= (4.25 \times 10^4) + (5.27 \times 10^4)$ $= 9.52 \times 10^4 \text{ J}$</td>
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<tr>
<td>8 (a)</td>
<td>When tube is inverted lead particles fall and lose gravitational potential energy... which is converted into kinetic energy. The kinetic energy is converted into thermal energy on impact with the bottom of the tube.</td>
<td>1</td>
<td>From your elementary studies in science these ought to be three very easy marks.</td>
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<tr>
<td>8 (b) (i)</td>
<td>Loss of potential energy $\Delta E_p = mg\Delta h$ $= 0.025 \times 9.81 \times 1.2 = 0.294 \text{ J}$</td>
<td>1</td>
<td>This type of experiment finally convinced scientists that what they had called ‘heat’ (thermal energy) is just another form of energy, into which other forms of energy may be completely converted.</td>
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<tr>
<td>8 (b) (ii)</td>
<td>Total loss of potential energy after 50 inversions $= 50 \times 0.294 = 14.7 \text{ J}$</td>
<td>1</td>
<td>When the lead particles come to rest again at the bottom of the tube, all of the gravitational potential energy they have lost is converted into thermal energy. Note that this calculation assumes that none of this thermal energy is lost to the surroundings. In practice the lead particles will lose energy once their temperature exceeds that of their surroundings.</td>
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<td>8 (b) (iii)</td>
<td>$\Delta Q = mc\Delta \theta$ $\therefore 14.7 = 0.025 \times c \times 4.5$ gives specific heat capacity of lead $c = 131 \text{ J kg}^{-1} \text{ K}^{-1}$</td>
<td>1</td>
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<tr>
<td>9 (a) (i)</td>
<td>Consider 1s: mass of water flowing $= \text{density} \times \text{volume} = 1000 \times 5.2 \times 10^{-5}$ $= 5.2 \times 10^{-2} \text{ kg s}^{-1}$</td>
<td>1</td>
<td>Flow problems are usually solved most easily by considering what happens in a time of 1 second. This question states that all of the electrical energy supplied should be assumed to become thermal energy in the water. Hence the power supplied to the shower is equal to the thermal energy gained by the water in one second, since power is the rate of supply of energy.</td>
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<tr>
<td>Thermal energy gained by water $\Delta Q = mc\Delta \theta = 5.2 \times 10^{-2} \times 4200 \times 32$ $= 6.99 \times 10^3 \text{ J s}^{-1}$ $\therefore$ power supplied to shower $= 6.99 \text{ kW}$</td>
<td>1</td>
<td></td>
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| 9 (b) | Time \( t \) taken to reach the floor is given by \[ s = ut + \frac{1}{2} a t^2 \] \[
\therefore 2.0 = 0 + ( \frac{1}{2} \times 9.81 \times t^2 )
\]
... from which \( t = 0.639 \) s
Horizontal distance travelled = \( v_{\text{max}} \times t \)
\[ = 2.5 \times 0.639 \]
\[ = 1.60 \text{ m} \] | 1 | The particles of water in the jet behave as tiny projectiles. Remember that the horizontal and vertical components of the motion of a projectile are treated separately. The vertical motion is subject to the acceleration due to gravity, whilst the horizontal motion is at constant speed. |
| 10 (a) (i) | Temperature of air = 22 + 273 = 295 K | 1 | It is essential to realise that the temperature must be expressed in K whenever \( pV = nRT \) is to be applied. The size of the room in this question is typical of the rooms in modern houses or apartments. The pressure is normal atmospheric pressure, and the temperature would be comfortable for an evening in winter. |
| 10 (a) (ii) | Use of \( pV = nRT \)
Gives \( 105 \times 10^3 \times 27.0 = n \times 8.31 \times 295 \)
\[ \therefore \text{number of moles of air in room} \]
\[ n = \frac{105 \times 10^3 \times 27.0}{8.31 \times 295} = 1160 \text{ mol} \] | 1 | Any 4 |
| 10 (a) (iii) | Number of molecules in room = \( 1160 \times N_A = 1160 \times 6.02 \times 10^{23} \)
\[ = 6.98 \times 10^{26} \] | 1 | |
| 10 (b) | Relevant points include these listed here. When the temperature falls... | | |
| 10 (b) (i) | The mean square speed of the gas molecules decreases because the mean square speed is proportional to the temperature. |
| 10 (b) (ii) | The pressure of the gas decreases
• because the number of collisions per second against the walls decreases...
• and the change in momentum per collision is smaller on average. |
| 11 (a) (i) | Graph plotted to have:
• axes labelled \( E_x/10^{-21} \) and \( T \)K with a scale occupying more than half of the area of the graph paper
• correct plotting of all 6 points
• a best fit straight line.
Reading from the graph, at 350 K
\[ E_x = 7.23 \text{ (± 0.05) } \times 10^{-21} \text{ J} \] | 3 | It is good practice to plot graphs in pencil, because any errors during the plotting are then easily corrected. The line itself is also best drawn with a sharp pencil, using a 300 mm transparent ruler. To be consistent with the data in the table, you should quote this value to three significant figures. Do not overlook the ‘\( \times 10^{-21} \) J’. |
| 11 (a) (ii) | Gradient of graph
\[ = \frac{(8.28 - 6.21) \times 10^{-21}}{(400 - 300)} \]
\[ = 2.07 \text{ (± 0.08) } \times 10^{-23} \text{ J K}^{-1} \]
The equation of the line is \( E_x = \frac{3}{2} kT \)
\[ \therefore \text{gradient of graph} = \frac{3}{2} kT \]
\[ \frac{3}{2} k = 2.07 \times 10^{-23} \text{ gives Boltzmann constant} \]
\[ k = 1.38 \text{ (± 0.05) } \times 10^{-23} \text{ J K}^{-1} \] | 1 | This question becomes a further exercise in applying the properties of a straight line graph of the form \( y = mx \), where \( m \) is the gradient. The Boltzmann constant \( k \) is the universal gas constant \( \text{per molecule} \), as opposed to \( R \), which is the universal gas constant \( \text{per mole} \), \( k = \frac{R}{N_A} \). |
### Section 6: Further mechanics and thermal physics

**Answers to practice questions**

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<td>11 (b) (i)</td>
<td>An elastic collision is one in which there is no loss of kinetic energy.</td>
<td>1</td>
<td>‘No loss of energy’ is not a satisfactory answer because energy is always conserved in any physical process.</td>
</tr>
</tbody>
</table>
| 11 (b) (ii) | **Other possible assumptions listed below.**  
• The motion of the molecules is random.  
• Intermolecular forces are negligible (except during collisions).  
• The volume of the molecules is negligible (compared to volume of container).  
• The duration of collisions is negligible (compared to time between collisions).  
• The molecules are identical.  
• A gas consists of a very large number of molecules.  
• The molecules behave according to the laws of Newtonian mechanics. | Any 1 | One mark for any one of these should not be too taxing! |
| 11 (b) (iii) | **Relevant points include:**  
• temperature is proportional to the average kinetic energy of the molecules  
• at the absolute zero of temperature the kinetic energy of the molecules would be zero. | | If the graph were extrapolated to lower temperatures, a point would be reached at which \( E_k = 0 \). This would be \( T = 0 \) (i.e. 0 K), at which temperature the graph suggests that molecules would stop moving. |
| 12 (a) | Mean kinetic energy of an air molecule  
\[
\frac{3}{2} kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 300 
\]
\[
= 6.21 \times 10^{-21} \text{ J} 
\] | 1 | The mean molecular kinetic energy depends only on the absolute temperature of the gas. |
| 12 (b) | Combining \( pV = \frac{1}{3} N m c_{\text{rms}}^2 \) with density  
\[
\rho = \frac{N m}{V} \quad \text{gives} \quad \rho = \frac{1}{3} \rho c_{\text{rms}}^2 
\]
\[
= 1.01 \times 10^5 = \frac{1}{3} \times 1.24 \times c_{\text{rms}}^2 
\]
leading to mean square speed of air molecules  
\[
c_{\text{rms}}^2 = 2.44 \times 10^5 \text{ m}^2 \text{ s}^{-2} 
\]

**Note that:**  
• \( c_{\text{rms}} \) is the square root of the mean square speed; therefore the mean square speed is \( c_{\text{rms}}^2 \)  
• root mean square speed \( c_{\text{rms}} = 494 \text{ m s}^{-1} \) | 1 | Alternatively (and rather more tediously):  
Consider 1.0 m\(^3\) of air. Substitution of given values into \( pV = nRT \) gives \( n = 40.5 \text{ mol.} \)  
\[
\therefore \quad \rho = \frac{1}{3} m c_{\text{rms}}^2 
\]
\[
= 1.01 \times 10^5 = \frac{1}{3} \times 5.08 \times 10^{-26} \times c_{\text{rms}}^2 
\]

\[c_{\text{rms}}^2 = 2.44 \times 10^5 \text{ m}^2 \text{ s}^{-2}.\] |
| 12 (c) | Gas molecules always move with a range of speeds.  
At 320 K many molecules will be moving much faster than 494 m s\(^{-1}\) but many will also be travelling at much lower speeds than this. | 1 | Raising the temperature from 300 K to 320 K will increase the mean square speed. At any temperature, the random motion means that there are many molecules travelling at both higher and lower speeds than the mean value. |