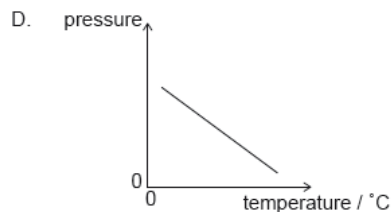
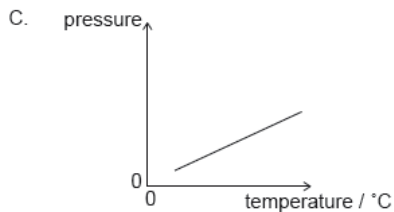
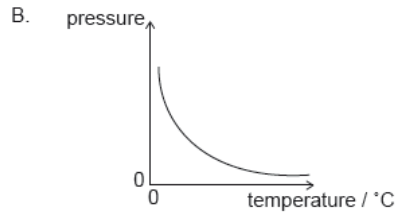
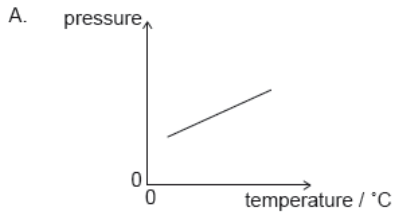


3_13_2 [147 marks]

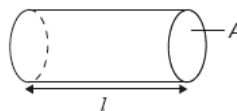
1. A fixed mass of an ideal gas is trapped in a cylinder of constant volume and its temperature is varied. Which graph shows the variation of the pressure of the gas with temperature in degrees Celsius? [1 mark]



2. What are the units of the ratio $\frac{\text{specific heat capacity of copper}}{\text{specific latent heat of vaporization of copper}}$? [1 mark]

- A. no units
- B. k
- C. k^{-1}
- D. k^{-2}

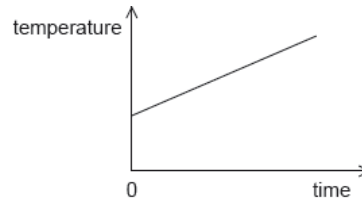
3. A sealed cylinder of length l and cross-sectional area A contains N molecules of an ideal gas at kelvin temperature T . [1 mark]



What is the force acting on the area of the cylinder marked A due to the gas?

- A. $\frac{NRT}{l}$
- B. $\frac{NRT}{lA}$
- C. $\frac{Nk_B T}{lA}$
- D. $\frac{Nk_B T}{l}$

4. The graph shows how the temperature of a liquid varies with time when energy is supplied to the liquid at a constant rate P . The gradient of the graph is K and the liquid has a specific heat capacity c . [1 mark]



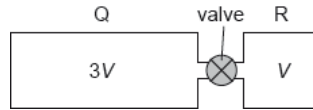
What is the mass of the liquid?

- A. $\frac{P}{cK}$
 B. $\frac{PK}{c}$
 C. $\frac{Pc}{K}$
 D. $\frac{cK}{P}$
5. A container that contains a fixed mass of an ideal gas is at rest on a truck. The truck now moves away horizontally at a constant velocity. What is the change, if any, in the internal energy of the gas and the change, if any, in the temperature of the gas when the truck has been travelling for some time? [1 mark]

	Change in internal energy	Change in temperature
A.	unchanged	unchanged
B.	unchanged	increased
C.	increased	unchanged
D.	increased	increased

6. A sealed container contains water at $5\text{ }^{\circ}\text{C}$ and ice at $0\text{ }^{\circ}\text{C}$. This system is thermally isolated from its surroundings. What happens to the total internal energy of the system? [1 mark]
- A. It remains the same.
 B. It decreases.
 C. It increases until the ice melts and then remains the same.
 D. It increases.
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7. Q and R are two rigid containers of volume $3V$ and V respectively containing molecules [1 mark] of the same ideal gas initially at the same temperature. The gas pressures in Q and R are p and $3p$ respectively. The containers are connected through a valve of negligible volume that is initially closed.



The valve is opened in such a way that the temperature of the gases does not change. What is the change of pressure in Q?

- A. $+p$
- B. $\frac{+p}{2}$
- C. $\frac{-p}{2}$
- D. $-p$

A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K .

- 8a. Calculate the pressure of the gas. [1 mark]

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When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K . The specific heat capacity of the gas is $3.1 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

- 8b. Calculate, in kg, the mass of the gas. [1 mark]

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- 8c. Calculate the average kinetic energy of the particles of the gas. [1 mark]

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8d. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. [3 marks]

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An ideal monatomic gas is kept in a container of volume $2.1 \times 10^{-4} \text{ m}^3$, temperature 310 K and pressure $5.3 \times 10^5 \text{ Pa}$.

9a. State what is meant by an ideal gas. [1 mark]

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9b. Calculate the number of atoms in the gas. [1 mark]

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9c. Calculate, in J, the internal energy of the gas. [2 marks]

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The volume of the gas in (a) is increased to $6.8 \times 10^{-4} \text{ m}^3$ at constant temperature.

9d. Calculate, in Pa, the new pressure of the gas.

[1 mark]

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9e. Explain, in terms of molecular motion, this change in pressure.

[2 marks]

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A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K .

When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K . The specific heat capacity of the gas is $3.1 \text{ kJ kg}^{-1} \text{ K}^{-1}$.

10a. Determine, in kJ, the total kinetic energy of the particles of the gas.

[3 marks]

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10b. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. [3 marks]

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11a. State what is meant by an ideal gas. [1 mark]

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11b. Calculate the number of atoms in the gas. [1 mark]

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11c. Calculate, in J, the internal energy of the gas. [2 marks]

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11d. Calculate, in Pa, the new pressure of the gas.

[1 mark]

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11e. Explain, in terms of molecular motion, this change in pressure.

[2 marks]

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12. A 1.0 kW heater supplies energy to a liquid of mass 0.50 kg. The temperature of the liquid changes by 80 K in a time of 200 s. The specific heat capacity of the liquid is 4.0 kJ kg⁻¹ K⁻¹. What is the average power lost by the liquid? [1 mark]

- A. 0
- B. 200 W
- C. 800 W
- D. 1600 W

13. Under what conditions of pressure and temperature does a real gas approximate to an ideal gas? [1 mark]

	Pressure	Temperature
A.	high	high
B.	high	low
C.	low	high
D.	low	low

14. What does the constant n represent in the equation of state for an ideal gas $pV = nRT$? [1 mark]

- A. The number of atoms in the gas
- B. The number of moles of the gas
- C. The number of molecules of the gas
- D. The number of particles in the gas

15. Unpolarized light of intensity I_0 is incident on a polarizing filter. Light from this filter is incident on a second filter, which has its axis of polarization at 30° to that of the first filter. [1 mark]

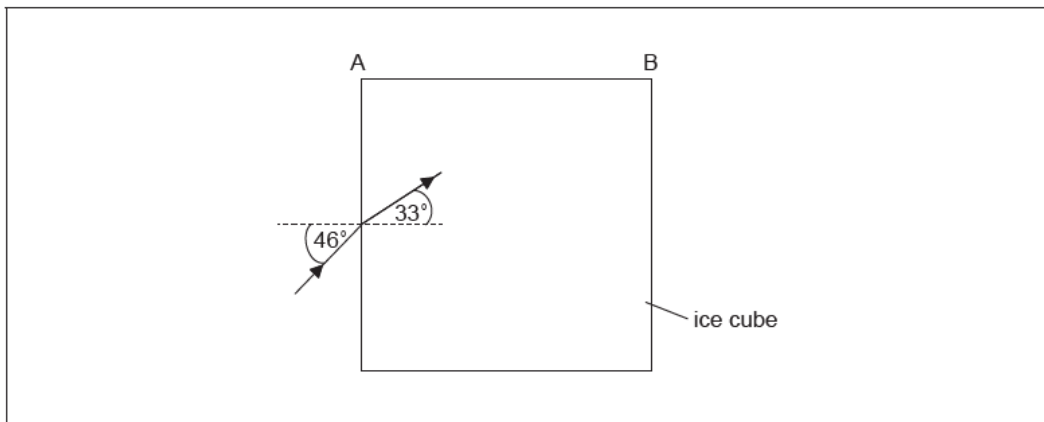
The value of $\cos 30^\circ$ is $\frac{\sqrt{3}}{2}$. What is the intensity of the light emerging through the second filter?

- A. $\frac{\sqrt{3}}{2} I_0$
- B. $\frac{3}{2} I_0$
- C. $\frac{3}{4} I_0$
- D. $\frac{3}{8} I_0$

16. The fraction of the internal energy that is due to molecular vibration varies in the different states of matter. What gives the order from highest fraction to lowest fraction of internal energy due to molecular vibration? [1 mark]

- A. liquid > gas > solid
- B. solid > liquid > gas
- C. solid > gas > liquid
- D. gas > liquid > solid

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46° to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33° .



- 17a. Calculate the speed of light inside the ice cube. [2 marks]

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17b. Show that no light emerges from side AB.

[3 marks]

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17c. Sketch, on the diagram, the subsequent path of the light ray.

[2 marks]

Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is $-20\text{ }^{\circ}\text{C}$.

17d. Determine the energy required to melt all of the ice from $-20\text{ }^{\circ}\text{C}$ to water at a temperature of $0\text{ }^{\circ}\text{C}$.

[4 marks]

Specific latent heat of fusion of ice = 330 kJ kg^{-1}
Specific heat capacity of ice = $2.1\text{ kJ kg}^{-1}\text{ K}^{-1}$
Density of ice = 920 kg m^{-3}

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17e. Outline the difference between the molecular structure of a solid and a liquid.

[1 mark]

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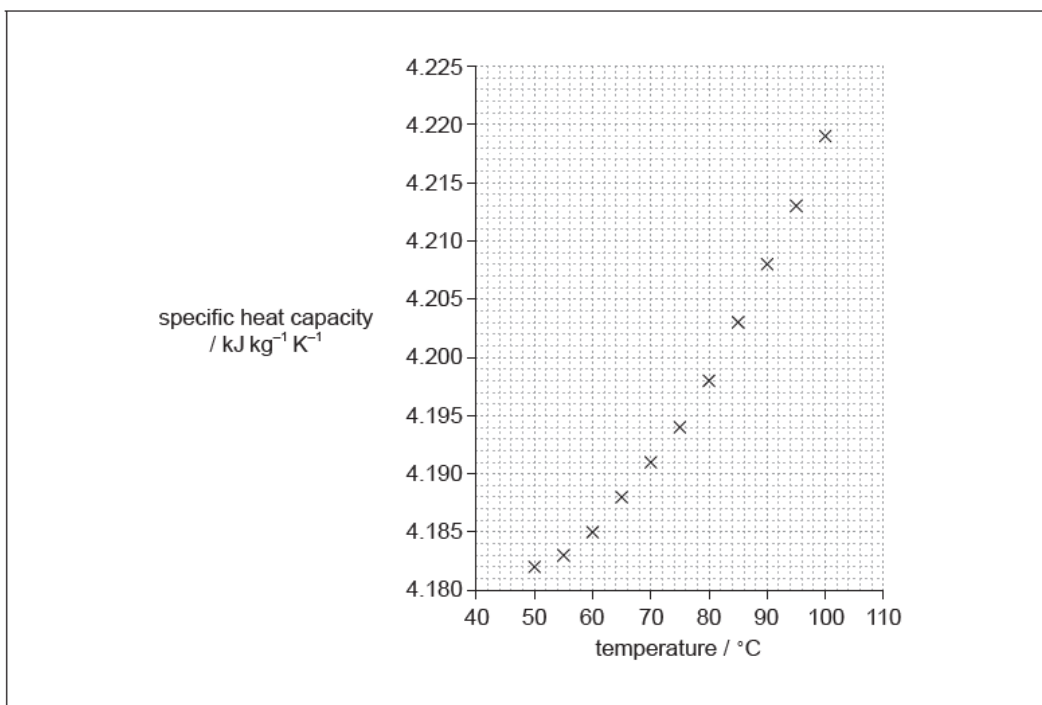
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In an experiment, data were collected on the variation of specific heat capacity of water with temperature. The graph of the plotted data is shown.



18a. Draw the line of best-fit for the data.

[1 mark]

18b. Determine the gradient of the line at a temperature of 80 °C.

[3 marks]

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18c. State the unit for the quantity represented by the gradient in your answer to (b)(i). [1 mark]

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The uncertainty in the values for specific heat capacity is 5%.

Water of mass (100 ± 2) g is heated from (75.0 ± 0.5) °C to (85.0 ± 0.5) °C.

18d. Calculate the energy required to raise the temperature of the water from 75 °C to 85 °C. [1 mark]

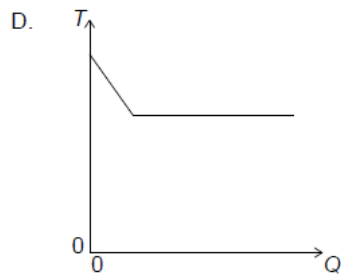
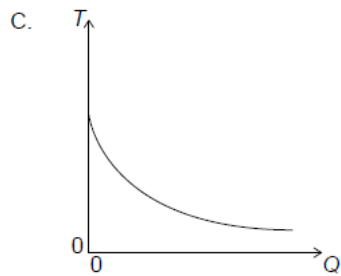
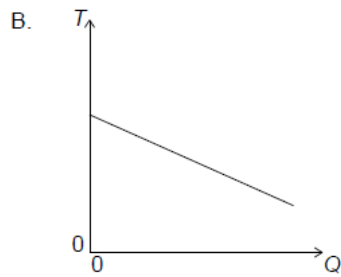
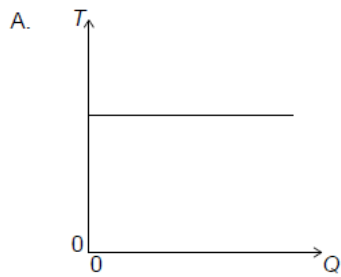
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18e. Using an appropriate error calculation, justify the number of significant figures that should be used for your answer to (c)(i). [3 marks]

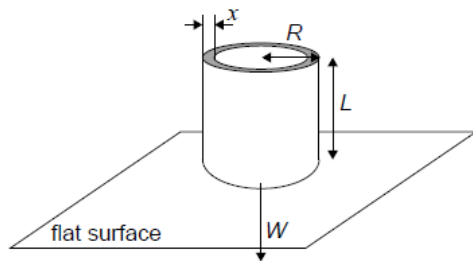
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19. A liquid is initially at its freezing point. Energy is removed at a uniform rate from the liquid until it freezes completely. [1 mark]

Which graph shows how the temperature T of the liquid varies with the energy Q removed from the liquid?



20. A thin-walled cylinder of weight W , open at both ends, rests on a flat surface. The cylinder has a height L , an average radius R and a thickness x where R is much greater than x . [1 mark]



What is the pressure exerted by the cylinder walls on the flat surface?

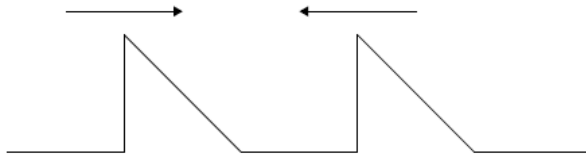
- A. $\frac{W}{2\pi Rx}$
 B. $\frac{W}{\pi R^2 x}$
 C. $\frac{W}{\pi R^2}$
 D. $\frac{W}{\pi R^2 L}$
21. A fixed mass of an ideal gas in a closed container with a movable piston initially occupies a volume V . The position of the piston is changed, so that the mean kinetic energy of the particles in the gas is doubled and the pressure remains constant. [1 mark]

What is the new volume of the gas?

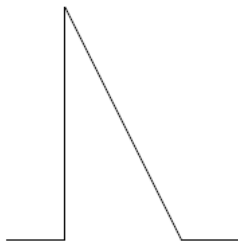
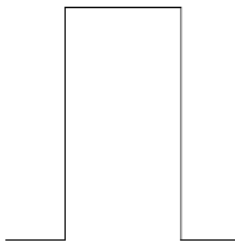

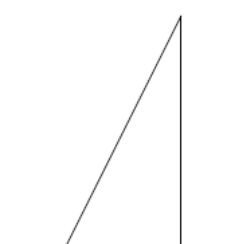
- A. $\frac{V}{4}$
 B. $\frac{V}{2}$
 C. $2V$
 D. $4V$

22. Two pulses are travelling towards each other.

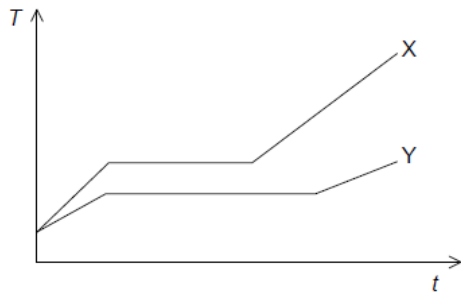
[1 mark]



What is a possible pulse shape when the pulses overlap?

- A. 
- B. 
- C. 
- D. 

23. The graph shows the variation with time t of the temperature T of two samples, X and Y. X and Y have the same mass and are initially in the solid phase. Thermal energy is being provided to X and Y at the same constant rate. [1 mark]



What is the correct comparison of the specific latent heats L_X and L_Y and specific heat capacities in the liquid phase c_X and c_Y of X and Y?

- | | | |
|----|-------------|-------------|
| A. | $L_X > L_Y$ | $c_X > c_Y$ |
| B. | $L_X > L_Y$ | $c_X < c_Y$ |
| C. | $L_X < L_Y$ | $c_X > c_Y$ |
| D. | $L_X < L_Y$ | $c_X < c_Y$ |

24. A mass m of ice at a temperature of $-5\text{ }^{\circ}\text{C}$ is changed into water at a temperature of $50\text{ }^{\circ}\text{C}$. [1 mark]

Specific heat capacity of ice = c_i

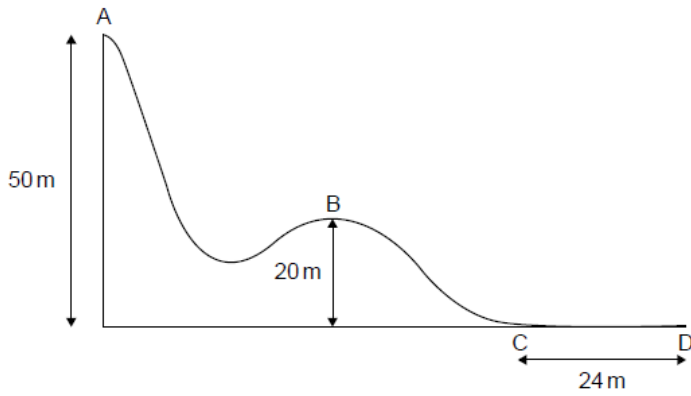
Specific heat capacity of water = c_w

Specific latent heat of fusion of ice = L

Which expression gives the energy needed for this change to occur?

- A. $55 m c_w + m L$
- B. $55 m c_i + 5 m L$
- C. $5 m c_i + 50 m c_w + m L$
- D. $5 m c_i + 50 m c_w + 5 m L$
25. A sealed container contains a mixture of oxygen and nitrogen gas. [1 mark]
- The ratio $\frac{\text{mass of an oxygen molecule}}{\text{mass of a nitrogen molecule}}$ is $\frac{8}{7}$.
- The ratio $\frac{\text{average kinetic energy of oxygen molecules}}{\text{average kinetic energy of nitrogen molecules}}$ is
- A. 1.
- B. $\frac{7}{8}$.
- C. $\frac{8}{7}$.
- D. dependent on the concentration of each gas.
26. An ideal gas has a volume of 15 ml , a temperature of $20\text{ }^{\circ}\text{C}$ and a pressure of 100 kPa . The volume of the gas is reduced to 5 ml and the temperature is raised to $40\text{ }^{\circ}\text{C}$. [1 mark]
- What is the new pressure of the gas?
- A. 600 kPa
- B. 320 kPa
- C. 200 kPa
- D. 35 kPa

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

- 27a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. [2 marks]
Show that the velocity at B is 12 m s^{-1} .

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- 27b. Some of the gravitational potential energy transferred into internal energy of the skis, [2 marks]
slightly increasing their temperature. Distinguish between internal energy and temperature.

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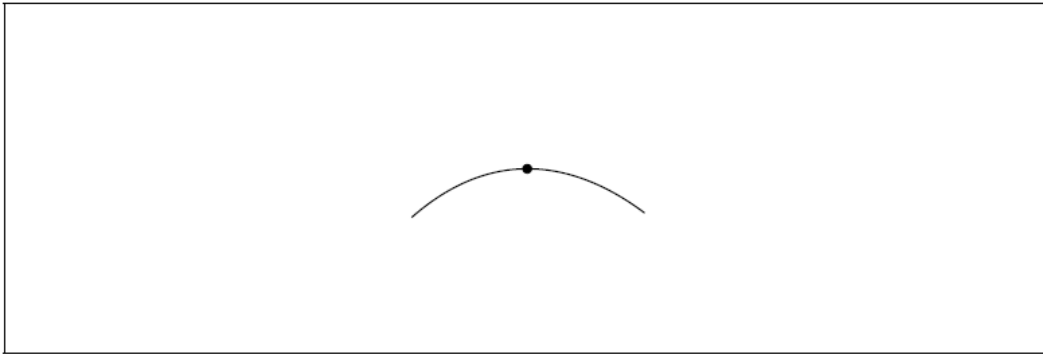
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27c. The dot on the following diagram represents the skier as she passes point B. [2 marks]
Draw and label the vertical forces acting on the skier.



27d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. [3 marks]

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27e. The skier reaches point C with a speed of 8.2 m s^{-1} . She stops after a distance of 24 m at point D. [3 marks]

Determine the coefficient of dynamic friction between the base of the skis and the snow.
Assume that the frictional force is constant and that air resistance can be neglected.

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At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m s^{-1} .

27f. Calculate the impulse required from the net to stop the skier and state an appropriate [2 marks] unit for your answer.

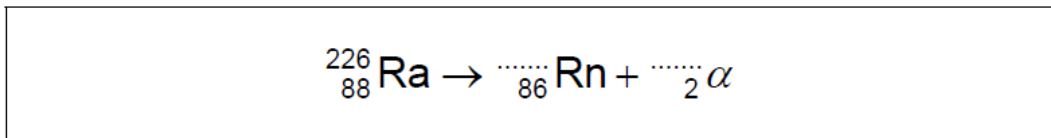
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27g. Explain, with reference to change in momentum, why a flexible safety net is less likely [2 marks] to harm the skier than a rigid barrier.

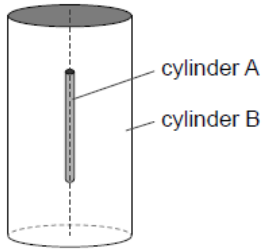
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The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 (${}^{226}_{88}\text{Ra}$) decays by alpha emission to form a nuclide known as radon (Rn).

28a. Write down the missing values in the nuclear equation for this decay. [1 mark]



28b. Rutherford and Royds put some pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B. [1 mark]



At the start of the experiment all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin.

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28c. Rutherford and Royds expected 2.7×10^{15} alpha particles to be emitted during the experiment. The experiment was carried out at a temperature of $18\text{ }^{\circ}\text{C}$. The volume of cylinder B was $1.3 \times 10^{-5}\text{ m}^3$ and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B. [3 marks]

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28d. Rutherford and Royds identified the helium gas in cylinder B by observing its emission [3 marks] spectrum. Outline, with reference to atomic energy levels, how an emission spectrum is formed.

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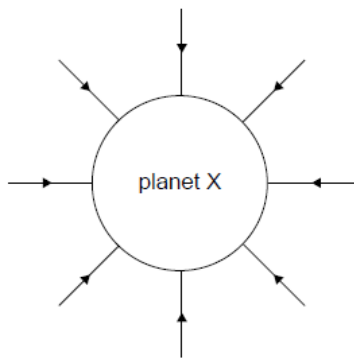
28e. The work was first reported in a peer-reviewed scientific journal. Outline [1 mark] why Rutherford and Royds chose to publish their work in this way.

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The diagram shows the gravitational field lines of planet X.



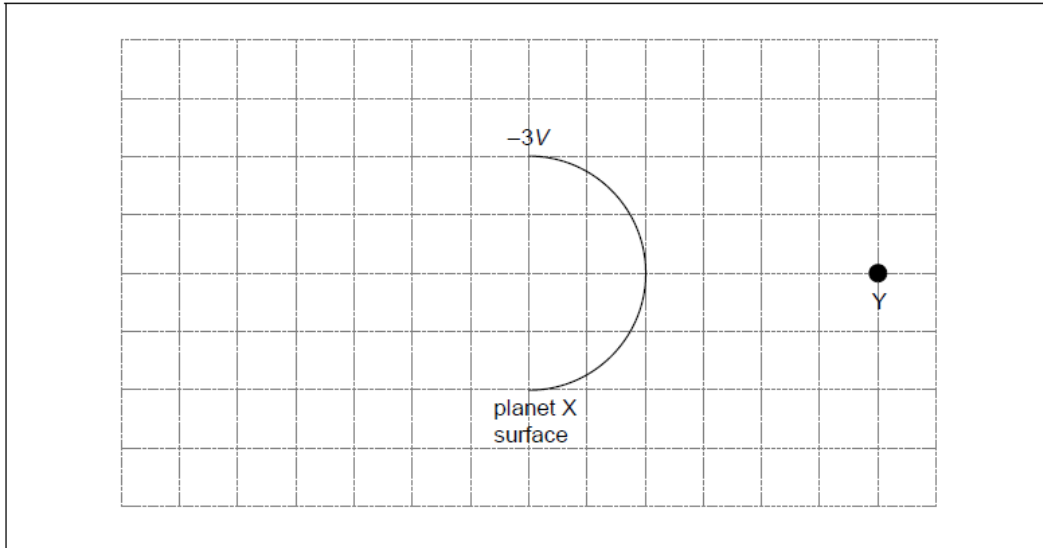
29a. Outline how this diagram shows that the gravitational field strength of planet X [1 mark] decreases with distance from the surface.

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29b. The diagram shows part of the surface of planet X. The gravitational potential at the surface of planet X is $-3V$ and the gravitational potential at point Y is $-V$. [2 marks]



Sketch on the grid the equipotential surface corresponding to a gravitational potential of $-2V$.

29c. A meteorite, very far from planet X begins to fall to the surface with a negligibly small initial speed. The mass of planet X is 3.1×10^{21} kg and its radius is 1.2×10^6 m. The planet has no atmosphere. Calculate the speed at which the meteorite will hit the surface. [3 marks]

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29d. At the instant of impact the meteorite which is made of ice has a temperature of $0\text{ }^{\circ}\text{C}$. [2 marks]
 Assume that all the kinetic energy at impact gets transferred into internal energy in the meteorite. Calculate the percentage of the meteorite's mass that melts. The specific latent heat of fusion of ice is $3.3 \times 10^5\text{ J kg}^{-1}$.

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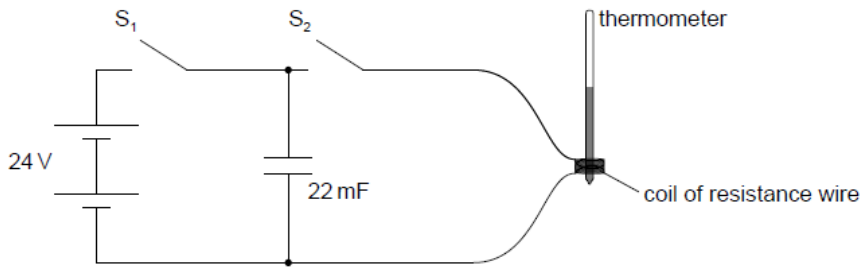
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The electrical circuit shown is used to investigate the temperature change in a wire that is wrapped around a mercury-in-glass thermometer.



A power supply of emf (electromotive force) 24 V and of negligible internal resistance is connected to a capacitor and to a coil of resistance wire using an arrangement of two switches. Switch S₁ is closed and, a few seconds later, opened. Then switch S₂ is closed.

30a. The capacitance of the capacitor is 22 mF. Calculate the energy stored in the capacitor when it is fully charged. [1 mark]

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30b. The resistance of the wire is 8.0Ω . Determine the time taken for the capacitor to discharge through the resistance wire. Assume that the capacitor is completely discharged when the potential difference across it has fallen to 0.24 V . [3 marks]

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30c. The mass of the resistance wire is 0.61 g and its observed temperature rise is 28 K . [2 marks]
Estimate the specific heat capacity of the wire. Include an appropriate unit for your answer.

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30d. Suggest **one** other energy loss in the experiment and the effect it will have on the value for the specific heat capacity of the wire. [2 marks]

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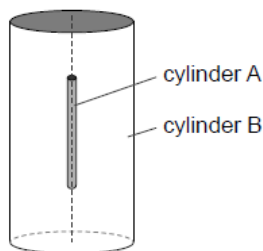
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The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 (${}^{226}_{86}\text{Ra}$) decays by alpha emission to form a nuclide known as radon (Rn).

31a. Write down the nuclear equation for this decay.

[2 marks]

At the start of the experiment, Rutherford and Royds put 6.2×10^{-4} mol of pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B.



The experiment lasted for 6 days. The decay constant of radium-226 is $1.4 \times 10^{-11} \text{ s}^{-1}$.

31b. Deduce that the activity of the radium-226 is almost constant during the experiment. [2 marks]

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31c. Show that about 3×10^{15} alpha particles are emitted by the radium-226 in 6 days. [3 marks]

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At the start of the experiment, all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

31d. The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin. [1 mark]

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31e. The experiment was carried out at a temperature of $18\text{ }^{\circ}\text{C}$. The volume of cylinder B was $1.3 \times 10^{-5}\text{ m}^3$ and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B over the 6 day period. Helium is a monatomic gas. [3 marks]

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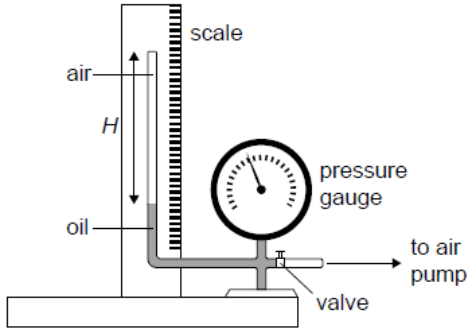
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The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure p of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

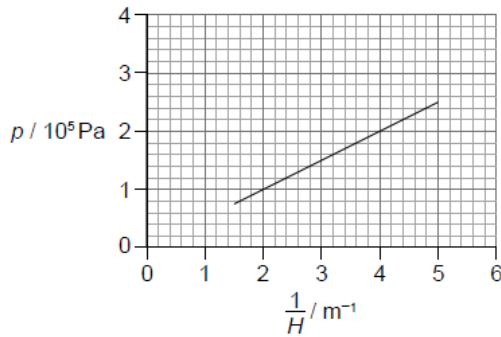
- 32a. The student measured the height H of the air column and the corresponding air pressure p . After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. [1 mark]

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- 32b. The following graph of p versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. [3 marks]



The equation of the line of best fit is $p = a + \frac{b}{H}$.

Determine the value of b including an appropriate unit.

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32c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. [2 marks]

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32d. The cross-sectional area of the tube is $1.3 \times 10^{-3} \text{ m}^2$ and the temperature of air is 300 K. Estimate the number of moles of air in the tube. [2 marks]

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32e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. [2 marks]

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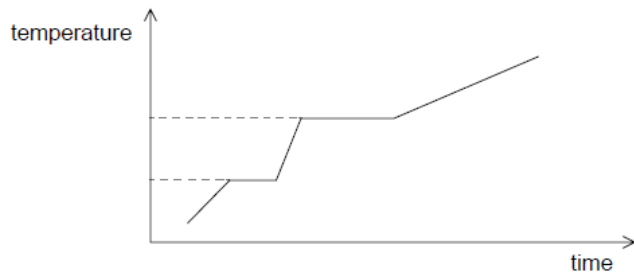
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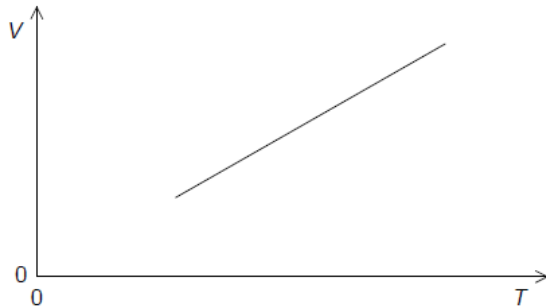
33. Energy is supplied at a constant rate to a fixed mass of a material. The material begins [1 mark] as a solid. The graph shows the variation of the temperature of the material with time.



The specific heat capacities of the solid, liquid and gaseous forms of the material are c_s , c_l and c_g respectively. What can be deduced about the values of c_s , c_l and c_g ?

- A. $c_s > c_g > c_l$
- B. $c_l > c_s > c_g$
- C. $c_l > c_g > c_s$
- D. $c_g > c_s > c_l$

34. An ideal gas of N molecules is maintained at a constant pressure p . The graph shows [1 mark] how the volume V of the gas varies with absolute temperature T .



What is the gradient of the graph?

- A. $\frac{N}{p}$
- B. $\frac{NR}{p}$
- C. $\frac{Nk_B}{p}$
- D. $\frac{N}{Rp}$

35. The pressure of a fixed mass of an ideal gas in a container is decreased at constant [1 mark] temperature. For the molecules of the gas there will be a decrease in

- A. the mean square speed.
- B. the number striking the container walls every second.
- C. the force between them.
- D. their diameter.

36a. Define *internal energy*.

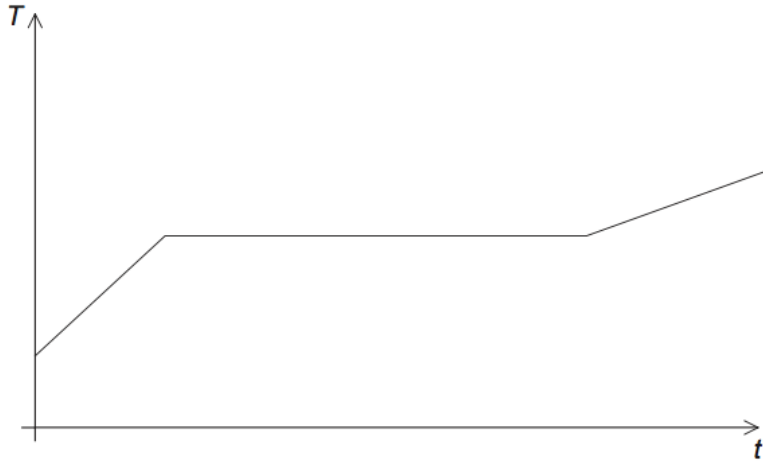
[2 marks]

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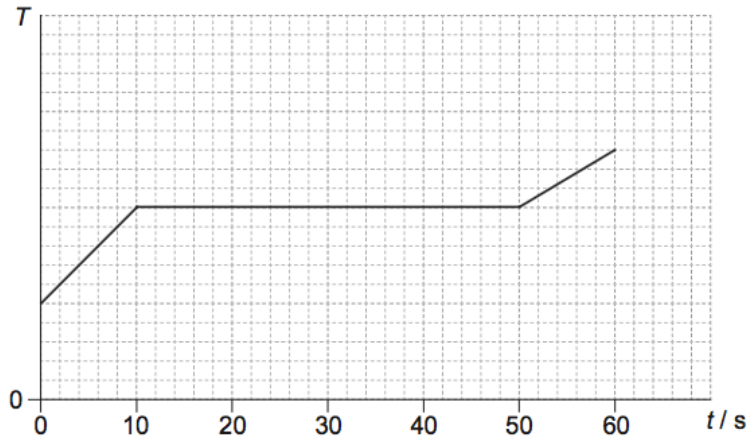
38. A substance is heated at constant power. The graph shows how the temperature T of the substance varies with time t as the state of the substance changes from liquid to gas. [1 mark]



What can be determined from the graph?

- A. The specific heat capacity of the gas is smaller than the specific heat capacity of the liquid.
 - B. The specific heat capacity of the gas is larger than the specific heat capacity of the liquid.
 - C. The specific latent heat of fusion of the substance is less than its specific latent heat of vaporization.
 - D. The specific latent heat of fusion of the substance is larger than its specific latent heat of vaporization.
39. Which of the following is **not** an assumption of the kinetic model of ideal gases? [1 mark]
- A. All particles in the gas have the same mass.
 - B. All particles in the gas have the same speed.
 - C. The duration of collisions between particles is very short.
 - D. Collisions with the walls of the container are elastic.
40. Under what conditions of density and pressure is a real gas best described by the equation of state for an ideal gas? [1 mark]
- A. Low density and low pressure
 - B. Low density and high pressure
 - C. High density and low pressure
 - D. High density and high pressure

41. A container with 0.60kg of a liquid substance is placed on a heater at time $t=0$. The specific latent heat of vaporization of the substance is 200kJkg^{-1} . The graph shows the variation of the temperature T of the substance with time t . [1 mark]



What is the power of the heater?

- A. 1200 W
- B. 3000 W
- C. 4800 W
- D. 13 300 W