T3 *[183 marks]*

1. Which of the following is numerically equal to the specific heat capacity of the substance of a solid body? *[1 mark]*

   A. The thermal energy required to melt the body

   B. The thermal energy required to increase the temperature of unit mass of the body by 1K

   C. The thermal energy required to increase the temperature of the body by 1K

   D. The total kinetic and potential energy of all the molecules in the body

2. In the kinetic model of an ideal gas, which of the following is **not** assumed? *[1 mark]*

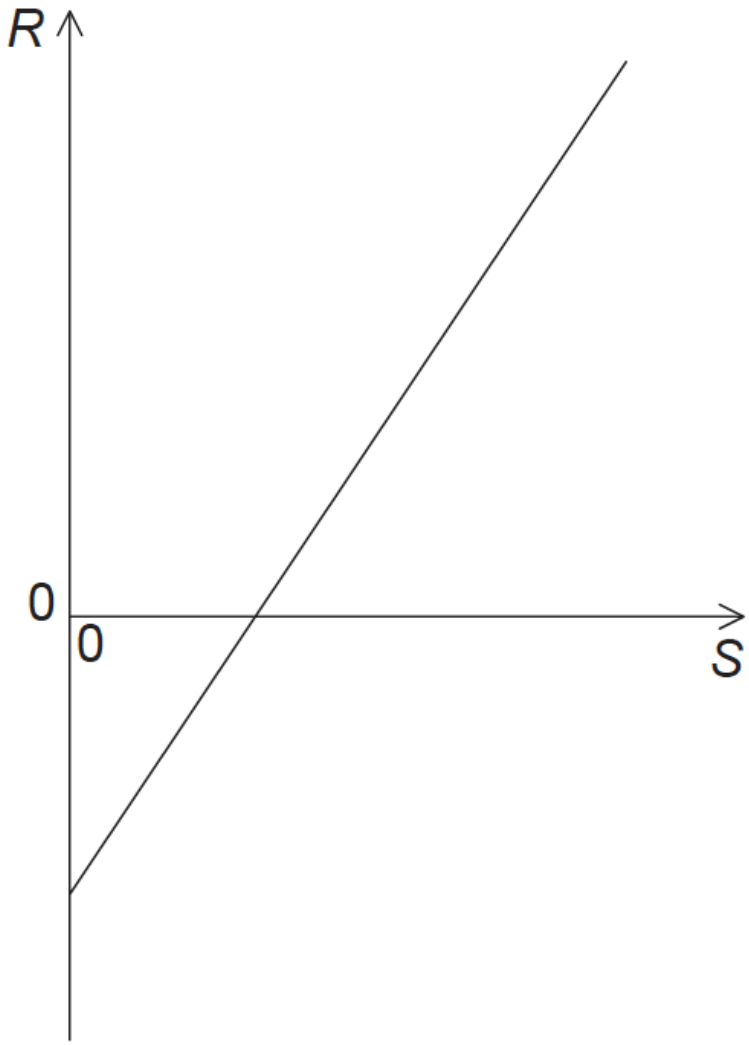
   A. The molecules collide elastically.

   B. The kinetic energy of a given molecule is constant.

   C. The time taken for a molecular collision is much less than the time between collisions.

   D. The intermolecular potential energy of the molecules is zero.

3. A fixed mass of an ideal gas has a constant volume. Two quantities, *R* and *S*, of the gas vary as shown by the graph below. *[1 mark]*



What quantities do *R* and *S* represent?

	R	***S***
A.	pressure	temperature in kelvin
B.	pressure	temperature in degree Celsius
C.	temperature in kelvin	pressure
D.	temperature in degree Celsius	pressure

4. A fixed mass of an ideal gas undergoes an isochoric (isovolumetric) change. This increases the pressure of the gas. Which describes the change of internal energy of the gas and the direction of transfer of thermal energy? *[1 mark]*

	Internal energy	Direction of transfer of thermal energy
A.	increase	to the gas
B.	increase	from the gas
C.	decrease	to the gas
D.	decrease	from the gas

5. What is the definition of the *mole*? *[1 mark]*

A. The amount of substance that has the same mass as 6.02×10^{23} atoms of carbon-12.

B. The amount of substance that contains as many nuclei as the number of nuclei in 12 g of carbon-12.

C. The amount of substance that has the same mass as one atom of carbon-12.

D. The amount of substance that contains as many elementary entities as the number of atoms in 12 g of carbon-12.

6. Molecules leave a boiling liquid to form a vapour. The vapour and the liquid have the same temperature. *[1 mark]*

What is the change of the average potential energy and the change of the average random kinetic energy of these molecules when they move from the liquid to the vapour?

	Average potential energy	Average random kinetic energy
A.	increases	increases
B.	increases	no change
C.	no change	increases
D.	no change	no change

7. Which of the following is equivalent to a temperature of –100°C? *[1 mark]*

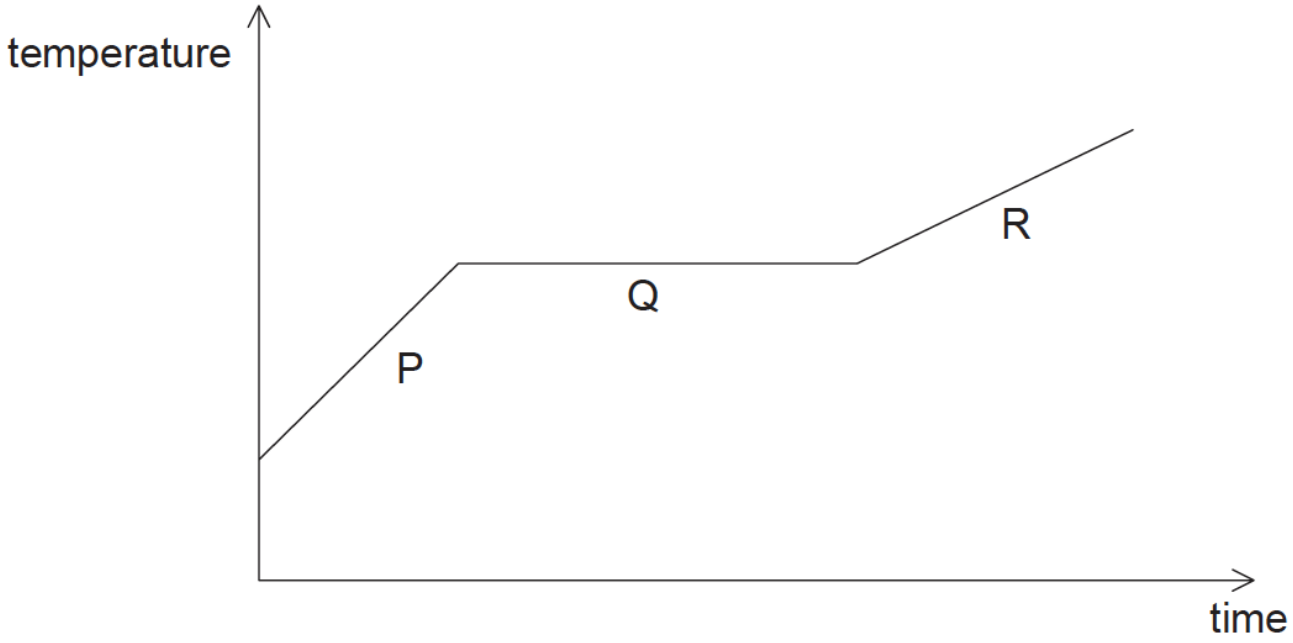
A. –373 K

B. –173 K

C. 173 K

D. 373 K

8. A sample of solid copper is heated beyond its melting point. The graph shows the variation of temperature with time. *[1 mark]*



During which stage(s) is/are there an increase in the internal energy of the copper?

A. P, Q and R

B. Q only

C. P and R only

D. Q and R only

9. Equal masses of water at 80°C and paraffin at 20°C are mixed in a container of negligible thermal capacity. The specific heat capacity of water is twice that of paraffin. What is the final temperature of the mixture? *[1 mark]*

A. 30°C

B. 40°C

C. 50°C

D. 60°C

10. Which of the following is an assumption of the kinetic model of an ideal gas? *[1 mark]*

A. The gas is at high pressure.

B. There are weak forces of attraction between the particles in the gas.

C. The collisions between the particles are elastic.

D. The energy of the particles is proportional to the absolute temperature.

This question is about thermal properties of matter.

11a. Explain, in terms of the energy of its molecules, why the temperature of a pure substance does not change during melting. *[3 marks]*

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11b. Three ice cubes at a temperature of 0°C are dropped into a container of water at a temperature of 22°C. The mass of each ice cube is 25 g and the mass of the water is 330 g. The ice melts, so that the temperature of the water decreases. The thermal capacity of the container is negligible. *[4 marks]*

The following data are available.

Specific latent heat of fusion of ice $= 3.3 \times 10^5 \text{J kg}^{-1}$

Specific heat capacity of water $= 4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

Calculate the final temperature of the water when all of the ice has melted. Assume that no thermal energy is exchanged between the water and the surroundings.

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12. This question is about internal energy. *[4 marks]*

(i) Mathilde raises the temperature of water in an electric kettle to boiling point. Once the water is boiling steadily, she measures the change in the mass of the kettle and its contents over a period of time.

The following data are available.

Initial mass of kettle and water = 1.880 kg
Final mass of kettle and water = 1.580 kg
Time between mass measurements = 300 s
Power dissipation in the kettle = 2.5 kW

Determine the specific latent heat of vaporization of water.

(ii) Outline why your answer to (b)(i) is an overestimate of the specific latent heat of vaporization of water.

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13. A fixed mass of water is heated by an electric heater of unknown power *P*. The following quantities are measured *[1 mark]*

I. mass of water
II. increase in water temperature
III. time for which water is heated.

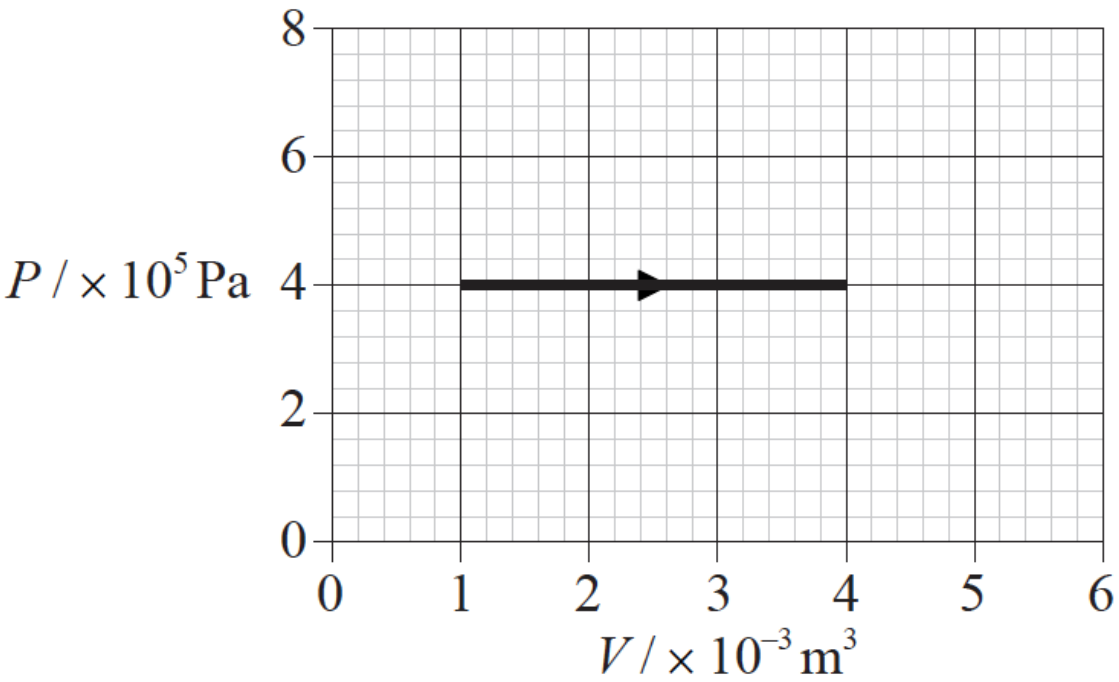
In order to calculate *P*, the specific heat capacity of the water is required. Which are also required?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

14. A block of iron of mass 10 kg and temperature 10°C is brought into contact with a block of iron of mass 20 kg and temperature 70°C. No energy transfer takes place except between the two blocks. What will be the final temperature of both blocks? *[1 mark]*

A. 30°C
B. 40°C
C. 50°C
D. 60°C

15. An ideal gas expands at constant pressure. The graph shows the relationship between pressure P and volume V for this change. *[1 mark]*



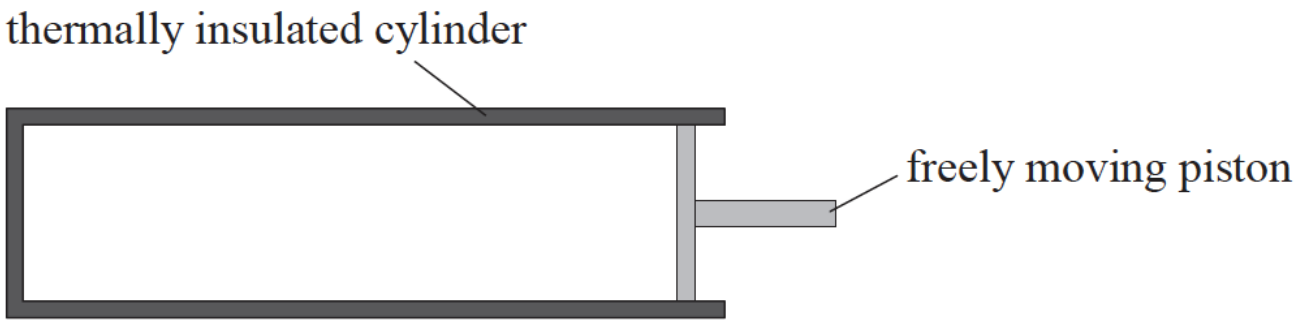
The change in the internal energy of the gas during this expansion is 1800 J. What is the amount and the direction of thermal energy transferred?

A. 3000 J into the gas
B. 3000 J out of the gas
C. 600 J into the gas
D. 600 J out of the gas

16. The specific latent heat is the energy required to change the phase of *[1 mark]*

A. one kilogram of a substance.
B. a substance at constant temperature.
C. a liquid at constant temperature.
D. one kilogram of a substance at constant temperature.

17. An ideal gas is contained in a thermally insulated cylinder by a freely moving piston. *[1 mark]*



The gas is compressed by the piston and as a result the temperature of the gas increases. What is the explanation for the temperature rise?

A. The rate of collision between the molecules increases.
B. Energy is transferred to the molecules by the moving piston.
C. The molecules of the gas are pushed closer together.
D. The rate of collision between the molecules and the walls of the cylinder increases.

18. Two containers, X and Y, are each filled by an ideal gas at the same temperature. The volume of Y is half the volume of X. The number of moles of gas in Y is three times the number of moles of the gas in X. The pressure of the gas in X is P_X and the pressure of the gas in Y is P_Y. *[1 mark]*

What is the ratio $\frac{P_X}{P_Y}$?

A. $\frac{1}{6}$

B. $\frac{2}{3}$

C. $\frac{3}{2}$

D. 6

This question is in **two** parts. **Part 1** is about nuclear reactions. **Part 2** is about thermal energy transfer.

Part 1 Nuclear reactions

19a. (i) Define the term *unified atomic mass unit.* *[2 marks]*

(ii) The mass of a nucleus of einsteinium-255 is 255.09 u. Calculate the mass in $MeVc^{-2}$.

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19b. When particle X collides with a stationary nucleus of calcium-40 (Ca-40), a nucleus of potassium (K-40) and a proton are produced. *[6 marks]*

$$^{40}_{20}\mathrm{Ca} + \mathrm{X} \rightarrow {}^{40}_{19}\mathrm{K} + {}^{1}_{1}\mathrm{p}$$

The following data are available for the reaction.

Particle	Rest mass / MeV c^{-2}
calcium-40	37 214.694
X	939.565
potassium-40	37 216.560
proton	938.272

(i) Identify particle X.

(ii) Suggest why this reaction can only occur if the initial kinetic energy of particle X is greater than a minimum value.

(iii) Before the reaction occurs, particle X has kinetic energy 8.326 MeV. Determine the total combined kinetic energy of the potassium nucleus and the proton.

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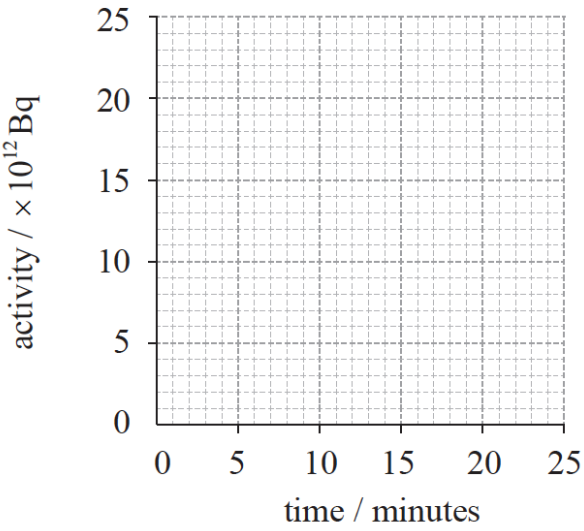
19c. Potassium-38 decays with a half-life of eight minutes. *[5 marks]*

(i) Define the term *radioactive half-life*.

(ii) A sample of potassium-38 has an initial activity of 24×10^{12}Bq. On the axes below, draw a graph to show the variation with time of the activity of the sample.



(iii) Determine the activity of the sample after 2 hours.

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Part 2 Thermal energy transfer

19d. (i) Define the *specific latent heat* of fusion of a substance. *[5 marks]*

(ii) Explain, in terms of the molecular model of matter, the relative magnitudes of the specific latent heat of vaporization of water and the specific latent heat of fusion of water.

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19e. A piece of ice is placed into a beaker of water and melts completely. *[5 marks]*

The following data are available.

Initial mass of ice = 0.020 kg
Initial mass of water = 0.25 kg
Initial temperature of ice = 0°C
Initial temperature of water = 80°C
Specific latent heat of fusion of ice = 3.3×10^{5} J kg^{-1}
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$

(i) Determine the final temperature of the water.

(ii) State **two** assumptions that you made in your answer to part (f)(i).

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20. Two objects are in thermal contact, initially at different temperatures. Which of the following determines the transfer of thermal energy between the objects? *[1 mark]*

I. The mass of each object
II. The thermal capacity of the objects
III. The temperature of the objects

A. I only

B. I and II only

C. II and III only

D. III only

21. The following can be determined for a solid substance. *[1 mark]*

I. The average kinetic energy $E_{\mathrm{K_{ave}}}$ of the molecules
II. The total kinetic energy $E_{\mathrm{K_{tot}}}$ of the molecules
III. The total potential energy $E_{\mathrm{P_{tot}}}$ of the molecules

Which is/are equal to the internal energy of this solid substance?

A. I only
B. I and III only
C. II only
D. II and III only

22. Two objects are in thermal contact, initially at different temperatures. Which of the following determines the transfer of thermal energy between the objects? *[1 mark]*

I. The mass of each object
II. The thermal capacity of the objects
III. The temperature of the objects

A. I only

B. I and II only

C. II and III only

D. III only

23. What are the conditions of temperature and pressure at which the behaviour of a real gas approximates to the behaviour of an ideal gas? *[1 mark]*

A. Low pressure and low temperature
B. Low pressure and high temperature
C. High pressure and low temperature
D. High pressure and high temperature

24. Molar mass is defined as *[1 mark]*

A. the number of particles in one mole of a substance.
B. $\frac{1}{12}$ the mass of one atom of carbon-12.
C. the mass of one mole of a substance.
D. the number of particles in $\frac{1}{12}$ of a mole of carbon-12

25. A solid of mass m is initially at temperature ΔT below its melting point. The solid has specific heat capacity c and specific latent heat of fusion L. How much thermal energy must be transferred to the solid in order to melt it completely? *[1 mark]*

A. $mL+mc$
B. $mc+mL\Delta T$
C. $mc\Delta T+L\Delta T$
D. $mc\Delta T+mL$

This question is in **two** parts. **Part 1** is about electric fields and radioactive decay. **Part 2** is about change of phase.

Part 1 Electric fields and radioactive decay

26a. Define *electric field strength*. *[2 marks]*

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26b. A simple model of the proton is that of a sphere of radius 1.0×10^{-15}m with charge concentrated at the centre of the sphere. Estimate the magnitude of the field strength at the surface of the proton. *[2 marks]*

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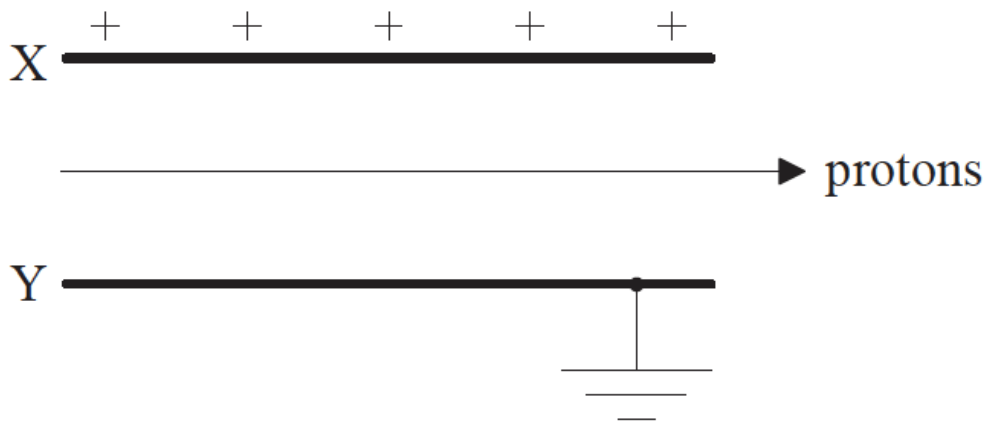
26c. Protons travelling with a speed of $3.9\times10^{6}\text{ms}^{-1}$ enter the region between two charged parallel plates X and Y. *[4 marks]*
Plate X is positively charged and plate Y is connected to earth.



A uniform magnetic field also exists in the region between the plates. The direction of the field is such that the protons pass between the plates without deflection.

(i) State the direction of the magnetic field.

(ii) The magnitude of the magnetic field strength is $2.3\times10^{-4}\text{T}$. Determine the magnitude of the electric field strength between the plates, stating an appropriate unit for your answer.

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26d. Protons can be produced by the bombardment of nitrogen-14 nuclei with alpha particles. The nuclear reaction equation for this process is given below. *[1 mark]*

$$^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow \text{X} + ^{1}_{1}\text{H}$$

Identify the proton number and nucleon number for the nucleus X.

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26e. The following data are available for the reaction in (d). *[3 marks]*

Rest mass of nitrogen-14 nucleus =14.0031 u
Rest mass of alpha particle =4.0026 u
Rest mass of X nucleus =16.9991 u
Rest mass of proton =1.0073 u

Show that the minimum kinetic energy that the alpha particle must have in order for the reaction to take place is about 0.7 Me V.

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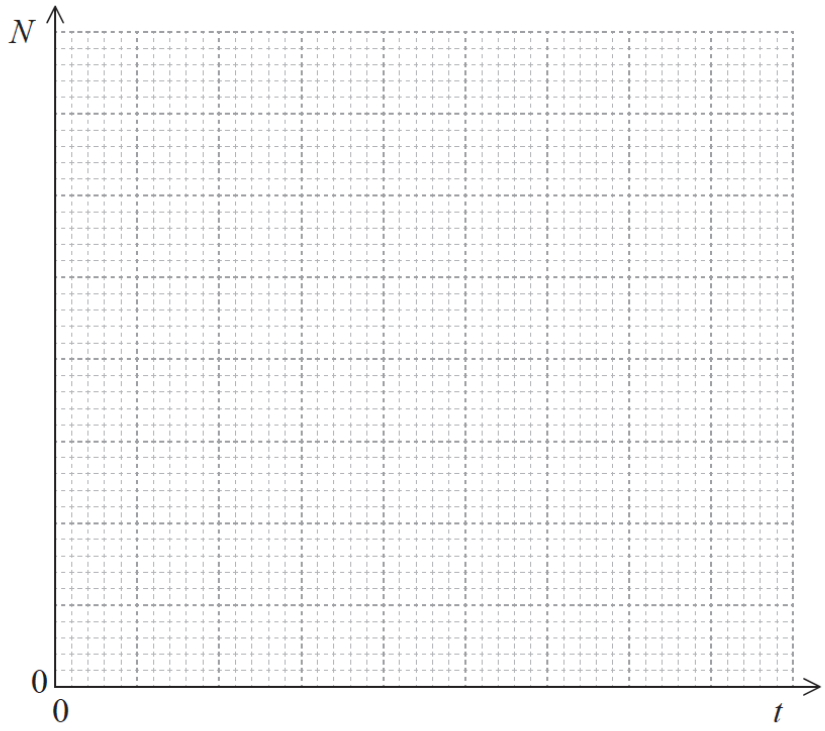
26f. A nucleus of another isotope of the element X in (d) decays with a half-life $T_{\frac{1}{2}}$ to a nucleus of an isotope of fluorine-19 (F-19). *[5 marks]*

(i) Define the terms *isotope* and *half-life*.

(ii) Using the axes below, sketch a graph to show how the number of atoms *N* in a sample of X varies with time *t*, from *t*=0 to $t = 3T_{\frac{1}{2}}$. There are N_0 atoms in the sample at *t*=0.



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Part 2 Change of phase

26g. Water at constant pressure boils at constant temperature. Outline, in terms of the energy of the molecules, the reason for this. *[2 marks]*

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26h. In an experiment to measure the specific latent heat of vaporization of water, steam at 100°C was passed into water in an insulated container. The following data are available. *[4 marks]*

Initial mass of water in container = 0.300kg
Final mass of water in container = 0.312kg
Initial temperature of water in container = 15.2°C
Final temperature of water in container = 34.6°C
Specific heat capacity of water = $4.18\times10^{3}\text{Jkg}^{-1}\text{K}^{-1}$

Show that the data give a value of about $1.8\times10^{6}\text{Jkg}^{-1}$ for the specific latent heat of vaporization L of water.

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26i. Explain why, other than measurement or calculation error, the accepted value of L is greater than that given in (h). *[2 marks]*

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This question is about an ideal gas.

27a. Describe how the ideal gas constant R is defined. *[2 marks]*

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27b. Calculate the temperature of 0.100 mol of an ideal gas kept in a cylinder of volume $1.40\times10^{-3}\text{ m}^{3}$ at a pressure of $2.32\times10^{5}\text{ Pa}$. *[1 mark]*

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27c. The gas in (b) is kept in the cylinder by a freely moving piston. The gas is now heated at constant pressure until the volume occupied by the gas is 3.60×10^{-3} m^3. The increase in internal energy of the gas is 760 J. Determine the thermal energy given to the gas. *[2 marks]*

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27d. After heating, the gas is compressed rapidly to its original volume in (b). Outline why this compression approximates to an adiabatic change of state of the gas. *[2 marks]*

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28. A pure solid is heated at its melting point. While it is melting the *[1 mark]*

A. mean kinetic energy of the molecules of the solid increases.
B. mean potential energy of the molecules of the solid increases.
C. temperature of the solid increases.
D. temperature of the solid decreases.

29. Which of the following is equivalent to a temperature of 350 K? *[1 mark]*

A. –623°C
B. –77°C
C. +77°C
D. +623°C

30. A liquid-in-glass thermometer is in thermal equilibrium with some hot water. The thermometer is left in the water. The water cools to the temperature of the surroundings. Which of the following is **unlikely to be true** for the thermometer? *[1 mark]*

A. It is in thermal equilibrium with the water.
B. It is in thermal equilibrium with the surroundings.
C. It is at the same temperature as the water.
D. It has the same thermal capacity as the water.

31. The molar mass of magnesium is 24g. 12g of magnesium contains the same number of particles as *[1 mark]*

A. 6 g of carbon-12.

B. 12 g of carbon-12.

C. 24 g of carbon-12.

D. 6.02×10^{23} g of carbon-12.

32. A fixed mass of an ideal gas is at temperature T. The pressure is doubled and the volume is halved. What is the temperature after these changes? *[1 mark]*

A. $\frac{T}{2}$

B. T

C. $2T$

D. $4T$

33. A mass of 0.20 kg of water at 20°C is mixed with 0.40 kg of water at 80°C. No thermal energy is transferred to the surroundings. What is the final temperature of the mixture? *[1 mark]*

A. 30°C
B. 40°C
C. 50°C
D. 60°C

34. What is the temperature, in K, that is equivalent to 57°C? *[1 mark]*

A. 220
B. 273
C. 330
D. 430

35. The internal energy of any substance is made up of the *[1 mark]*

A. total random kinetic and potential energy of its molecules.
B. total potential energy of its molecules.
C. total random kinetic energy of its molecules.
D. total vibrational energy of its molecules.

36. Thermal energy is transferred to a solid. Three properties of the solid are *[1 mark]*

I. volume
II. mass
III. specific heat capacity.

Which of the above properties determine the rise in temperature of the solid?

A. I and III only
B. II and III only
C. II only
D. III only

37. The specific latent heat of a substance is defined as the energy required at constant temperature to *[1 mark]*

A. change the phase.
B. change the phase of 1 kg.
C. change the phase of 1 m^3.
D. change the phase of 1 kg every second.

38. The total potential energy and random kinetic energy of the molecules of an object is equal to the *[1 mark]*

A. heat energy in the object.

B. internal energy of the object.

C. thermal energy in the object.

D. work stored in the object.

39. An ideal gas has an absolute temperature T. The average random kinetic energy of the molecules of the gas is *[1 mark]*

A. independent of T.

B. equal to T.

C. proportional to T.

D. inversely proportional to T.

40. Which of the following correctly identifies the properties of the molecules of a substance that determine the substance's internal energy? *[1 mark]*

A. The total potential energy and random kinetic energy
B. The random kinetic energy
C. The total gravitational potential energy and random kinetic energy
D. The total potential energy

Part 2 Properties of a gas

41a. With respect to a gas, explain the meaning of the terms thermal energy and internal energy. *[2 marks]*

Thermal energy: . . . . . .

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Internal energy: . . . . . .

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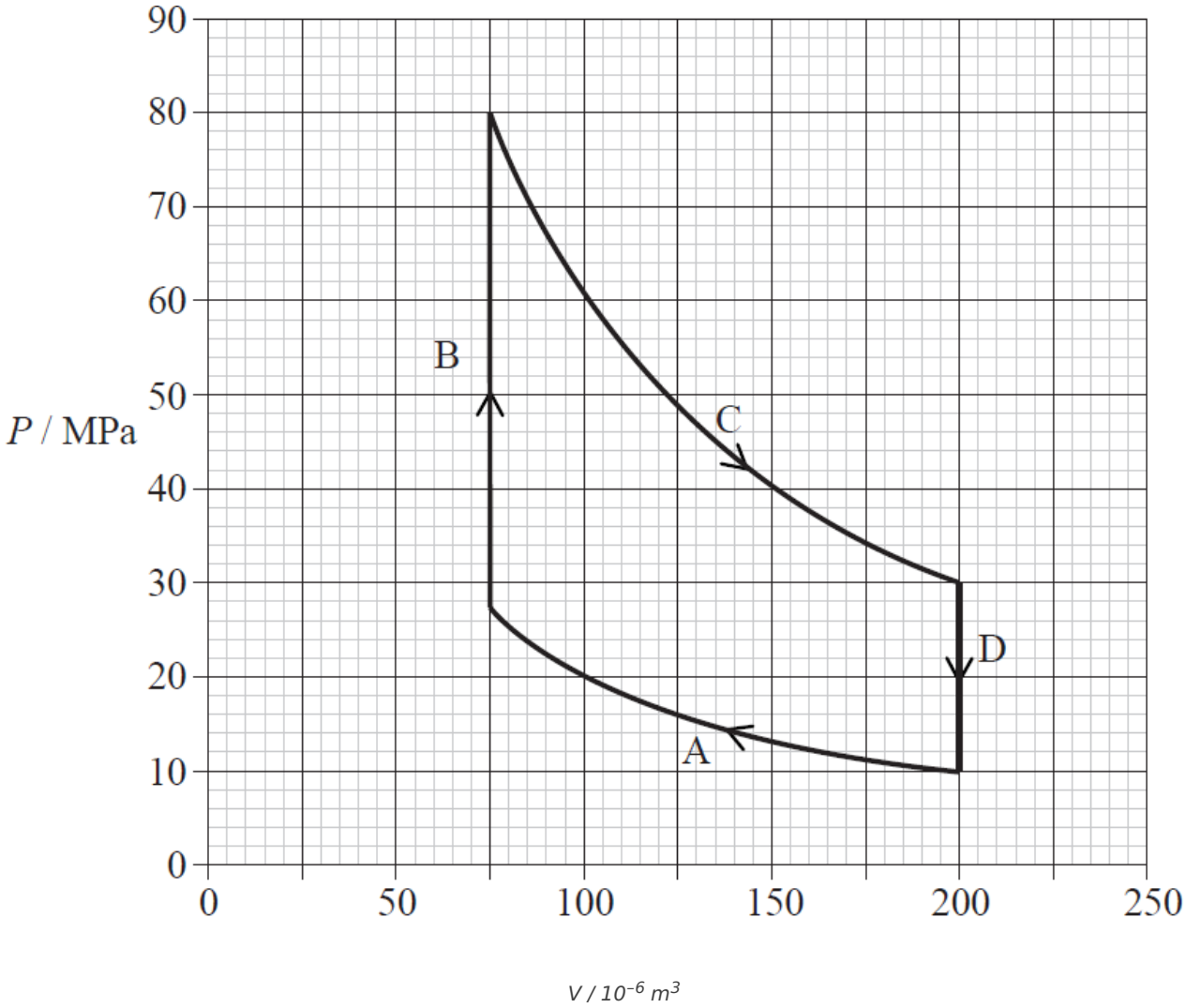
41b. The graph shows how the pressure *P* of a sample of a fixed mass of an ideal gas varies with volume *V*. The gas is taken through a cycle **ABCD.** *[10 marks]*



(i) Estimate the net work done during the cycle.

(ii) Explain whether the net work is done on the gas or by the gas.

(iii) Deduce, using the data from the graph, that the change **C** is isothermal.

(iv) Isothermal change **A** occurs at a temperature of 450 K. Calculate the temperature at which isothermal change **C** occurs.

(v) Describe the changes **B** and **D**.

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Part 2 Thermal concepts

42a. Distinguish between internal energy and thermal energy (heat). *[2 marks]*

Internal energy:

Thermal energy:

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42b. A 300 W immersion heater is placed in a beaker containing 0.25 kg of water at a temperature of 18°C. The heater is switched on for 120 s, after which time the temperature of the water is 45°C. The thermal capacity of the beaker is negligible and the specific heat capacity of water is 4.2×10^{3} J kg^{-1}K^{-1}. *[4 marks]*

(i) Estimate the change in internal energy of the water.

(ii) Determine the rate at which thermal energy is transferred from the water to the surroundings during the time that the heater is switched on.

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This question is in **two** parts. **Part 1** is about ideal gases and specific heat capacity. **Part 2** is about simple harmonic motion and waves.

Part 1 Ideal gases and specific heat capacity

43a. State **two** assumptions of the kinetic model of an ideal gas. *[2 marks]*

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43b. Argon behaves as an ideal gas for a large range of temperatures and pressures. One mole of argon is confined in a cylinder by a freely moving piston. *[4 marks]*

(i) Define what is meant by the term *one mole of argon*.

(ii) The temperature of the argon is 300 K. The piston is fixed and the argon is heated at constant volume such that its internal energy increases by 620 J. The temperature of the argon is now 350 K.

Determine the specific heat capacity of argon in J kg^{-1} K^{-1} under the condition of constant volume. (The molecular weight of argon is 40)

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43c. At the temperature of 350 K, the piston in (b) is now freed and the argon expands until its temperature reaches 300 K. *[3 marks]*

Explain, in terms of the molecular model of an ideal gas, why the temperature of argon decreases on expansion.

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44. The temperature of an object is -153°C. Its temperature is raised to 273°C. What is the temperature change of the object? *[1 mark]*

A. 699 K
B. 426 K
C. 153 K
D. 120 K

This question is about thermal energy transfer.

A hot piece of iron is placed into a container of cold water. After a time the iron and water reach thermal equilibrium. The heat capacity of the container is negligible.

45a. Define *specific heat capacity.* *[2 marks]*

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45b. The following data are available. *[5 marks]*

Mass of water = 0.35 kg
Mass of iron = 0.58 kg
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$
Initial temperature of water = 20°C
Final temperature of water = 44°C
Initial temperature of iron = 180°C

(i) Determine the specific heat capacity of iron.

(ii) Explain why the value calculated in (b)(i) is likely to be different from the accepted value.

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Part 2 Internal energy

Humans generate internal energy when moving, while their core temperature remains approximately constant.

46a. Distinguish between the concepts of internal energy and temperature. *[3 marks]*

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46b. An athlete loses 1.8 kg of water from her body through sweating during a training session that lasts one hour. *[2 marks]*

Estimate the rate of energy loss by the athlete due to sweating. The specific latent heat of evaporation of water is 2.3×10^6 J kg^{-1}.

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This question is about internal energy.

Humans generate internal energy when moving, while their core temperature remains approximately constant.

47. Distinguish between the concepts of internal energy and temperature. *[3 marks]*

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Part 2 Melting of the Pobeda ice island

48a. The Pobeda ice island forms regularly when icebergs run aground near the Antarctic ice shelf. The "island", which consists of a slab of pure ice, breaks apart and melts over a period of decades. The following data are available. *[8 marks]*

Typical dimensions of surface of island = 70 km × 35 km
Typical height of island = 240 m
Average temperature of the island = –35°C
Density of sea ice = 920 kg m^{-3}
Specific latent heat of fusion of ice = 3.3×10^{5} J kg^{-1}
Specific heat capacity of ice = 2.1×10^{3} J $kg^{-1}K^{-1}$

(i) Distinguish, with reference to molecular motion and energy, between solid ice and liquid water.

(ii) Show that the energy required to melt the island to form water at 0°C is about 2×10^{20} J. Assume that the top and bottom surfaces of the island are flat and that it has vertical sides.

(iii) The Sun supplies thermal energy at an average rate of 450 W m^{-2} to the surface of the island. The albedo of melting ice is 0.80. Determine an estimate of the time taken to melt the island assuming that the melted water is removed immediately and that no heat is lost to the surroundings.

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48b. Suggest the likely effect on the average albedo of the region in which the island was floating as a result of the melting of the Pobeda ice island. *[2 marks]*

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49. A solid piece of tungsten melts into liquid without a change in temperature. Which of the following is correct for the molecules in the liquid phase compared with the molecules in the solid phase? *[1 mark]*

	Kinetic energy	Potential energy
A.	same	greater
B.	same	same
C.	greater	greater
D.	greater	same

50. The energy of the molecules of an ideal gas is *[1 mark]*

A. thermal only.

B. thermal and potential.

C. potential and kinetic.

D. kinetic only.

51. Oil with volume V has specific heat capacity c at temperature T. The density of oil is ρ. Which of the following is the thermal capacity of the oil? *[1 mark]*

A. ρcV

B. $\frac{cV}{\rho}$

C. ρcVT

D. $\frac{cV}{\rho T}$

52. The volume of an ideal gas in a container is increased at constant temperature. Which of the following statements is/are correct about the molecules of the gas? *[1 mark]*

I. Their average speed remains constant.
II. The frequency of collisions of molecules with unit area of the container wall decreases.
III. The force between them decreases.

A. I only
B. I and II only
C. I and III only
D. II and III only

This question is about internal energy and thermal energy (heat).

53a. Distinguish between internal energy and thermal energy. *[3 marks]*

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53b. Describe, with reference to the energy of the molecules, the difference in internal energy of a piece of iron and the internal energy of an ideal gas. *[2 marks]*

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53c. A piece of iron is placed in a kiln until it reaches the temperature θ of the kiln. The iron is then quickly transferred to water held in a thermally insulated container. The water is stirred until it reaches a steady temperature. *[4 marks]*

The following data are available.

Thermal capacity of the piece of iron = $60 JK^{-1}$
Thermal capacity of the water = $2.0 \times 10^{3} JK^{-1}$
Initial temperature of the water = 16°C
Final temperature of the water = 45°C

The thermal capacity of the container and insulation is negligible.

(i) State an expression, in terms of θ and the above data, for the energy transfer of the iron in cooling from the temperature of the kiln to the final temperature of the water.

(ii) Calculate the increase in internal energy of the water as the iron cools in the water.

(iii) Use your answers to (c)(i) and (c)(ii) to determine θ.

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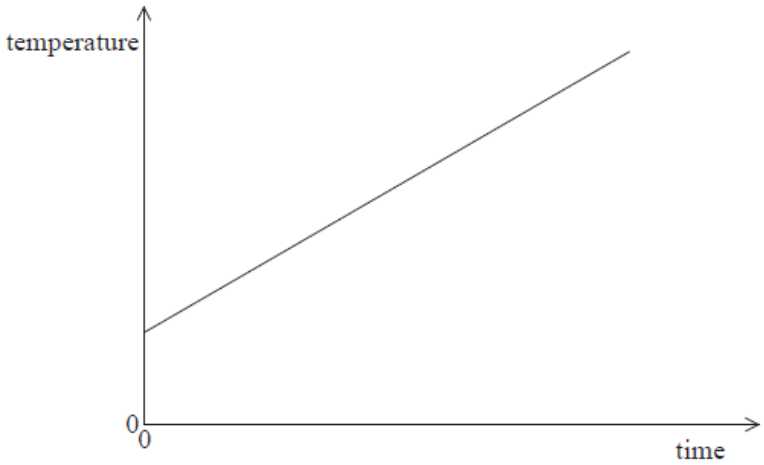
54. What is the mass of carbon-12 that contains the same number of atoms as 14 g of silicon-28? *[1 mark]*

A. 6 g
B. 12 g
C. 14 g
D. 24 g

55. A heater of constant power heats a liquid of mass *m* and specific heat capacity *c*. The graph below shows how the temperature of the liquid varies with time. *[1 mark]*



The gradient of the graph is k and no energy is lost to the surroundings. What is the power of the heater?

A. *kmc*

B. $\frac{k}{mc}$

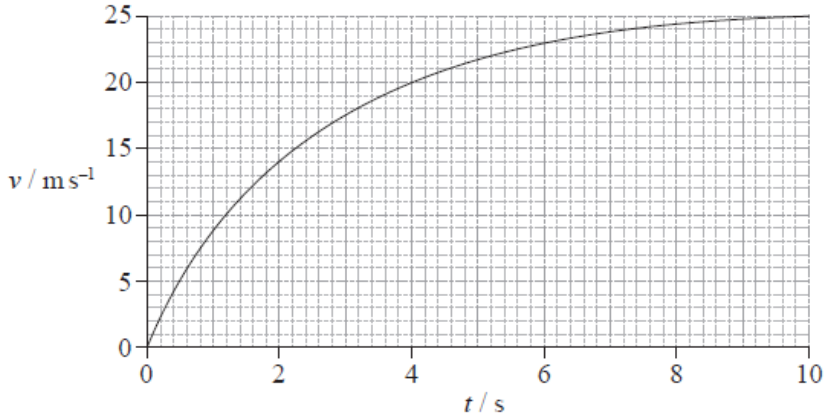
C. $\frac{mc}{k}$

D. $\frac{1}{kmc}$

This question is in **two** parts. **Part 1** is about mechanics and thermal physics. **Part 2** is about nuclear physics.

Part 1 Mechanics and thermal physics

The graph shows the variation with time t of the speed v of a ball of mass 0.50 kg, that has been released from rest above the Earth's surface.



The force of air resistance is **not** negligible. Assume that the acceleration of free fall is $g = 9.81 \text{ms}^{-2}$.

56a. State, without any calculations, how the graph could be used to determine the distance fallen. *[1 mark]*

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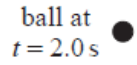
56b. (i) In the space below, draw and label arrows to represent the forces on the ball at 2.0 s. *[7 marks]*



Earth's surface ——————————————

(ii) Use the graph opposite to show that the acceleration of the ball at 2.0 s is approximately 4 ms^{-2}.

(iii) Calculate the magnitude of the force of air resistance on the ball at 2.0 s.

(iv) State and explain whether the air resistance on the ball at t = 5.0 s is smaller than, equal to **or** greater than the air resistance at t = 2.0 s.

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56c. After 10 s the ball has fallen 190 m. *[6 marks]*

(i) Show that the sum of the potential and kinetic energies of the ball has decreased by 780 J.

(ii) The specific heat capacity of the ball is 480 J kg^{-1} K^{-1}. Estimate the increase in the temperature of the ball.

(iii) State an assumption made in the estimate in (c)(ii).

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