



GuideMyGrades

— YOUR GOALS. OUR EXPERTISE. —

OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Thermal physics (5.1)

A Level Physics A (H556) · Module 5: Newtonian world and astrophysics

42 questions · 302 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

 guidemygrades.com

 @Guidemygrades

 @Guidemygrades

 @Guidemygrades

 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
1. Q7 <i>also 4.4</i>	H556/01 Modelling physics June 2017	1	5
2. Q14 <i>also 3.2</i>	H556/01 Modelling physics June 2017	1	6
3. Q3	H556/01 Modelling physics June 2018	1	7
4. Q6	H556/01 Modelling physics June 2018	1	8
5. Q14 <i>also 3.2</i>	H556/01 Modelling physics June 2018	1	9
6. Q9 <i>also 3.3</i>	H556/01 Modelling physics June 2019	1	10
7. Q15	H556/01 Modelling physics November 2020	1	11
8. Q4	H556/01 Modelling physics November 2021	1	13
9. Q9 <i>also 3.2</i>	H556/01 Modelling physics November 2021	1	14
10. Q7	H556/01 Modelling physics June 2022	1	15
11. Q8	H556/01 Modelling physics June 2022	1	16
12. Q9 <i>also 3.2</i>	H556/01 Modelling physics June 2022	1	17
13. Q10 <i>also 3.2</i>	H556/01 Modelling physics June 2023	1	18
14. Q1 <i>also 2.1</i>	H556/01 Modelling physics June 2024	1	19
15. Q2 <i>also 2.1</i>	H556/01 Modelling physics June 2024	1	20
16. Q1	H556/01 Modelling physics June 2025	1	21
17. Q2 <i>also 3.3</i>	H556/01 Modelling physics June 2025	1	22
18. Q22	H556/01 Modelling physics June 2017	5	24
19. Q20	H556/01 Modelling physics June 2017	6	26
20. Q20 <i>also 2.2</i>	H556/01 Modelling physics June 2025	7	28
21. Q23 <i>also 5.5 & 5.4</i>	H556/01 Modelling physics June 2019	9	31
22. Q1 <i>also 4.4</i>	H556/03 Unified physics June 2024	9	34
23. Q19 <i>also 3.2</i>	H556/01 Modelling physics June 2025	9	36
24. Q22 <i>also 3.5 & 5.4</i>	H556/01 Modelling physics June 2018	10	39
25. Q3 <i>also 3.5 & 3.3 & 5.5</i>	H556/03 Unified physics November 2020	10	41
26. Q23 <i>also 2.2 & 3.3 & 5.5 & 5.4</i>	H556/01 Modelling physics June 2023	10	44
27. Q16 <i>also 4.3 & 4.2</i>	H556/02 Exploring physics June 2024	10	46
28. Q21 <i>also 3.5 & 3.2</i>	H556/01 Modelling physics November 2020	11	51
29. Q19 <i>also 3.2</i>	H556/01 Modelling physics June 2022	11	53
30. Q17	H556/01 Modelling physics November 2020	12	56



	QUESTION		SOURCE	MARKS	PAGE
31.	Q4	<i>also 3.2 & 6.3</i>	H556/03 Unified physics November 2021	12	59
32.	Q21	<i>also 3.3</i>	H556/01 Modelling physics June 2022	12	63
33.	Q1	<i>also 4.2</i>	H556/03 Unified physics June 2018	13	66
34.	Q21		H556/01 Modelling physics June 2019	13	70
35.	Q1	<i>also 3.2 & 3.1</i>	H556/03 Unified physics June 2019	13	72
36.	Q4	<i>also 3.1 & 5.4</i>	H556/03 Unified physics November 2020	13	75
37.	Q18		H556/01 Modelling physics November 2021	13	78
38.	Q20	<i>also 3.3 & 3.2 & 4.2</i>	H556/01 Modelling physics June 2024	13	80
39.	Q5	<i>also 4.4 & 5.3</i>	H556/03 Unified physics June 2017	14	83
40.	Q20	<i>also 3.2</i>	H556/01 Modelling physics June 2023	14	87
41.	Q17	<i>also 3.2</i>	H556/01 Modelling physics June 2017	18	90
42.	Q6	<i>also 4.3 & 4.2</i>	H556/03 Unified physics June 2023	18	95



QUESTIONS

42 questions · 302 marks · lowest tariff first



MULTIPLE-CHOICE QUESTIONS

17 questions in this booklet



- 7 The intensity against wavelength graph of an object at 750°C peaks at a wavelength of λ . The temperature of the object is raised to 960°C .

What is the wavelength now at the new peak intensity in terms of λ ?

A 0.78λ

B 0.83λ

C 1.2λ

D 1.3λ

Your answer

[1]



- 14** A container has an ideal gas. The mean square speed of the gas molecules in the container is $3.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$.

Over a period of time, a third of the gas molecules escape from the container. The pressure and volume of the gas in the container remain the same.

What is the mean square speed of the molecules left in the container?

- A** $1.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- B** $2.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- C** $4.5 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- D** $9.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$

Your answer

[1]



- 3 A metal block of mass 0.28 kg has an initial temperature of 82 °C. It is dropped into cold water. The temperature of the block after 1.2 minutes is 20 °C. The specific heat capacity of the metal is $130 \text{ J kg}^{-1} \text{ K}^{-1}$.

What is the average thermal power transferred away from the metal block?

- A 31 W
- B 41 W
- C 1900 W
- D 2700 W

Your answer

[1]

© OCR 2018



- 6 The latent heat of vaporisation of a liquid is 2300 kJ kg^{-1} and it has a molar mass of $0.018 \text{ kg mol}^{-1}$.

What is the energy required to change 30 moles of the liquid to gas?

A $4.1 \times 10^4 \text{ J}$

B $1.2 \times 10^6 \text{ J}$

C $6.9 \times 10^7 \text{ J}$

D $3.8 \times 10^9 \text{ J}$

Your answer

[1]



- 14 The volume of one mole of an ideal gas is V . The gas exerts pressure p and has thermodynamic temperature T .

Which of the following has the units $\text{J mol}^{-1} \text{K}^{-1}$?

A pV

B $\frac{p}{T}$

C $\frac{V}{T}$

D $\frac{pV}{T}$

Your answer

[1]

- 9 A solid molecular substance is supplied with energy and it starts to melt.

Which of the following pairs of quantities remains the same as the substance melts?

- A Kinetic energy of molecules and internal energy of molecules.
- B Potential energy of molecules and internal energy of molecules.
- C Kinetic energy of molecules and temperature of substance.
- D Potential energy of molecules and temperature of substance.

Your answer

[1]



- 15 The kinetic theory of matter is a model used to describe the behaviour of particles (atoms or molecules) in an ideal gas. There are a number of assumptions made in the kinetic model for an ideal gas.

Which one of the following assumptions is **not** correct?

- A The collisions of particles with each other and the container walls are perfectly inelastic.
- B The electrostatic forces between particles are negligible except during collisions.
- C The particles occupy negligible volume compared to the volume of the gas.
- D There are a large number of particles in random motion.

Your answer

[1]



SECTION B

Answer **all** the questions.



- 4 The freezing point of ethanol is 159 K.

What is 159 K in °C?

A –432 °C

B –114 °C

C 114 °C

D 432 °C

Your answer

[1]

- 9 A piston has a fixed amount of trapped ideal gas.

The gas exerts pressure p and has volume V . The thermodynamic (absolute) temperature of the gas is T . The mass of each atom is m . There are N atoms of the gas. The Boltzmann constant is k .

What quantities are required to determine the root mean square speed $\sqrt{c^2}$ of the atoms?

- A k and T
- B p and V
- C p , V and T
- D p , V , N and m

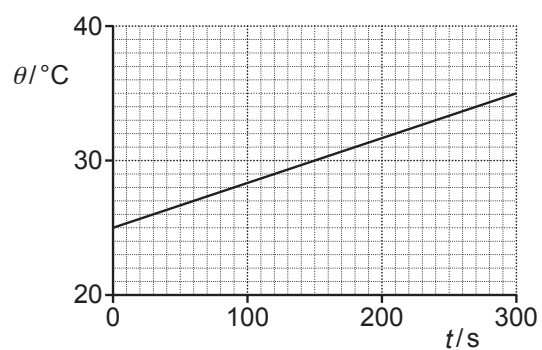
Your answer

[1]

© OCR 2021



- 7 A metal block of mass m is heated by an electric heater.
The graph of temperature θ against time t for this block is shown below.



The power of the heater is P . The gradient of the straight-line graph is G .

What is the correct expression for the specific heat capacity c of the metal?

- A** $c = G$
B $c = \frac{PG}{m}$
C $c = \frac{mP}{G}$
D $c = \frac{P}{mG}$

Your answer

[1]

8 Which statement(s) below are implied by the assumptions of the kinetic theory model of gases?

- 1 A gas is mostly empty space.
- 2 Gas particles spend more time between collisions than time during collisions.
- 3 There are always forces between the gas particles.

A Only 1 and 2

B Only 1 and 3

C Only 2 and 3

D 1, 2 and 3

Your answer

[1]

© OCR 2022

- 9 A container has 1.0 mole of gas at pressure 100 kPa.
The root mean square (r.m.s.) speed of the gas particles is 500 ms^{-1} . The mass of each gas particle is $4.7 \times 10^{-26} \text{ kg}$.

What is the volume of the container?

A $3.9 \times 10^{-26} \text{ m}^3$

B $4.7 \times 10^{-5} \text{ m}^3$

C $2.4 \times 10^{-2} \text{ m}^3$

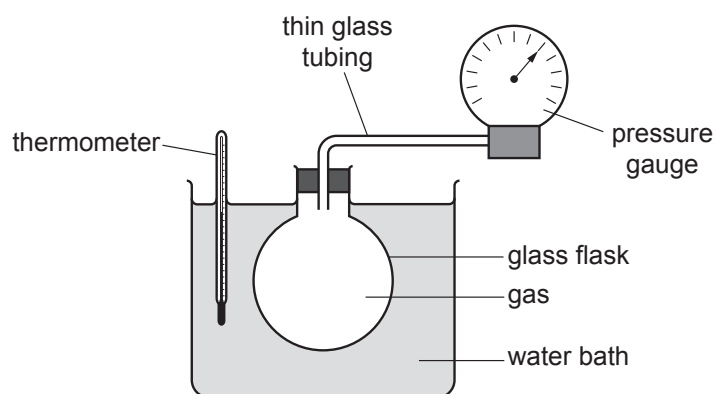
D $4.7 \times 10^{-2} \text{ m}^3$

Your answer

[1]



- 10 An experiment is carried out to estimate the value of absolute zero using the variation of gas pressure with temperature. The apparatus is shown below.



Which variable must be controlled during the experiment?

- A Pressure of the gas
- B Temperature of the gas
- C Volume of the gas
- D None of the above

Your answer

[1]

- 1 Which row in the table shows two equivalent physical quantities?

A	0 °C	−273.15 K
B	1 kg ms ^{−1}	1000 N s
C	10 kW	10 000 N m
D	1.0 mPa	0.0010 N m ^{−2}

Your answer

[1]



2 What are the SI base units of the Boltzmann constant k ?

A J K^{-1}

B $\text{kg m s}^{-2} \text{K}^{-1}$

C $\text{kg m}^2 \text{s}^{-2} \text{K}^{-1}$

D Nm K^{-1}

Your answer

[1]

1 Which of these physical constants requires the greatest number of **different** base SI units?

- A Avogadro constant, N_A
- B Boltzmann constant, k
- C Gravitational constant, G
- D Molar gas constant, R

Your answer

[1]



- 2 A metal block of mass m is at temperature T_0 . An electrical heater of constant power P heats the block for time t and it reaches a temperature T_1 . The overall efficiency of the process is x .

Which expression gives the correct value of c , specific heat capacity of the block?

A $\frac{Pt}{m(T_1 - T_0)}$

B $\frac{Pt}{mx(T_1 - T_0)}$

C $\frac{Pt x}{m(T_1 - T_0)}$

D $\frac{Px}{mt(T_1 - T_0)}$

Your answer

[1]

5-MARK QUESTIONS

1 question in this booklet



22 (a) Define the *internal energy* of a substance.

.....
.....
..... [1]

(b) A block of paraffin wax is melting at a constant temperature of 52°C . Use the behaviour of paraffin molecules to describe and explain the changes to the internal energy of the molecules of the paraffin wax as it melts.

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
..... [4]

6-MARK QUESTIONS

1 question in this booklet



- 20 A plastic kettle is filled with 0.60 kg of water at a temperature of 20 °C.
A 2.2 kW electric heater is used to heat the water for a time of 4.0 minutes.

(a) Calculate the total energy supplied by the heater during the time of 4.0 minutes.

energy = ... J [2]

- (b) The specific heat capacity of water is $4200 \text{ J kg}^{-1} \text{ K}^{-1}$ and the specific latent heat of vaporisation of water is $2.3 \times 10^6 \text{ J kg}^{-1}$. The boiling point of water is 100 °C.

Calculate the mass of water **remaining** in the kettle after 4.0 minutes.
Assume that all the thermal energy from the heater is transferred to the water.

mass of water remaining = ... kg [4]

7-MARK QUESTIONS

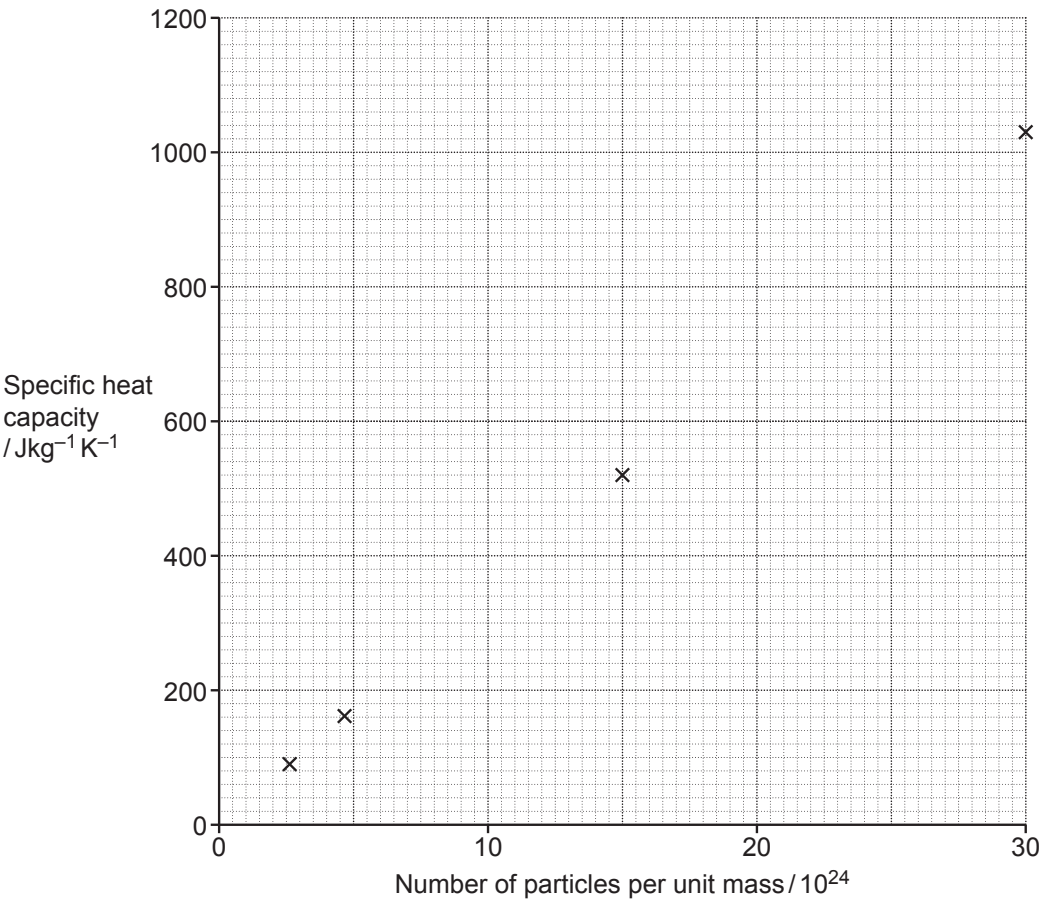
1 question in this booklet



20 The specific heat capacities and molar masses of some common gases are given in the table.

Gas	Specific heat capacity / Jkg ⁻¹ K ⁻¹	Molar mass / kg mol ⁻¹	Number of particles per unit mass / 10 ²⁴
Neon	1030	0.020	30
Argon	520	0.040	15
Krypton	250	0.084	
Xenon	160	0.130	4.6
Radon	90	0.220	2.7

(a) Complete the missing value in the table. [1]



(b) Plot the missing data point on the graph above and draw a line of best fit. [2]

(c) Describe the relationship suggested by the graph and suggest an explanation.

.....

.....

.....

.....

.....

.....

.....

..... [4]

9-MARK QUESTIONS

3 questions in this booklet



- 23 (a)* In 2017, an ultra-cool star TRAPPIST-1 was discovered with at least five of its own orbiting planets. Astronomers are interested about the possibility of finding life on some of the planets orbiting TRAPPIST-1.

The table below shows some data.

	TRAPPIST-1	Sun
Luminosity L/W	2.0×10^{23}	3.8×10^{26}
Surface temperature T/K	2500	5800
Radius of star/m	R	7.0×10^8
Distance between Earth and Sun/m		1.5×10^{11}
Distance between planets and TRAPPIST-1/m	1.6×10^9 to 9.0×10^9	

The temperature T in kelvin of a planet, its distance d from the star and the luminosity L of the star are related by the expression

$$\frac{T^4 d^2}{L} = \text{constant.}$$

- The average temperature of the Earth is about 290 K. Explain how life may be possible on some of the planets orbiting TRAPPIST-1.
- Use your knowledge of luminosity to show that the radius R of TRAPPIST-1 is smaller than the Sun.
- Support your answers by calculations. [6]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Additional answer space if required.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question 23 continues on page 28

(b) Kepler's third law can be applied to a satellite in a geostationary orbit around the Earth.

- (i) Complete the equation for Kepler's third law below.
You do not need to define any of the terms.

$$\dots\dots\dots = \frac{4\pi^2}{GM} \dots\dots\dots \quad [1]$$

- (ii) The mass of Earth is 6.0×10^{24} kg.
Calculate the radius of the circular path of a satellite in a geostationary orbit around the Earth.

radius = ... m [2]

1 A flute is a musical instrument made from a long tube that is open at both ends.

A stationary sound wave in the tube produces a musical note.

The lowest frequency note that a standard flute produces in air is 262 Hz.

The speed of sound in air at a temperature of 20 °C is 340 ms^{−1}.

(a) Show that a standard flute has an approximate length of 0.65 m.

[3]

(b) In an ideal gas, the speed v of sound is given by

$$v = \left(\frac{\gamma RT}{M} \right)^{1/2}$$

where

γ is a dimensionless constant that depends on the gas

R is the molar gas constant

T is the absolute temperature

M is the molar mass of the gas.

The table below shows values of γ and M for both air and helium.

Gas	γ	$M/\text{g mol}^{-1}$
Air	1.40	29.0
Helium	1.67	4.00

- (i) The kinetic model of an ideal gas assumes that there are a large number of particles in rapid, random motion.

State **two** further assumptions for the kinetic model of an ideal gas.

1

.....

2

..... [2]

- (ii) A standard flute is placed inside a sealed chamber.

The chamber is filled with helium at a temperature of -10°C .

Calculate the lowest frequency that the flute could produce inside the chamber.

frequency = ... Hz [4]

- 19** A lorry used to transport liquid oxygen has a tank with a maximum volume of 10 m^3 .

The tank is filled until it contains 9.8 m^3 of liquid oxygen.

The pressure of the gas above the liquid is 100 kPa and the temperature of the gas and the liquid is -183°C , the boiling point of oxygen.

The temperature of the oxygen remains constant.

The walls of the tank allow thermal energy to pass through at a constant rate of 1.3 kW .

The latent heat of vaporisation of oxygen is 214 kJ kg^{-1} .

The density of **liquid** oxygen is 1140 kg m^{-3} .

- (a)** State why thermal energy passes into the tank.

.....
.....
..... **[1]**

- (b)** Explain, in terms of particle energies, why the temperature of the oxygen remains constant despite the transfer of thermal energy into the tank.

.....
.....
..... **[2]**

- (c)** Show that in one hour the volume of liquid oxygen that evaporates is about 0.02 m^3 .



(d) After one hour the number of moles of gas above the remaining liquid oxygen is 710.

Calculate the pressure of the gas.

pressure = ... kPa [3]



10-MARK QUESTIONS

4 questions in this booklet



- 22 (a) A helium atom **X** travelling at 610 m s^{-1} makes an elastic collision with a stationary helium atom **Y**. The magnitude of the velocity of **X** after the collision is 258 m s^{-1} . The directions of the velocities of **X** and **Y** are as shown in Fig. 22.

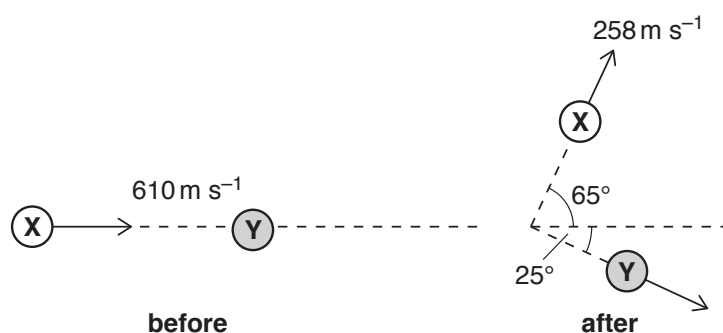


Fig. 22

- (i) Explain what is meant by an *elastic collision*.

.....
 [1]

- (ii) The mass of a helium atom is $6.64 \times 10^{-27} \text{ kg}$.
 Calculate the magnitude of the momentum p of **Y** after the collision.

$p = \dots\dots\dots \text{ kg m s}^{-1}$ [3]

- (b)* There is a lot of helium in the Universe. This was also true of the Earth when it was formed billions of years ago. However, only small traces of helium are now found in the atmosphere of the Earth.

Use the kinetic theory of gases to explain why only small amounts of helium are found in the Earth's atmosphere. Use the information below to do suitable calculations to support your answer.

- typical atmospheric temperature = 10°C
- mass of helium atom = $6.64 \times 10^{-27} \text{ kg}$
- escape velocity from the Earth = 11 km s^{-1}

Blank lined paper for writing.

Turn over



3 This question is about the Sun and its radiation.

- (a) (i) Use the data below to show that the luminosity of the Sun is about $4 \times 10^{26} \text{ W}$.
- radius of Sun = $7.0 \times 10^8 \text{ m}$
 - surface temperature of Sun = 5800 K

[1]

- (ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature T of Sirius.

$T = \dots\dots\dots \text{ K}$ [3]

***(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.
You should include relevant formulae, but no numbers or calculations are required.

[6]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Additional answer space if required.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

- 23** The Hipparcos space telescope used stellar parallax with a precision of 9.7×10^{-4} arcseconds to determine the distance to stars.

One of the stars studied was Polaris A. Data about this star is in the table below.

Parallax angle	7.5×10^{-3} arcseconds
Radius	2.1×10^{10} m
Mass	1.1×10^{31} kg
Surface temperature	6000 K
Temperature of the atmosphere of the star	4.0×10^6 K

- (a) (i)** Estimate the maximum stellar distance in parsecs that could be measured using Hipparcos.

maximum stellar distance = ...pc **[1]**

- (ii)** Calculate the percentage uncertainty in the calculated value of the distance to Polaris A.

percentage uncertainty = ... % **[2]**

- (b)** A continuous stream of particles called a solar wind flows from the surface of the star into the surrounding space.

These particles include helium nuclei of mass 6.6×10^{-27} kg.

Assume that the atmosphere is modelled as an ideal gas.

- (i)** Show that the typical kinetic energy of a helium nucleus in the atmosphere is about 10^{-16} J.

[2]

- (ii) The gravitational potential energy of a helium nucleus in the outer layer of the star is $-2.3 \times 10^{-16} \text{ J}$.

Calculate the gravitational potential energy U at the maximum distance from the star that a helium nucleus could reach.

$$U = \dots\dots\dots \text{ J [1]}$$

- (iii) Calculate the distance from the centre of the star reached by this helium nucleus.

$$\text{distance} = \dots\dots\dots \text{ m [3]}$$

- (iv) Explain why the star has a solar wind that reaches a much greater distance from the star than found in (iii).

.....
..... [1]

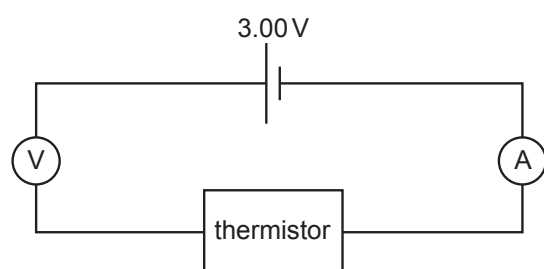


16 Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



(a) Describe how the student should change the circuit.

.....
..... [1]

(b) The circuit was corrected and then used to collect data.

The table shows data collected from the investigation.

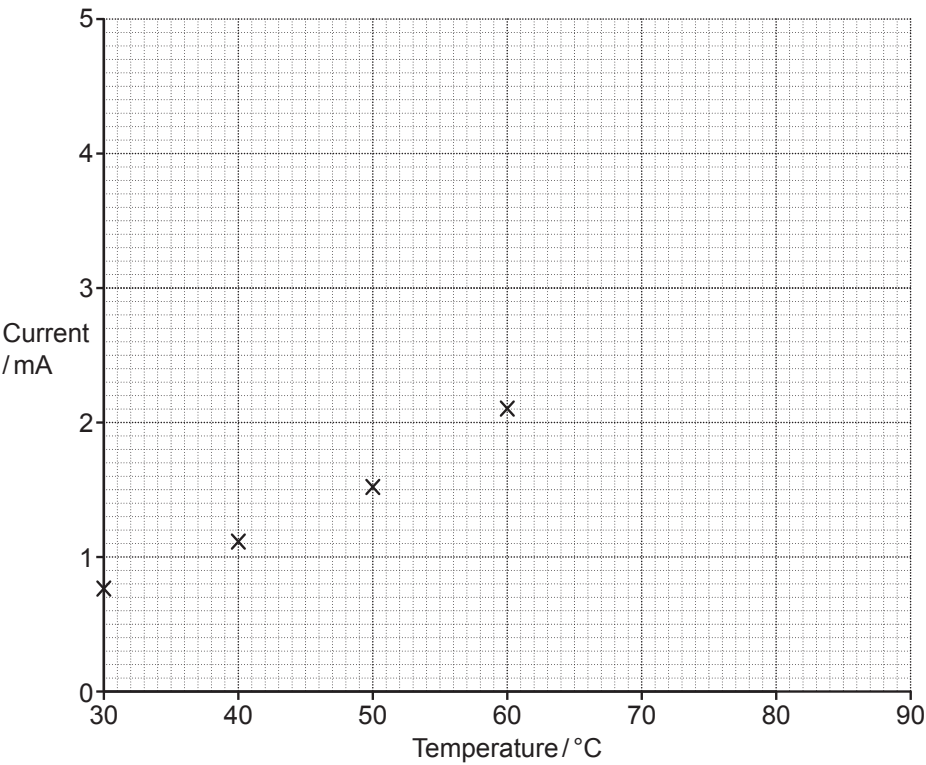
Temperature/°C	Current/mA	Voltage/V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

(i) The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

(ii) Draw a suitable line of best fit through the data points.

[1]



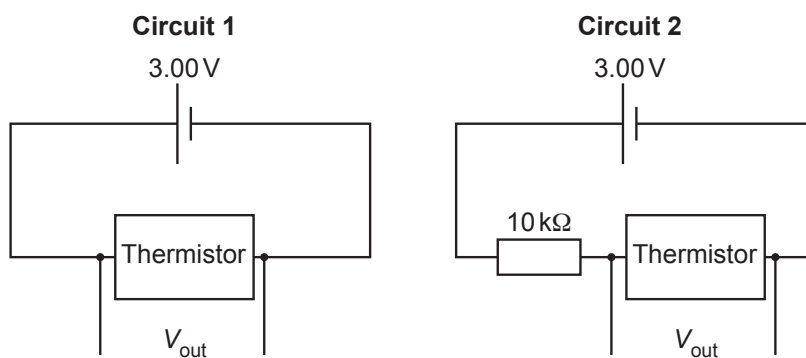
- (c) Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

[3]

[3]

- (d) The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.



In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

.....

.....

.....

.....

.....

.....

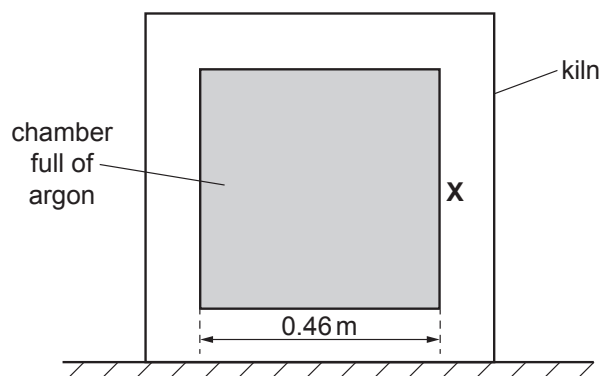
..... [4]

11-MARK QUESTIONS

2 questions in this booklet



21 A kiln used to harden ceramics is shown below.



The internal chamber is a cube. Each side of this cube has length 0.46 m. The chamber is sealed and full of argon. Argon behaves as an ideal gas.

- (a) The kiln is initially at 20 °C.
The argon in the kiln has an initial pressure of 100 kPa.
- (i) Calculate the amount of argon n in the chamber in moles.

$n = \dots\dots\dots$ mol [2]

- (ii) The temperature of the kiln is increased from 20 °C to 1300 °C.

Calculate the pressure in kPa at 1300 °C.

pressure = $\dots\dots\dots$ kPa [2]

- (b) The temperature of the kiln is 1300°C .
A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber.
The initial speed of this atom is 990 m s^{-1} . After collision, it rebounds at the same speed.

- (i) Calculate the change in momentum Δp of this atom.
• mass of argon atom = $6.6 \times 10^{-26}\text{ kg}$

$$\Delta p = \dots\dots\dots \text{ kg m s}^{-1} \text{ [2]}$$

- (ii) Assume that this atom does not collide with any other argon atoms inside the chamber.
Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.

- 1 Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0 s.

[1]

- 2 Calculate the average force F on side **X** made by the atom.

$$F = \dots\dots\dots \text{ N [2]}$$

- (iii) Without calculation, explain how your answer to (ii)2 could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.

.....

 [2]

- 19 (a)** A fixed mass of nitrogen changes phase from liquid to gas at a constant temperature.

Explain the change in the total internal energy of nitrogen.

.....

 [2]

- (b)** In a factory, nitrogen gas is added to packets of food to keep it fresh for longer.
 In 1.0 hour, the factory uses 15 m^3 of nitrogen at pressure 100 kPa and temperature 23°C .

- (i)** Show that the number of moles n , of nitrogen used per hour is about 600.

[3]

- (ii)** Calculate the mass of nitrogen gas used in one hour.

molar mass of nitrogen = 0.028 kg mol^{-1}

mass = ... kg [1]

- (iii)** The volume of nitrogen being used cannot be changed.

State how the rate of mass of nitrogen used can be reduced.

.....
 [1]

- (iv) The nitrogen at the factory is stored as a liquid.
The liquid expands at constant temperature to form gas in a short section of pipe.

When the air temperature is 0°C , a thick layer of ice forms on the outside of the pipe from water vapour in the air. In 1.0 hour, the mass of ice formed is 1.3 kg at a temperature of 0°C .

Use the data below and your answer to (b)(ii), to estimate the specific latent heat of vaporisation L of nitrogen.

- specific latent heat of fusion of ice = $3.34 \times 10^5 \text{ J kg}^{-1}$
- specific latent heat of vaporisation of water = $2.26 \times 10^6 \text{ J kg}^{-1}$

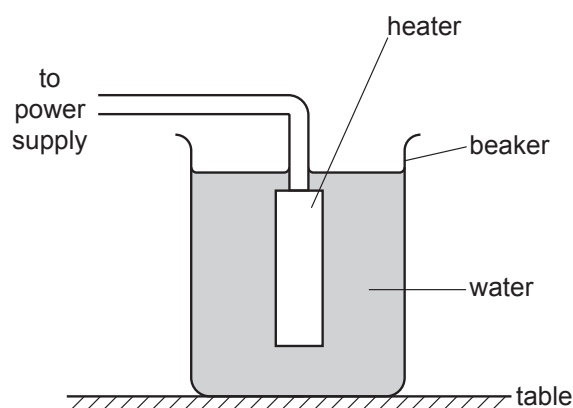
$L = \dots\dots\dots \text{ J kg}^{-1}$ [4]

12-MARK QUESTIONS

3 questions in this booklet



- 17 (a) A heater is used to heat water in a beaker.



- (i) Before switching on, the metal heater and the water are both at room temperature.

Describe the motion of the atoms of the metal heater and of the water molecules.

.....

.....

.....

.....

.....

..... [3]

- (ii) The heater is now switched on.
 The power of the heater is 200 W.
 The mass of the water in the beaker is 500 g.
 It takes 10.0 minutes to increase the temperature of the water in the beaker from 20 °C to 60 °C.

Calculate the energy transferred from the water to the **beaker and the surroundings**.

- specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

energy transferred = ... J [3]

- (b)* A student is carrying out an experiment to determine the specific latent heat of fusion L_f of ice. The student has two sets of apparatus next to each other on the laboratory bench, as shown in Fig. 17.1 and Fig. 17.2.

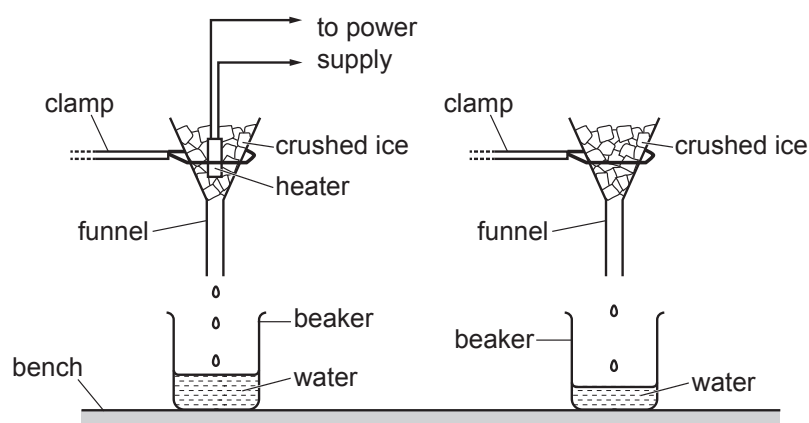


Fig. 17.1

Fig. 17.2

Both funnels are identical and have the same mass of crushed ice at 0°C .

The current in the heater is 5.0A and the potential difference across it is 12V .

Fig. 17.3 shows the variation of mass of water m collected in each beaker with time t .

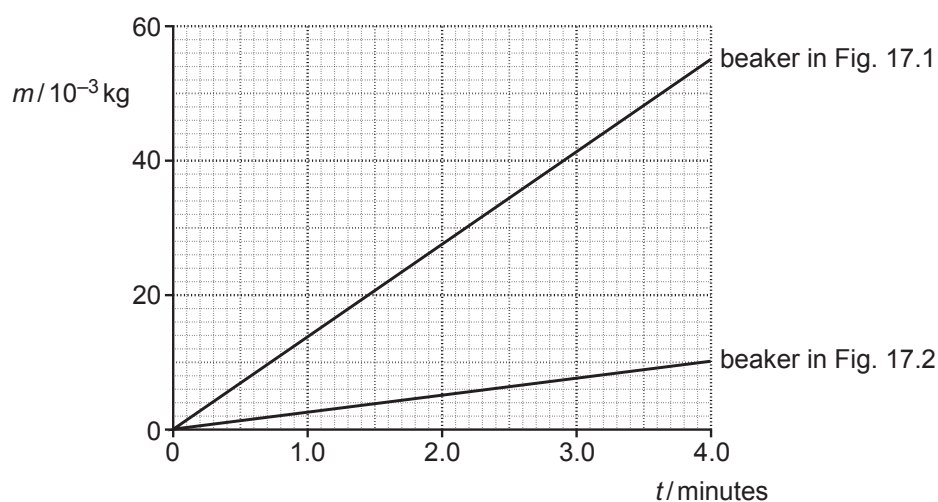


Fig. 17.3

Describe and explain the shape of the two graphs in **Fig. 17.3** and use them to determine the specific latent heat of fusion L_f of ice. **[6]**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Additional answer space if required

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

- 4 This question is about an electric cooker, which consists of an oven and an electromagnetic induction hob.

*(a) The oven is not sealed, so the air inside remains at atmospheric pressure of $1.0 \times 10^5 \text{ Pa}$. The volume of the oven is 0.065 m^3 . The air inside the oven behaves as an ideal gas.

The temperature of the oven increases from room temperature to 200°C .

Show that the internal energy of the air in the oven is the same at **all** temperatures of the oven. Support your answer with an explanation of the motion of the air molecules in terms of kinetic theory. [6]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Additional answer space if required

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Question 4 continues on page 12



(b) The electromagnetic induction hob is shown in **Fig. 4.1**.

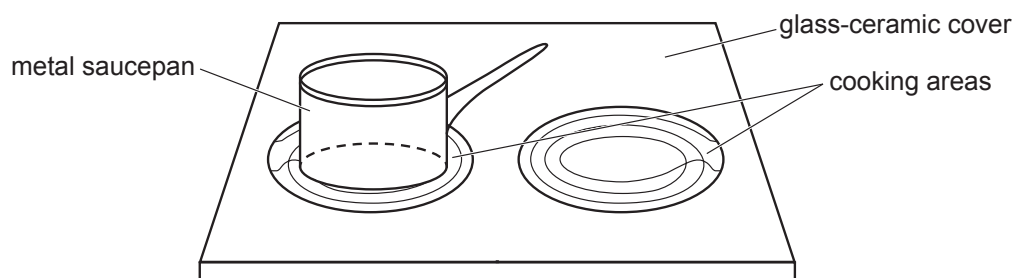


Fig. 4.1

Each cooking area has a coil below the glass-ceramic cover. When switched on, the coils carry a high-frequency **alternating** current.

A metal saucepan is placed above one of the coils. A large alternating current is induced in the saucepan base, and this causes the saucepan to heat up.

(i) **Fig. 4.2** shows one of the coils at a time when the current is in the direction indicated by the arrows.

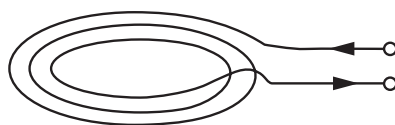


Fig. 4.2

On **Fig. 4.2**, sketch the magnetic field pattern for the current-carrying coil.

[2]

- (ii) Fig. 4.3 shows the path of the large alternating current induced in the metal base of the saucepan.

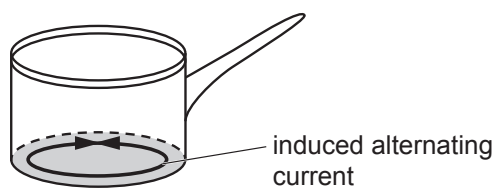


Fig. 4.3

Explain the origin of this large current.

.....

.....

.....

.....

.....

..... [2]

- (iii) Explain why it would be safe for a person to place a hand on the cooking area before the saucepan is put onto it.

.....

.....

.....

..... [2]

- 21 (a) A nebula is a giant cloud of gas and dust in space. The nebula can produce a star over a long period of time.

State what causes the initial collapse of the nebula.

..... [1]

- (b) A nebula X is modelled as a sphere of gas and dust particles of diameter 6.4 pc.

The nebula has 1.0×10^{12} gas and dust particles per m^3 and a temperature of 250 K. The nebula behaves like an ideal gas.

- (i) Show that the volume of the nebula is $4.1 \times 10^{51} \text{ m}^3$.

$$1 \text{ pc} = 3.1 \times 10^{16} \text{ m}$$

[2]

- (ii) Calculate the **total** kinetic energy E_k of the gas and dust particles in the nebula.

$$E_k = \dots\dots\dots \text{ J [3]}$$

- (c) The nebula that formed the Sun is estimated to have a diameter of 3.0 pc and had a similar composition to nebula **X** in (b).

The mass of the nebula **X** is **much greater** than the mass of the Sun.

- (i) Calculate the ratio $\frac{\text{mass of nebula X}}{\text{mass of the Sun}}$.

ratio = ... [2]

- (ii) After a long time, nebula **X** will form a stable star.

Describe the eventual evolution of this star.

.....
.....
.....
.....
.....
.....
.....
..... [4]



13-MARK QUESTIONS

6 questions in this booklet



1 This question is about a resistance wire made of nichrome.

(a)* It is suggested that the resistance R of a length of nichrome wire varies with temperature θ in $^{\circ}\text{C}$ according to the equation

$$R = R_0 (1 + k\theta)$$

where R_0 is the resistance of the wire at 0°C and k is a constant for the wire.

Fig. 1.1 shows a diagram of the arrangement of apparatus in an experiment to test the relationship between R and θ and to determine the value of k .

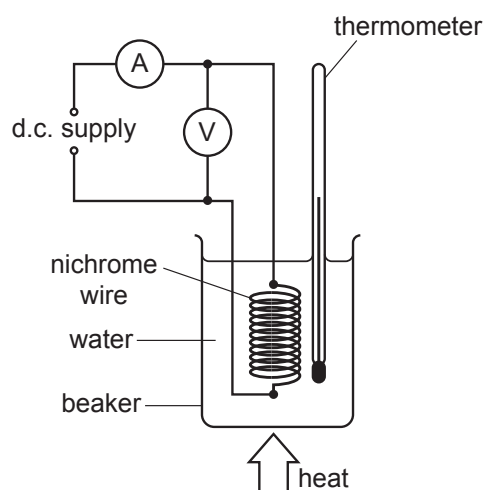


Fig. 1.1

The resistance wire is coiled and placed in a water bath.

Describe how you would carry out the experiment, analyse the data to verify the relationship between R and θ and determine a value for k .

In your description, state any precautions that you would take to improve the accuracy and precision of the measurements.

[6]

Question 1 is continued on page 4.

© OCR 2018

Turn over



- (b) A student is investigating a 230 V, 1.0 kW heating element. The heating element is shown in Fig. 1.2.

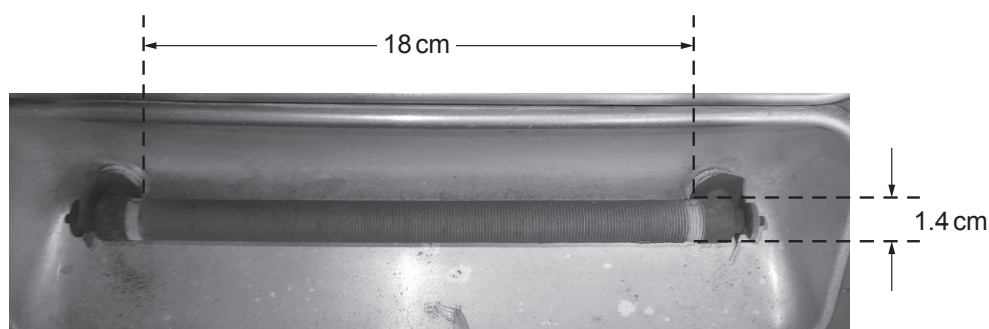


Fig. 1.2

A length of nichrome wire is wound in a spiral groove along 18 cm of a ceramic cylinder of diameter 1.4 cm. The distance between the centres of adjacent turns of the wire is 1.5 mm.

The numbers labelling the reels of loose wire on the laboratory shelf are the *imperial standard wire gauge* (swg). The student wishes to find out which reel holds the same wire as that wound on the heating element of Fig. 1.2.

The book of data gives the following information:

resistivity of nichrome at operating temperature = $1.1 \times 10^{-6} \Omega \text{ m}$

swg	24	26	28	30	32
diameter of wire / 10^{-3} m	0.56	0.46	0.38	0.32	0.27
cross-sectional area / 10^{-6} m^2	0.25	0.16	0.11	0.08	0.06

- (i) Show that the resistance of the nichrome wire wound on the ceramic cylinder is 53Ω .

[2]

(ii) Show that the length of wire wound on the heating element is 5.3 m.

[2]

(iii) Use the information given in (i) and (ii) to determine the swg number of the wire used as the heating element.

swg number = ... [3]

- 21** A substance can exist as a crystalline solid, a liquid or a gas.
A solid sample of the substance is placed in a sealed container and heated at a constant rate until it changes into a gas.

Fig. 21 shows the variation with time t of the temperature θ for the substance.

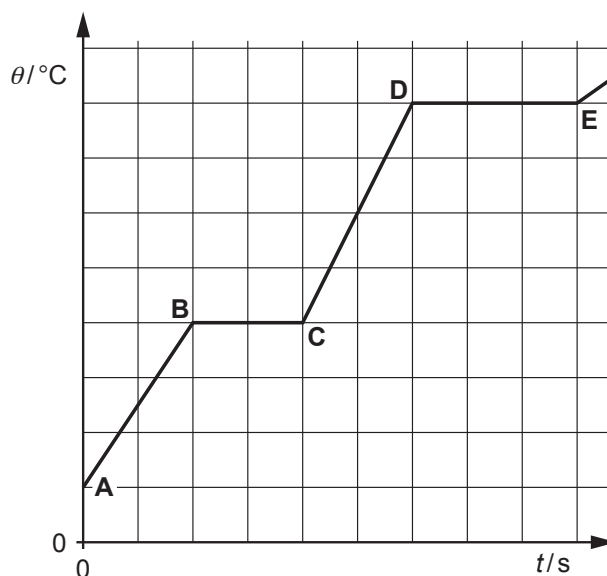


Fig. 21

- (a)** Use the kinetic theory of matter to describe the solid phase (section **AB**) and the liquid phase (section **CD**) in terms of the motion and arrangement of the molecules of the substance.

Section **AB**:

.....

Section **CD**:

.....

[4]

- (b) Use Fig. 21 to explain how the specific heat capacity of the liquid compares with the specific heat capacity of the solid.

.....

 [2]

- (c) State what is meant by the **internal energy** of the substance.

.....
 [1]

- (d) Beyond the point **E** in Fig. 21, the substance behaves as an ideal gas.

- (i) The mass of a gas molecule is 4.8×10^{-26} kg.
 Calculate the root mean square speed of the gas molecules at a temperature of 250°C .

root mean square speed = ... ms^{-1} [3]

- (ii) Calculate the internal energy of 1.3 moles of the gas at 250°C .

internal energy = ... J [3]

- 1 A toy rocket is made from a 1.5 litre plastic bottle with fins attached for stability.

The bottle initially contains 0.30 litres of water, leaving 1.2 litres of trapped air at a temperature of 17 °C.

A pump is used to increase the pressure of the air within the plastic bottle to $2.4 \times 10^5 \text{ Pa}$ at the start of lift-off.

Fig. 1.1 shows the rocket at the start of lift-off.

$$1 \text{ litre} = 10^{-3} \text{ m}^3$$

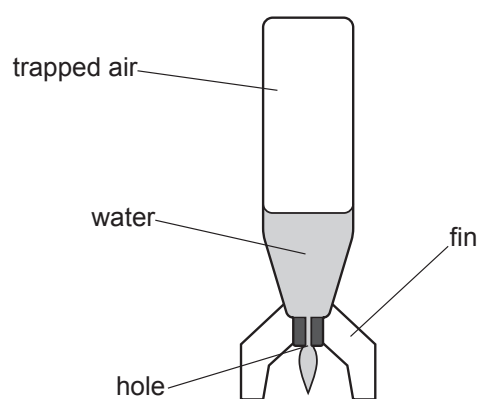


Fig. 1.1

- (a) Calculate, in moles, the amount of trapped air in the bottle at the start of lift-off.

amount of air = ... mol [2]

- (b) The trapped air pushes the water downwards out of the hole, causing the rocket to rise. The temperature of this air remains constant.

Calculate the final pressure of the trapped air just before all the water has been released.

final pressure = ... Pa [3]

- (c) Here is some data on the toy rocket.

mass of empty bottle and fins = 0.050 kg
area of cross-section of hole = $1.1 \times 10^{-4} \text{ m}^2$
initial pressure of trapped air = $2.4 \times 10^5 \text{ Pa}$
atmospheric pressure = $1.0 \times 10^5 \text{ Pa}$
density of water = $1.0 \times 10^3 \text{ kg m}^{-3}$

- (i) Use the data above to show that the **upwards** force on the rocket at the start of lift-off is about 15 N.

[2]



(ii) Hence calculate the initial vertical acceleration of the rocket.

initial acceleration = ... ms^{-2} [3]

(d) Discuss whether adding more water initially would enable the rocket to reach a greater height.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

- 4 The International Space Station (ISS) orbits the Earth at a height of $4.1 \times 10^5 \text{ m}$ **above** the Earth's surface.

The radius of the Earth is $6.37 \times 10^6 \text{ m}$. The gravitational field strength g_0 at the Earth's surface is 9.81 N kg^{-1} .

- (a) Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

.....

 [1]

- (b) (i) Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

$g = \dots\dots\dots \text{N kg}^{-1}$ [3]

- (ii) The speed of the ISS in its orbit is 7.7 km s^{-1} . Show that the period of the ISS in its orbit is about 90 minutes.

[2]

Question 4 continues on page 12

Turn over

(c) Use the information in (b)(ii) and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = $2.9 \times 10^{-2} \text{ kg mol}^{-1}$
- temperature of air inside the ISS = 20°C

[3]

- (d) The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

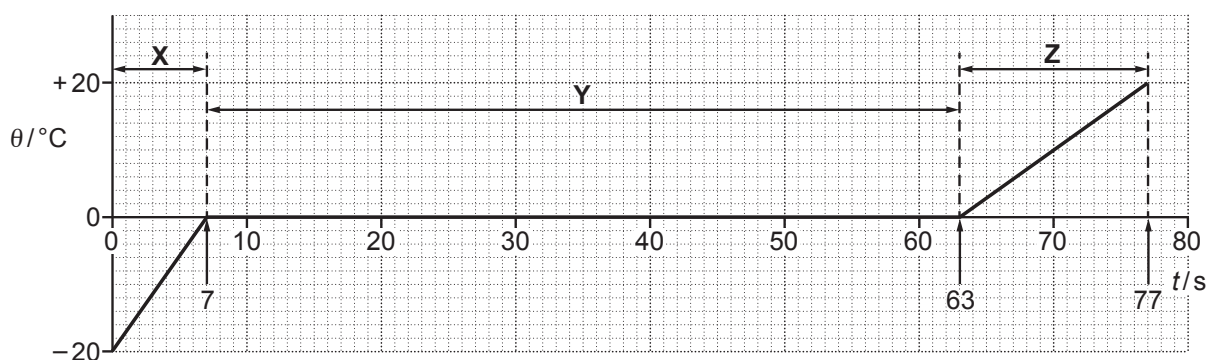
Use the data below and your answer to (b)(ii) to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is 2500 m^2 .
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is 1.4 kW m^{-2} outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ... W [4]

- 18 A 150 W heater is used to heat 25 g of ice in a sealed and well-insulated container. The initial temperature of the ice is -20°C .

The graph shows the variation of temperature θ with time t as the ice is heated.



There are three distinct regions of the graph, X, Y and Z.

- (a) (i) Use the graph to determine the specific heat capacity c of the ice.

$$c = \dots\dots\dots \text{J kg}^{-1} \text{K}^{-1} \text{ [3]}$$

- (ii) Use the graph to determine the specific latent heat of fusion of ice L_f .

$$L_f = \dots\dots\dots \text{J kg}^{-1} \text{ [2]}$$

- (iii) Use the graph to compare the specific heat capacities of ice and water. Explain your answer.

.....

 [2]

- (b) (i) Describe the motions of the molecules in region X and in region Z.

.....

 [2]

- (ii) The internal energy of the ice increases from $t = 0$ to $t = 77$ s.
 Complete the table below using the following key for the physical quantities:

- K = kinetic energy of molecules
- P = potential energy of molecules.

Region	Physical quantity, or quantities, that increases as time increases	Physical quantity, or quantities, that remain constant as time increases
X		
Y		
Z		

[3]

- (iii) State the temperature of the ice at which its molecules have zero kinetic energy.

..... [1]

20

(a)

- (i) Define the internal energy of an ideal gas.

.....

.....

..... [1]

- (ii) Use the formulae below to show that the average kinetic energy of a particle of an ideal gas is directly proportional to the absolute temperature of the gas.

$$pV = \frac{1}{3}Nm\overline{c^2} \quad pV = NkT$$

[2]

- (b) The velocities of four gas particles at 290 K are given below in
- ms^{-1}
- .

310 370 440 550

- (i) Show that the root-mean-square (r.m.s.) speed of the sample is about
- 430 ms^{-1}
- .

[2]

- (ii) Calculate the molar mass of the gas assuming an absolute temperature of 290 K and r.m.s. speed of
- 430 ms^{-1}
- .

molar mass = ... kg mol^{-1} [3]

- (c) Spherical filament lamps are manufactured by a process where they are filled with a gas at 290 K and low pressure.

When the filament lamp is switched on, the filament reaches a constant temperature of 2400 K. At this temperature, the pressure inside the filament lamp is 120 kPa.

- (i) Explain, in terms of energy transfers, why the temperature of the filament does **not** increase beyond 2400 K. You are **not** expected to refer to the electrical characteristics of the filament lamp.

.....

.....

.....

.....

..... [3]

- (ii) Calculate the pressure of the gas within the filament lamp during manufacture.

pressure = ... kPa [2]



14-MARK QUESTIONS

2 questions in this booklet



- 5 (a) A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.



Fig. 5.1

The maximum displacement of the air particles from their mean positions is $2.0 \times 10^{-6} \text{ m}$.

The speed of sound in air at 17°C is 340 ms^{-1} .

- (i) On Fig. 5.2, sketch the sinusoidal variation of the displacement of the air with distance between **C** and **R**.

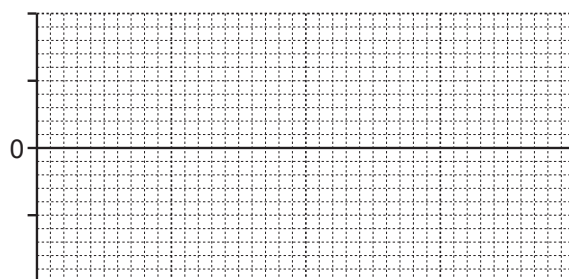


Fig. 5.2

- 1 Label the axes and include sensible scales.
- 2 On Fig. 5.2, mark one point where air particles are moving at maximum speed. Label it **X**.
- 3 On Fig. 5.2, mark one point where air particles are moving at maximum speed but travelling in the opposite direction to the air particles in 2. Label it **Y**.

[4]

- (ii) Calculate

- 1 the maximum speed v_{max} of the oscillating particles in the sound wave

$$v_{\text{max}} = \dots \text{ms}^{-1} \quad [2]$$

- 2 the root mean square speed $c_{\text{r.m.s.}}$ of the air molecules in the room.
The molar mass of air is $2.9 \times 10^{-2} \text{ kg mol}^{-1}$.

$$c_{\text{r.m.s.}} = \dots \text{ms}^{-1} \quad [2]$$

- (b)* Students are given the equipment in Fig. 5.1 together with a metre rule. They are also given a second loudspeaker connected to the same signal generator at 1.7 kHz. They are asked to design an experiment where they would need to take just **one** measurement and be able to determine the value of the speed of sound.

They set up the experiment in two different ways as shown in Fig. 5.3(a) and (b).

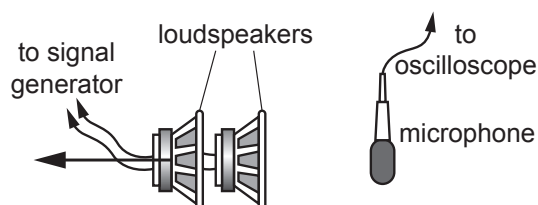


Fig. 5.3(a)

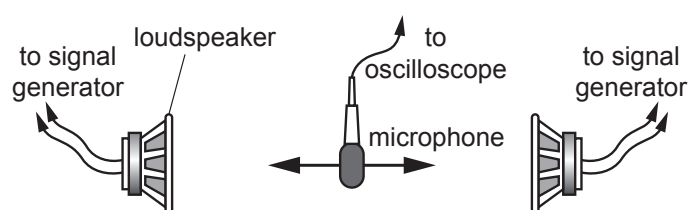


Fig. 5.3(b)

In method **(a)** the microphone is fixed and one loudspeaker is moved to the left as shown in Fig. 5.3(a).

In method **(b)** the microphone is moved to the left or to the right with the loudspeakers fixed a certain distance apart as shown in Fig. 5.3(b).

Describe and explain how both methods can be used to accurately determine the speed of sound. In your description, discuss how the uncertainty in the value for the speed of sound can be minimised in one of the methods, without using any other apparatus. [6]

[illegible]

© OCR 2017

.....
Turn over



© OCR 2017



BLANK PAGE

Question 6 begins on page 18.



- 20 (a)** A sealed container contains n moles of an ideal gas. The gas has pressure p , absolute temperature T and occupies volume V .

The mass of one mole of the gas is M .

Use an ideal gas equation to show that the density ρ of the gas is given by the expression

$$\rho = \frac{pM}{RT}.$$

[3]

- (b)** An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is $12\,000\text{ m}^3$.

The temperature of the helium and the surrounding air is 20°C .

Atmospheric pressure is $1.0 \times 10^5\text{ Pa}$.

The molar mass of air is 0.029 kg mol^{-1} .

The volume of the cabin is negligible compared to the volume of the gasbag.

- (i)** Show that the density of air under the conditions described is about 1.2 kg m^{-3} .

[1]

- (ii)** Calculate the weight of air displaced by the airship.

weight of air N [2]

- (iii) Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

.....

 [2]

- (iv) The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
 Suggest why a larger pressure is not used.

.....

 [2]

- (c) The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1} , so the airship starts to move.

All other conditions given in (b) remain the same.

Calculate the thrust that the engine produces.

thrust N [2]

- (d) The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine.

Explain these observations.

.....

 [2]



18-MARK QUESTIONS

2 questions in this booklet



- 17 A group of students are conducting an experiment in the laboratory to determine the value of absolute zero by heating a fixed mass of gas. The volume of the gas is kept constant. Fig. 17.1 shows the arrangement used by the students.

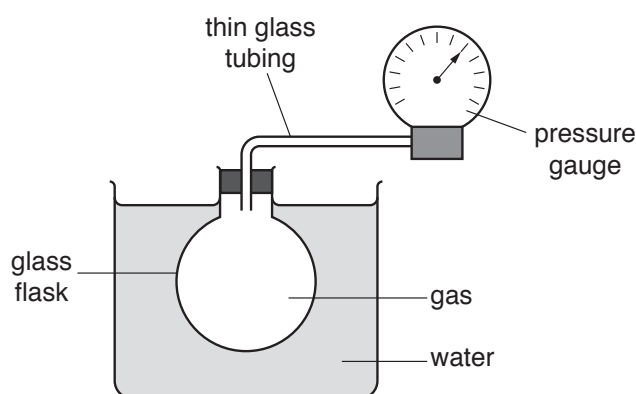


Fig. 17.1

The gas is heated using a water bath. The temperature θ of the water is increased from 5°C to 70°C . The temperature of the water bath is assumed to be the same as the temperature of the gas. The pressure p of the gas is measured using a pressure gauge.

The results from the students are shown in a table.

$\theta/^\circ\text{C}$	p/kPa
5 ± 1	224 ± 3
13 ± 1	231 ± 3
22 ± 1	238 ± 3
35 ± 1	248 ± 3
44 ± 1	
53 ± 1	262 ± 3
62 ± 1	269 ± 3
70 ± 1	276 ± 3

- (a) Describe and explain how the students may have made accurate measurements of the temperature θ .

.....

.....

..... [2]

- (b) Fig. 17.2 shows the pressure gauge. Measurements of p can be made using the kPa scale or the psi (pounds per square inch) scale. The students used the psi scale to measure pressure and then converted the reading to pressure in kPa.



Fig. 17.2

- (i) Suggest why it was sensible to use the psi scale to measure p .

.....
 [1]

- (ii) The students made a reading of p of 37.0 ± 0.5 psi when θ was $44 \pm 1^\circ\text{C}$. Convert this value of p from psi to kPa. Complete the table for the missing value of p . Include the absolute uncertainty in p .

1 pound of force = 4.448 N
 1 inch = 0.0254 m

[2]

(c) Fig. 17.3 shows the graph of p against θ .

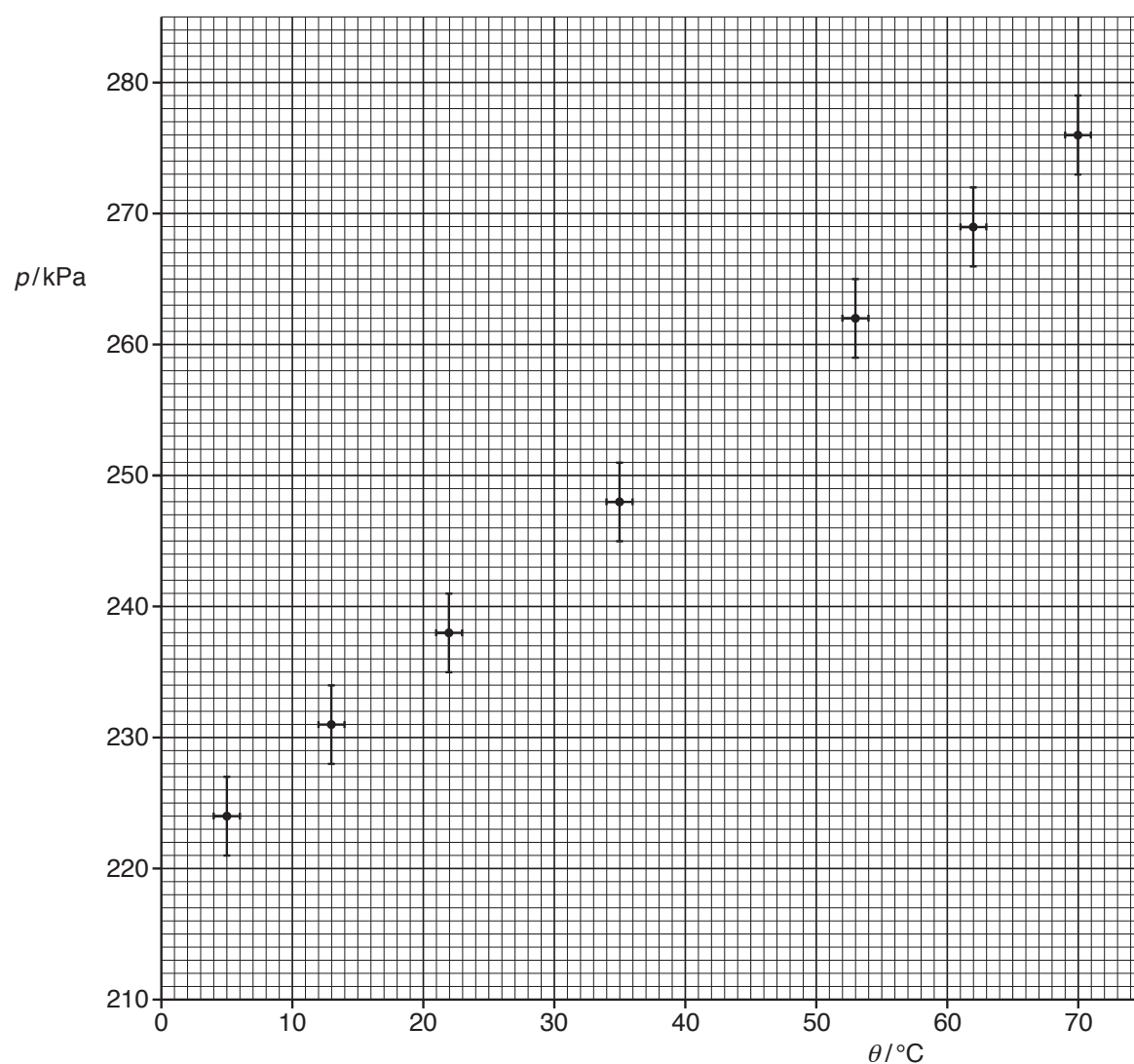


Fig. 17.3

(i) Plot the missing data point and the error bars on Fig. 17.3.

[1]

- (d) Describe, without doing any calculations, how you could use Fig. 17.3 to determine the actual uncertainty in the value of absolute zero in (c)(ii).

.....
.....
.....
..... [2]

- (e) The experiment is repeated as the water bath quickly cools from 70 °C to 5 °C. Absolute zero was found to be –390 °C.

Compare this value with your value from (c)(ii) and explain why the values may differ. Describe an experimental approach that could be taken to avoid systematic error in the determination of absolute zero.

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
..... [4]

- 6 A 3D printer can manufacture small objects.

Some 3D printers use polylactic acid (PLA). PLA is supplied in the form of long filaments. The 3D printer melts the PLA and builds up the shape of the desired object in layers.

The electrical supply to the heater in the printer has an e.m.f., $\mathcal{E}$, of 12 V. The power of the heater is 40 W.

- (a) Calculate the resistance, R , of the heater.

$$R = \dots\dots\dots \Omega \text{ [2]}$$

- (b) The specific latent heat of fusion of PLA is $9.4 \times 10^4 \text{ J kg}^{-1}$ and its melting point is 160°C .

- (i) Define **specific latent heat of fusion**.

.....

 [1]

- (ii) Calculate the **maximum** mass m of PLA that the heater could melt in one minute.

$$m = \dots\dots\dots \text{ kg [2]}$$

- (iii) Explain why the printing process is slower in practice than your answer to (ii) suggests.

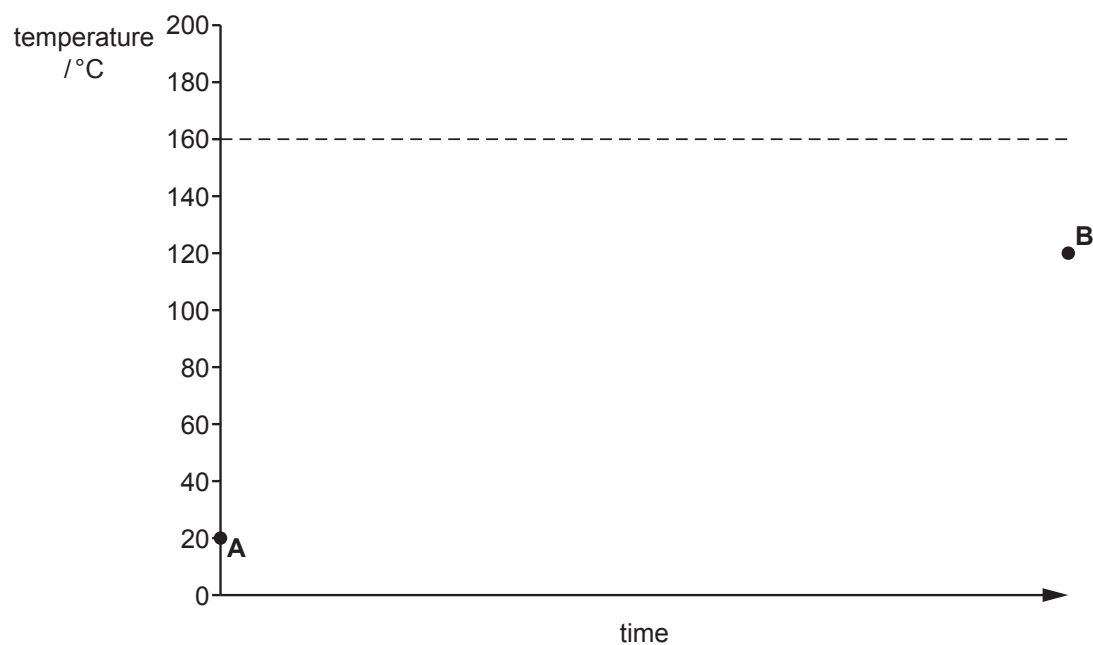
.....

 [2]

(iv) Fig. 6.1 shows the initial and final temperature of the PLA during the printing process.

Initially (point **A**), the solid PLA is at 20 °C and is just entering the heater. Later (point **B**), the PLA has been added to the object and is solid again.

Fig. 6.1



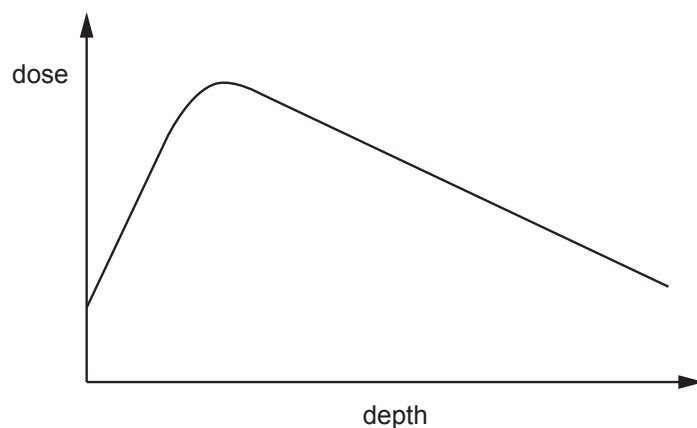
Complete Fig. 6.1 to show how the temperature of the PLA changes between **A** and **B**. You are **not** required to label the time axis. [3]

- (c) High-energy X-ray photons can destroy living cells. In radiotherapy, these photons are targeted at cancer cells.

The radiation **dose** is the amount of energy that a patient's body absorbs from the high-energy X-ray photons.

Fig. 6.2 shows how this dose changes with depth below the surface of the skin.

Fig. 6.2



The dose initially rises with depth because the high-energy X-ray photons produce electrons and positrons as they pass through the body. These electrons and positrons are quickly absorbed, increasing the dose.

- (i) Explain why high-energy X-ray photons produce electrons **and** positrons as they pass through the body.

.....

.....

.....

..... [2]

- *(ii) A 3D object called a **bolus** is used in radiotherapy for patients with skin cancer. A bolus targets the maximum radiation dose near the surface of the skin. So using a bolus makes the radiotherapy more effective.

A bolus can be made from PLA using a 3D printer. The bolus must fit the shape of the patient's body exactly. This shape is found beforehand by giving the patient either a CAT scan or a PET scan.

- Explain how CAT scans and PET scans work.
- Discuss the advantages and disadvantages of having a scan to produce a bolus for radiotherapy.

[6]

Additional answer space if required

.....

.....

.....



.....

.....

.....

.....

.....

.....

.....

.....

.....

.....



MARK SCHEMES

official OCR mark schemes



7	B	1	
----------	----------	----------	--



14	C		1	
----	---	--	---	--



3	A		1	
----------	----------	--	----------	--



6	B	1	
---	---	---	--



14	D		1	
----	---	--	---	--



9	C	1	
---	---	---	--



15	A	1	
	Total	15	

7

SECTION B

General rule: For substitution into an equation, allow any subject – unless stated otherwise in the guidance

Question	Answer	Marks	Guidance
----------	--------	-------	----------



4	B	1	
----------	----------	----------	--



9	D	1	
---	---	---	--



7	D		1	
---	---	--	---	--



8	A		1	
---	---	--	---	--



9	C		1	
---	---	--	---	--



10	C	1	
----	---	---	--



1	D	1	
---	---	---	--



2	C		1	
---	---	--	---	--



1	D	1	
----------	----------	----------	--



2	C	1	
-	-	-	



22	(a)		The sum of (the random distribution of) the KE and PE of (its) molecules	B1	Not if no clear indication of particulate nature, i.e. allow particles or atoms for molecules
	(b)		No change in KE because temperature is constant (during melting) PE of (the molecules) increases (during melting) The internal energy increases	M1 A1 M1 A1	Allow 'KE is not changing' Not 'KE is not increasing' Note: This A1 mark can only be scored if both M1 marks have been awarded.
			Total	5	



20	(a)	power $\times$ time = $2200 \times 4.0 \times 60$ energy = 5.3×10^5 (J)	C1 A1	Note: Answer to 3 s.f. is 5.28×10^5 (J)
	(b)	Energy used to heat water to 100°C = $0.60 \times 4200 \times 80$ (= 201.6 kJ) Energy remaining to vaporise water = 528 (kJ) – 201.6 (kJ) (= 326.4 (kJ)) mass vaporised = $326.4 \times 10^3 / 2.3 \times 10^6 = 0.1419$ (kg) mass of water left = $0.60 - 0.1419$ mass of water left = 0.46 (kg)	C1 C1 C1 A1	Possible ecf from (a)
		Total	6	

20	(a)		7.1 or 7.2	B1	2sf answer required
	(b)		Correct plotting at (7.2, 250) within half a small square Straight line of best fit with balanced spread of points either side of the line.	B1 B1	ECF allowed from (a)
	(c)		Relationship - s.h.c is directly proportional to the number of particles per unit mass Explanation Any three from: - Straight line through the origin - s.h.c. is the energy required to increase temperature of unit mass by unit temperature - Increasing temperature requires increasing <u>KE</u> of particles - More particles (per unit mass) will therefore require more energy	B1 B1 B1 B1	Do not allow inversely proportional to molar mass Allow equation with correct constant (3.4×10^{-23}) Allow 'kg' for 'unit mass' and 'degree or kelvin' for 'unit temperature' Allow equation with terms defined Allow both number of particles and required energy are both directly proportional to mass
			TOTAL	7	

23	(a)*	Level 3 (5–6 marks) Correct calculations for radius and temperature range or distance or intensity for Earth-like temperature within given distance range, with clear explanation. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Radius calculated or at least one temperature of planet calculated and some explanation. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Some explanation and an attempt at least one calculation. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1× 6 Use level of response annotation in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks etc. Indicative scientific points may include: Explanation • TRAPPIST-1 is cooler than the Sun • The planets are closer to TRAPPIST-1 • Possible for temperature on planets to be like Earth • For life to exist, temperature is not the only factor • $L = 4\pi r^2 \sigma T^4$ (Any subject) Calculations • Calculation of 'constant' for Earth: $4(.19) \times 10^5$ • For inner-most planet, $T = 430$ K • For outer-most planet, $T = 180$ K • Calculation of distance for $T = 290$ K, i.e. 3.4×10^9 (m) • There must therefore be a planet with temperature similar to that of the Earth • $L = 4\pi r^2 \sigma T^4$ used to calculate radius of TRAPPIST-1 • Radius of TRAPPIST-1 is 8.5×10^7 (m) or L/T^4 is smaller for TRAPPIST-1 • Comparison of calculated intensities at extreme distances around TRAPPIST-1 to intensity at Earth
----	------	--	--

Question			Answer	Marks	Guidance
	(b)	(i)	$T^2 = \frac{4\pi^2}{GM} r^3$	B1	
		(ii)	$86400^2 = (4\pi^2/6.0 \times 10^{24} \times 6.67 \times 10^{-11}) r^3$ (Any subject) radius = 4.23×10^7 (m)	C1 A1	
			Total	9	



Question	Answer	Marks	Guidance
----------	--------	-------	----------



1	(a)		$\lambda = \frac{v}{f} \left(= \frac{340}{262} \right)$ $\lambda = 2L$ $(L =) \frac{1.30}{2} = 0.65 \text{ (m)}$	B1 Formula may be implied by substitution Allow c for v B1 Relationship may be inferred from a correct diagram of fundamental drawn in a tube open at both ends, or from a statement such as 'half a wavelength fits inside the tube' B1 Some working leading to correct answer must be shown; don't accept a bald answer Allow $L = 0.649$ (0.64885) as evidence of working Do not allow working backwards from the answer
	(b)	(i)	Any two from - particles occupy negligible volume (compared to volume of container/gas) - collisions are (perfectly) elastic - time of collisions is negligible (compared to the time between collisions) - negligible <u>forces</u> exist between particles (except during collisions)	B1 × 2 Mark as for Short Answer Questions (requiring only a list by way of a response) and contradictory responses see page 3. Allow zero / no / none for negligible throughout Ignore particles occupy negligible space Ignore particles are very small Allow <u>kinetic</u> energy is conserved (during collisions) Allow the particles move at constant velocity (in between collisions) Ignore type of force if specified

Question			Answer	Mark	Guidance
			$\frac{f_1}{f_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1} \right)^{1/2} \text{ or } \frac{v_1}{v_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1} \right)^{1/2}$ $T = 263 \text{ (K)}$ $\left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1} \right)^{1/2} = \left(\frac{1.67 \times 263 \times 29}{1.4 \times 293 \times 4} \right)^{1/2}$ $= 2.786$ $f (= 2.786 \times 262) = 730 \text{ (Hz)}$	C1 C1 C1 A1	$T = -10 \text{ (K)}$ is XP onwards (first C1 mark can still be scored) but allow ECF for incorrect conversion of T This C1 mark is for substitution and the ratio 2.786 does not need to be calculated for the mark The values for M may be given in kg/mol or left in g/mol as long as there is consistency Allow $M = 4$ to 1sf Allow $f = 740 \text{ (Hz)}$ If using $\frac{v_1}{v_2}$ then $v = 2.786 \times 340 = 947$ giving $f (= v / \lambda = 947 / 1.3) = 730 \text{ (Hz)}$ but ECF candidate's own value of λ or L ($\lambda = 2L$) from 1a
			Total	9	

Question	Answer	Mark	Guidance
----------	--------	------	----------



19	(a)		Energy transfers from higher temperature to lower / AW	B1	Allow oxygen and surroundings are not in thermal equilibrium Allow idea that tank is cooler than the surroundings
	(b)		The potential energy (of the particles) is increasing	B1	Accept to provide latent heat
			The kinetic energy (of the particles) is constant	B1	'not increasing' is insufficient
	(c)		Energy transferred = 3600×1300 (= 4.68 MJ) / AW Mass vaporised = $4.68 \text{ MJ} \div 214\,000$ (=21.9 kg) /AW $V = 21.9 \div 1140$ seen and evaluated to 0.019(2) (m ³)	M1 M1 A1	Alternate $E = mL = \rho VL$ and $Pt = \rho VL$ (M1) $V = Pt \div \rho L = (1300 \times 3600) \div (1140 \times 214000)$ (M1) $V = 0.0192$ (A1) allow 0.019

Question		Answer	Mark	Guidance
	(d)	Volume occupied by gas= $0.2 + 0.019 = 0.22 \text{ m}^3$ $p = ((nRT)/V) = 710 \times 8.31 \times (-183+273) / 0.22$ $p = 2410 \text{ (kPa)}$	C1 C1 A1	Rearrangement and substitution NOTE: use of incorrect volume data in the question e.g, $V = 9.8 + 0.2 = 10$, $V = 9.8$ can still score this substitution and rearrangement mark but nothing else. No ECF. ECF incorrect addition or non-addition of volumes e.g use of either 0.2 or 0.02 or 0.019 for 2 marks. Treat incorrect conversion to kelvin as AE and allow ECF Non-conversion of temperature to kelvin is XP so cannot score second and third mark.
		TOTAL	9	

22	(a)	(i)	<u>KE</u> is conserved (as well as momentum)	B1	Allow: No <u>KE</u> lost
		(ii)	Attempt at conservation of momentum in x- or y- direction Correct expression of conservation of momentum in x- or y- direction / correct determination for velocity of Y of 55(3) m s⁻¹ $p = 3.7 \times 10^{-24} \text{ (kg m s}^{-1}\text{)}$	C1 Allow confusion of sin and cos at this stage Allow attempt at conservation of KE C1 Allow any subject e.g. $p \cos(25^\circ) + m \times 258 \cos(65^\circ) = m \times 610$ or $p \sin(25^\circ) = m \times 258 \sin(65^\circ)$ or $(p)^2 + (m \times 258)^2 = (m \times 610)^2$ or $\frac{1}{2} mv^2 + \frac{1}{2} m (258)^2 = \frac{1}{2} m (610)^2$ A1 Answer is $3.67 \times 10^{-24} \text{ (kg m s}^{-1}\text{)}$ to 3 sf	



Question	Answer	Marks	Guidance
(b)*	Level 3 (5–6 marks) Clear explanation and correct calculation. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some explanation and limited calculation, or limited explanation and correct calculation. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation and missing or incomplete calculation. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response (NR) or no response worthy of credit (0).	B1x6	Indicative scientific points may include: Explanation - At a certain temperature all atoms have the same <u>average</u> kinetic energy - Helium behaves as an ideal gas $E_K = \frac{3}{2} kT$ - Mean / r.m.s speed of atoms is less than the escape velocity - Atoms have range of speeds / velocity or mention of Maxwell-Boltzmann distribution - Faster atoms have escaped the Earth (over long period of time) - Earth was significantly hotter in the (ancient) past Calculation $T = 283 \text{ K}$ $\frac{1}{2} m \overline{c^2} = \frac{3}{2} kT$ $c_{r.m.s.} = \sqrt{\frac{3kT}{m}}$ $c_{r.m.s.} = 1.3 \text{ km s}^{-1}$
	Total	10	



3	(a)	(i)	$L (= 4\pi r^2 \sigma T^4) = 4 \times \pi \times (7.0 \times 10^8)^2 \times 5.67 \times 10^{-8} \times 5800^4$ $L = 3.95 \times 10^{26} \text{ (W)}$	M1 A0	Mark is for substitution of values Allow σ for 5.67×10^{-8}
		(ii)	By ratios: $25 = 1.7^2 \times (T/5800)^4$ $T^4 = 9.8 \times 10^{15}$ $T = 9950 \text{ (K)}$	C1 C1 A1	or $T^4 = \frac{25L/4\pi\sigma(1.7r)^2}{4\pi \times 5.67 \times 10^{-8} \times (1.7 \times 7 \times 10^8)^2}$ $= \frac{25 \times 3.95 \times 10^{26}}{4\pi \times 5.67 \times 10^{-8} \times (1.7 \times 7 \times 10^8)^2}$ ECF for L in a(i) but only if $L = 4 \times 10^{26}$ to 1s.f. ECF for incorrect σ in a(i) Allow 9.9×10^{15} (using $L = 4 \times 10^{26}$) Allow 10,000 K
	(b)		see next page	B1 x 6	
			Total	10	

H556/03

Mark Scheme

November 2020

Question			Answer	Marks	Guidance
3	(b)	*	Level 3 (5 - 6 marks) Clear expansion of three statements <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear expansion of two statements or Limited attempt at all three <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited attempt at one or two statements <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: statement 1 • fusion reactions are occurring • which change H into He • and mass is lost which releases energy • energy released = $c^2\Delta m$ • Δm per second = luminosity / c^2 statement 2 • average k.e. of each proton is $\frac{3}{2}kT$ • high T means protons are travelling at high speed • so fast enough to overcome repulsive forces • and get close enough to fuse • p.e. = $e^2/4\pi\epsilon_0 r$ so T must be high enough for $\frac{3}{2}kT > e^2/4\pi\epsilon_0 r$ • r is approximately 3fm statement 3 • k.e. $\propto T$ so average energy at 10^7 K is only one thousandth of the average energy at 10^{10} K when protons might fuse • but M-B distribution applies so at the high energy end there will be a few p with enough energy • quantum tunnelling across potential barrier is possible • small probability of many favourable collisions to boost energy of p • 4 p must fuse to produce He; it is complicated process making probability of fusion much less • number of p in Sun is so huge that, even with such a small probability, 4×10^9 kg of p still interact s^{-1} • a larger probability means lifetime of the Sun would be shorter



H556/03

Mark Scheme

November 2020

Question	Answer	Marks	Guidance
----------	--------	-------	----------



23	(a)	(i)	$= 1 \div 0.00097$ $= 1000$ parsecs	A1	1030 to 3sf
		(ii)	$= 0.00097 \div 7.5 \times 10^{-3} (\times 100\%)$ $= 13\%$	C1 A1	NOT half of the precision here (reference specification) Accept 1 sig fig value 10% Unrounded answer is 12.93... %
	(b)	(i)	Use of $KE_{\text{mean}} = \frac{3}{2} kT = \frac{3}{2} \times k \times 4.0 \times 10^6$ $= \frac{3}{2} \times 1.38 \times 10^{-23} \times 4 \times 10^6$ $= 8.3 \times 10^{-17} \text{ J.}$	C1 A1	Allow k Unrounded answer is $8.28 \dots \times 10^{-17}$
		(ii)	$= -2.3 \times 10^{-16} + 8.3 \times 10^{-17}$ $= -1.5 \times 10^{-16} \text{ J.}$	B1	Allow use of 10^{-16} J from stem to give $-1.3 \times 10^{-16} \text{ J}$ Reject response without negative sign

Question			Answer	Mark	Guidance
		(iii)	selection of GMm/r Substitution of values for M, m and energy and rearrangement $3.2 \times 10^{10} \text{ m}$ e.g. $(-) \frac{GMm}{r} = (-) 1.5 \times 10^{-16}$ $r = \frac{6.67 \times 10^{-11} \times 1.1 \times 10^{31} \times 6.6 \times 10^{-27}}{1.5 \times 10^{-16}}$ $= 3.2 \times 10^{10} \text{ m}$	C1 C1 A1	Allow ECF from (b)(ii) NB Use of values in stem gives 3.7×10^{10}
		(iv)	Reference to Boltzmann distribution / AW OR Some particles will have greater kinetic energies / lower masses	B1	
			TOTAL	10	



16	(a)		Connect the <u>voltmeter</u> in parallel with the thermistor	B1	Allow correctly drawn on diagram Allow “across” for “in parallel with” Allow voltmeter in parallel with cell																
	(b)	(i)	Points plotted correctly, within ½ small square	B1																	
		(ii)	Smooth curve passing within 1 vertical small square of plotted points	C1	No credit for straight line If thick line drawn, all width of line must lie within 1 vertical small square																
	(c)		Current increases as temperature increases (and voltage is constant) Use of at least two sets of data to calculate resistance The resistance decreases, therefore it is ntc thermistor	B1 M1 A1	Accept standard symbols (T , I , θ etc) for variables in explanation <table><tr><td>Temp / °C</td><td>Resistance / kΩ</td></tr><tr><td>30</td><td>4.0</td></tr><tr><td>40</td><td>2.7</td></tr><tr><td>50</td><td>2.0</td></tr><tr><td>60</td><td>1.4</td></tr><tr><td>70</td><td>1.1</td></tr><tr><td>80</td><td>0.82</td></tr><tr><td>90</td><td>0.63</td></tr></table> Allow 1sf for resistance values from calculations Ignore POT error for M mark	Temp / °C	Resistance / kΩ	30	4.0	40	2.7	50	2.0	60	1.4	70	1.1	80	0.82	90	0.63
Temp / °C	Resistance / kΩ																				
30	4.0																				
40	2.7																				
50	2.0																				
60	1.4																				
70	1.1																				
80	0.82																				
90	0.63																				

Question		Answer	Mark	Guidance
16	(d)	In circuit 1, p.d. (across the thermistor) will remain (almost) constant (with varying temperature)	M1	Allow voltage for p.d.
		In circuit 2, p.d. (across the thermistor) will vary (with varying temperature)	M1	Allow variation of pd to be increase or decrease
		Hence, circuit 2 will be best to choose / circuit 1 is not suitable	A1	Both M marks required for A mark
		Correct potential divider argument OR explanation of operation of circuit	B1	e.g. Use of $V_{out} = V_{in} \times (R / R + 10\,000)$ / the ratio of the resistances will vary (with temperature) e.g. as the milk gets hotter, the rate of heating reduces B mark is for qualifying statement

21	(a)	(i)	$(pV = nRT)$ $100 \times 10^3 \times (0.46)^3 = n \times 8.31 \times (273 + 20)$ $n = 4.0$	C1 A1	Note $T = 20$ is XP Not 1 SF answer of 4 Note answer is 4.00 to 3SF
		(ii)	$\frac{100}{293} = \frac{p}{1573}$ or $p \times (0.46)^3 = n \times 8.31 \times 1573$ pressure = 540 (kPa)	C1 A1	Note $T = 1300$ is XP Allow use of correct, unrounded n
	(b)	(i)	$(p =) 6.6 \times 10^{-26} \times 990$ or $6.5(3) \times 10^{-23} \text{ (kg m s}^{-1}\text{)}$ $(\Delta p =) 2 \times 6.6 \times 10^{-26} \times 990$ $\Delta p = 1.3 \times 10^{-22} \text{ (kg m s}^{-1}\text{)}$	C1 A1	Ignore sign of answer
		(ii)1	$990/[2 \times 0.46] (= 1080)$	B1	
		(ii)2	$(F = \Delta p/\Delta t)$ $(F =) 1.3 \times 10^{-22} \times 1000$ $F = 1.3 \times 10^{-19} \text{ N}$	C1 A1	Possible ECF from (b)(i) Note 1080 would give $1.4 \times 10^{-19} \text{ (N)}$
		(iii)	Use of $p = F/A$ or pressure = (total) force/area Idea of multiplying by total number of atoms	B1 B1	Allow particles or molecules for atoms
			Total	11	

19	a		Kinetic energy of particles is constant and the potential energy increases. internal energy has increased (as the internal energy = KE + PE)	B1	
				B1	Allow internal energy of a gas is the kinetic energy of the particles Allow potential energy of particles in a liquid is negative/the potential energy has increased to zero
	b	i	$pV = nRT$ and $T = 296$ (K) $100 \times 10^3 \times 15 = n \times 8.31 \times 296$ $n = 610$ (mol)	C1 C1 A1	Note answer is 609.81559... Allow 1 mark for 7850; 23 used instead of 300 K
		ii	(mass = 610×0.028) = 17 (kg)	B1	Allow ecf from (b)(i) Expect $n=600,610,609(.8\dots)$
		iii	Reduce the pressure or increase the temperature (at which it is added)	B1	
		iv	The energy is transferred from the water vapour is equal to the energy gained by the liquid nitrogen $L_v = \frac{m_{H_2O} \times (L_{fusion\ H_2O} + L_{evaporation\ H_2O})}{m_{N_2}}$ $L_v = \frac{1.3 \times (334000 + 2260000)}{17}$ $L_v = 2.0 \times 10^5$ (J kg ⁻¹)	C1 C1 C1 A1	Allow use of only one of the specific latent heats of water at this stage e.g. $m_{N_2} \times L_{N_2} = m_{H_2O} \times L_{vaporisation\ H_2O}$ NOTE: this can be awarded across whole response Evidence of addition of both latent heats (of water) is required Note answer is 1.97×10^5 to 3 SF Note: 1 mark only for : answer using only fusion = 2.5 or 2.6×10^4 (J kg ⁻¹) answer using only vaporisation = 1.7×10^5 (J kg ⁻¹)
			Total	11	



17	(a)	(i)	Any THREE from: Atoms of metal vibrate (about fixed points) Water molecules have translational KE The motion of the water molecules is random Metal atoms and water molecules have the same KE	B1x3	Allow particles for atoms / molecules throughout Allow idea that water particles move past each other Not idea that the water molecules have more KE than metal atoms
		(ii)	$(E_{\text{heater}} =) 200 \times 10 \times 60$ or 120000 (J) $(E_{\text{water}} =) 0.5 \times 4200 \times 40$ or 84000 (J) (energy transferred = 120000 – 84000) energy transferred = 3.6×10^4 (J)	C1 C1 A1	

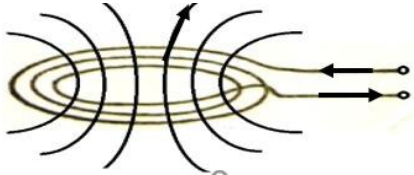
	(b)*	Level 3 (5–6 marks) Clear description and explanation and correct calculations leading to value of L_f <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear description and explanation or Correct calculations leading to value of L_f or Some description or explanation and some correct calculations <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or explanation or Limited calculations <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1×6	Indicative scientific points may include: Description and explanation • $m \propto t$ (for both) • Greater gradient for funnel with heater / greater rate of water from funnel with heater • Energy supplied to the ice is at a constant rate (for both beakers) • Idea that arrangement in Fig 17.2 is a control • Beaker in 17.2 heated just by surroundings / air / room • Arrangement in Fig. 17.1 gains energy from heater and surroundings / air / room Calculation • Gradient(s) calculated • $\Delta m = 45 \times 10^{-3} \text{ kg}$ • $\Delta E = mL_{(f)}$ • $\Delta E = 5 \times 12 \times 240 = 14400 \text{ J}$ • $L_{(f)} = 14400 / 45 \times 10^{-3} = 3.2 \times 10^5$ • Units: J kg^{-1} Note: $L_{(f)}$ can be calculated using $L_{(f)} = VI \div \Delta \text{gradient}$
		Total	12	

4	(a)	*	Level 3 (5 - 6 marks) Clear explanation using kinetic theory ideas and either a clear proof using formulae or a correct calculation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A partial explanation using kinetic theory ideas and either a partial proof using formulae or a partial calculation <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) An attempt at either explanation or proof or calculation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Indicative scientific points may include: Explanation using kinetic theory • pressure = force/area • force is caused by air molecules colliding with oven walls • Newton's 2nd Law states force = rate of momentum change • increased temperature means each molecule has greater KE • hence greater velocity and hence greater momentum • and more collisions with walls per second • hence greater rate of momentum change on hitting walls. • This would lead to greater pressure if N remained constant • so number of molecules in oven must decrease (air escapes) • so fewer but 'harder' collisions at higher temperatures giving constant pressure. • Rms velocity c increases with temperature but number N decreases and so effects balance out to keep total KE ($\frac{1}{2}Nmc^2$) constant Proof using formulae • equate $pV = NkT$ and $E = \frac{3}{2}NkT$ to show $E = \frac{3}{2}pV$ • in an ideal gas, all internal energy E is kinetic energy • so E is independent of temperature Calculation • Internal energy = $\frac{3}{2}pV = 1.5 \times 0.065 \times 1.0 \times 10^5 = 9.8 \text{ kJ}$ • At $T = 293\text{K}$, $N = pV/kT = 1.6 \times 10^{24}$ and $n = 2.7$ moles • At $T = 473\text{K}$, $N = 1.0 \times 10^{24}$ and $n = 1.7$ moles • so we can show that NT (and/or nT) remain constant
---	-----	---	--	--------	---

H556/03

Mark Scheme

October 2021

Question			Answer	Marks	Guidance
4	(b)	(i)		B1 B1	One correct line (or dot and cross) drawn Line must go through centre of coil Allow an incomplete line or a complete circle round the coil Ignore direction of arrow More than one line drawn All lines drawn must go through centre of coil and follow correct shape and <u>direction</u> of field Ignore spacing of lines Ignore any lines to the right of the coil
		(ii)	• (the magnetic) flux (of the coil) links the <u>base</u> / <u>saucepan</u> • (the size/direction of) the flux linkage (constantly) <u>changes/alternates</u> (causing an alternating induced e.m.f.) • (induced) <u>current</u> is large because metal/base/ saucepan has low resistance	B1 x 2	2 out of 3 possible marking points Allow (the magnetic) field lines cut the (base of the) <u>saucepan</u> Allow the (magnetic) field constantly changes/alternates Allow a bald statement of Faraday's Law
		(iii)	The resistance of glass-ceramic/the (cook's) hand is (very) large So (induced) <u>current</u> (or heating effect of <u>current</u>) is zero/negligible	M1 A1	Allow glass-ceramic/hand is an insulator/not a (good) conductor Do not allow the induced <u>e.m.f.</u> is (very) small
			Total	12	

9

H556/03

Mark Scheme

October 2021

Question	Answer	Marks	Guidance
----------	--------	-------	----------



21	a		Gravitational force	B1	Allow 'gravity'
	b	i	(diameter =) $6.4 \times 3.1 \times 10^{16}$ or 2.0×10^{17} (m) (volume =) $\frac{4}{3} \pi \times (9.9 \times 10^{16})^3$ (volume =) 4.1×10^{51} (m ³)	C1 C1 A0	Allow (radius =) $3.2 \times 3.1 \times 10^{16}$ or 9.9×10^{16} (m)
		ii	$(E = \frac{3}{2} kT) \frac{3}{2} \times 1.38 \times 10^{-23} \times 250$ or 5.2×10^{-21} (J) ($N =$) $1.0 \times 10^{12} \times 4.1 \times 10^{51}$ or 4.1×10^{63} ($E_k = 4.1 \times 10^{63} \times 5.2 \times 10^{-21}$) $E_k = 2.1 \times 10^{43}$ (J)	C1 C1 A1	
	c	i	Mass is proportional to volume or diameter ³ or radius ³ or $(\frac{6.4}{3})^3$ or $(\frac{3.2}{1.5})^3$ ratio = 9.7	C1 A1	Allow attempt at calculating volume of second nebula and comparing volumes directly Allow 9.76 (if volume divided by volume of Sun's nebula)
		ii	Fuel (hydrogen) runs out Super red giant star (Mass of core > Chandrasekhar limit /1.4 therefore) supernova neutron star or black hole (formed)	B1 B1 × 3	Note: incorrect order is CON Allow alternative route: Red giant formed (mass of star < 10 solar masses, therefore) planetary nebula (and) white dwarf formed
			Total	12	

Question	Answer	Marks	Guidance
1 *(a)	Level 3 (5–6 marks) Clear description and analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1 x 6	Indicative scientific points may include: Description - Determine R_0 using ice water mixture or* - Record V and I for various temperatures - If wire is not insulated some conduction through water/use insulated wire - Use small current to minimise heating effect or connect to supply for short time for readings - Stir the water - Wait for temperature to stabilise/bath to come to equilibrium - Avoid parallax errors when reading instruments - Comment about large scale increments on instruments/digital meters for precision of measurements/AW Analysis - Determine resistance from $R = V/I$ - Graph of R against θ is a straight line / Graph of R/R_0 against θ is a straight line - Correct interpretation of gradient m to find k; i.e. $k = m/R_0$ or $k = m$ *R_0 by extrapolation from linear graph *descriptors D1 and A4 are alternatives

Question			Answer	Marks	Guidance
	(b)	(i)	$R = V^2/P$ or $P = V^2/R$ $R = 230^2/1000 = 52.9$ or $53(\Omega)$	C1 A1	or $P = VI$ and $R = V/I$ with $I = 4.34$ (A) This is a 'show that' question so the A1 mark is for giving both the full substitution of values and the final answer. The final answer may be to 2 or more SF.
		(ii)	number of turns, $n = 180/1.5$ (= 120) length ($l = \pi dn$) = 3.14 (or π) $\times 0.014 \times 120 = 5.28$ (m)	C1 A1	This is a 'show that' question so the A1 mark is for giving both the full substitution of values and the final answer. The final answer may be to 2 or more SF.
		(iii)	$A = (\rho l/R) = 1.1 \times 10^{-6} \times 5.28/52.9$ $A = 0.11 \times 10^{-6} \text{ (m}^2\text{)}$ so swg = 28	M1 A1 A1	allow 53 allow solution which calculates diameter of wire using $\pi d^2/4$ rather than finding A give max 1/3 for using data from the table, i.e. finding $R = 53 \Omega$ using correct value of A or $d = 0.37$ (mm) the A marks cannot be awarded unless the M mark is awarded.
			Total	13	

Question	Answer	Marks	Guidance
----------	--------	-------	----------



21	(a)	Section AB Any <u>two</u> from • Particles close together • Particle spacing increase with increasing time or increasing temperature • Particles in a fixed structure/(regular) lattice • Particles vibrate/perform SHM • Particles vibrate with increasing amplitude (from A to B) Section CD Any <u>two</u> from • Particles close together /(slightly) further apart (than in AB) • No regular structure /AW • Particles (are free to) move around / move past each other / flow • Particles move with increasing speed from C to D / greater KE	B1 × 2 B1 × 2	Not: “vibrates more”
	(b)	$E = mc\Delta\theta$ (any subject) <u>and</u> gradient is larger for CD The specific heat capacity of the liquid is less than that of the solid.	M1 A1	ORA Allow: $\Delta\theta$ is larger for liquid in the same time interval or same energy supplied for “gradient” Allow $c \propto \text{gradient}^{-1}$ Not: $c = 1 / \text{gradient}$
	(c)	The sum of the (random) kinetic <u>and</u> potential energy of atoms or molecules in a substance	B1	Allow ‘particles’

Question			Answer	Marks	Guidance
	(d)	(i)	$\frac{1}{2} m c_{\text{RMS}}^2 = 3/2 kT$ $c_{\text{RMS}}^2 = 3 \times 1.38 \times 10^{-23} \times 523 / 4.8 \times 10^{-26}$ (Any subject) root mean square speed = 670 (m s ⁻¹)	C1 C1 A1	Allow this mark even when $T = 250$ is used subsequently Not 250°C Allow $c^2 = 4.5 \times 10^5$ Allow 2 marks for 4.5×10^5 ; mean square speed calculated Allow 1 mark for 464; no conversion to kelvin.
		(ii)	(number of molecules =) $1.3 \times 6.02 \times 10^{23}$ or 7.83×10^{23} mean KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 523$ or 1.08×10^{-20} total kinetic energy = 8.5×10^3 (J)	C1 C1 A1	Not 250°C Allow 8.4×10^3 for use of 670 m s ⁻¹ Allow full credit for use of total KE = $1.5nRT$ Allow full credit for use of E_k for one molecule = $\frac{1}{2} m c_{\text{RMS}}^2$ (which may include ECF for their c_{RMS} in (d)(i)) Allow 2 marks for $4.0(5\dots) \times 10^3$ (J) ; no conversion to kelvin.
			Total	13	

Question	Answer	Marks	Guidance
----------	--------	-------	----------



1	(a)	$n (= pV/RT) = 2.4 \times 10^5 \times 1.2 \times 10^{-3} / 8.31 \times \underline{290}$ $n = 0.12 \text{ (mol)}$	C1 A1	Allow any correct rearrangement of the equation Allow use of $pV = NkT$ and $n = Nk/R$ or $n = N/N_A$ $(n = 0.1195)$
	(b)	$pV = \text{constant (or } p_1V_1 = p_2V_2)$ $p_{\text{final}} = 2.4 \times 10^5 \times 1.2/1.5$ $= 1.9(2) \times 10^5 \text{ (Pa)}$	C1 C1 A1	<u>Alternative method:</u> $p = nRT/V$ (p must be the subject) Allow use of $p = NkT/V$ (with $N = 7.2 \times 10^{22}$ and $k = 1.38 \times 10^{-23}$) Substitute $p = 0.12 \times 8.31 \times 290 / 1.5 \times 10^{-3}$ ECF from 1a for incorrect n and/or T $p = 1.9(3) \times 10^5 \text{ (Pa)}$
	(c)	(i) $\Delta p = (2.4 - 1.0) \times 10^5 = 1.4 \times 10^5 \text{ (Pa)}$ upwards force ($= \Delta pA$) $= (2.4 - 1.0) \times 10^5 \times 1.1 \times 10^{-4}$ $= 15 \text{ (N)}$	C1 C1 A0	<u>Alternative method:</u> Downwards force (from trapped air) $= pA = 2.4 \times 10^5 \times 1.1 \times 10^{-4}$ $= 26.4 \text{ (N)}$ and upwards force (from atmosphere) $= pA = 1.0 \times 10^5 \times 1.1 \times 10^{-4} = 11.0 \text{ (N)}$ So total upwards force $= 26.4 - 11.0$ $= 15.4 \text{ (N)}$ Ignore any attempt to calculate weight Special case: Allow 1/2 for the use of $\Delta p = 2.4 \times 10^5 \text{ (Pa)}$ giving upwards force $= 26.4 \text{ (N)}$

H556/03			Mark Scheme		June 2019
Question		Answer	Marks	Guidance	
	(ii)	$m = 0.3 + 0.05 (= 0.35) \text{ (kg)}$ (Resultant force = upwards force – $W = ma$) $15.4 - (0.35 \times 9.81) = 0.35a$ or $a = 12/0.35$ $a = 34 \text{ (m s}^{-2}\text{)}$	C1 C1 A1	$0.050 + (10^3 \times 0.3 \times 10^{-3})$ <u>Alternative approach:</u> $a = (15.4/m) - g$ ECF for incorrect value of m No ECF ci (since we are told that upwards force = $15(.4)(N)$) Upwards force = 15 (N) gives $a = 33 \text{ (m s}^{-2}\text{)}$	
	(d)	• (initial) upward force unchanged • (initial) downwards force/weight increases • (initial) resultant force decreases • (initial) acceleration decreases • (initial) <u>rate of</u> change in momentum of rocket decreases • time taken to expel water increases • valid conclusion that the maximum height depends on more than one factor	B1 x 3	Maximum 3 marks from 7 marking points: Ignore comments which assume an increase in pressure Ignore heavier Allow net or unbalanced or total for resultant Allow fuel for water e.g. the height depends on the bottle's velocity and its height when all the water has been expelled / the height depends on both the acceleration and the time taken to expel the water	
		Total	13		

H556/03		Mark Scheme		June 2019
Question	Answer	Marks	Guidance	



4	(a)		There is no contact force between the astronaut and the (floor of the) space station (so no method of measuring / experiencing weight)	B1	Allow astronaut and the space station have same acceleration (towards Earth) / floor is falling (beneath astronaut)
	(b)	(i)	$M = 5.97 \times 10^{24}(\text{kg})$ or ISS orbital radius $R = 6.78 \times 10^6(\text{m})$ or $g \propto 1/r^2$ $(gr^2 = \text{constant so}) g \times (6.78 \times 10^6)^2 = 9.81 \times (6.37 \times 10^6)^2$ $g = 8.66 (\text{N kg}^{-1})$	C1 C1 A1	 or $g (= GM/R^2) = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / (6.78 \times 10^6)^2$ Allow rounding of final answer to 2 SF i.e. 8.7 (N kg ⁻¹)
		(ii)	$2\pi r/T = v$ or $T = 2 \times 3.14 \times 6.78 \times 10^6 / 7.7 \times 10^3$ $T = 5.5 \times 10^3 \text{ s } (= 92 \text{ min})$	M1 A1	ECF incorrect value of R from b(i)
	(c)		$\frac{1}{2}Mc^2 (\frac{1}{2}N_A mc^2) = \frac{3}{2}RT$ $c^2 = 3 \times 8.31 \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$ $\sqrt{c^2} = 500 (\text{m s}^{-1})$ $(= 7.7 \times 10^3 / 15)$	C1 C1 A1 A0	or $\frac{1}{2}mc^2 = \frac{3}{2}kT$ or $c^2 = 3kT/m$ or $c^2 = 3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$ not $(7.7 \times 10^3 / 15) = 510 (\text{m s}^{-1})$
	(d)		power reaching cells $(= IA) = 1.4 \times 10^3 \times 2500 = 3.5 \times 10^6 \text{ W}$ power absorbed $= 0.07 \times 3.5 \times 10^6 = 2.45 \times 10^5 \text{ W}$ cells in Sun for $(92 - 35 =) 57$ minutes average power $= 57/92 \times 2.45 \times 10^5 = 1.5 \times 10^5 (\text{W})$	C1 C1 C1 A1	 mark given for multiplication by 0.07 at any stage of calculation (90 – 35 =) 55 minutes using $T = 90$ minutes ECF value of T from b(ii) 55/90 $\times 2.45 \times 10^5 = 1.5 \times 10^5 (\text{W})$ using $T = 90$ minutes
			Total	13	

H556/03**Mark Scheme****November 2020**

Question	Answer	Marks	Guidance
----------	--------	-------	----------



18	(a)	(i)	(energy =) 150×7 or 1050 (J) $1050 = 0.025 \times c \times 20$ (c =) 2100 (J kg ⁻¹ K ⁻¹)	C1 C1 A1	Allow any correct re-arrangement
		(ii)	(energy=) $150 \times (63 - 7)$ or 8400 (J) $8400 = L_f \times 0.025$ (L_f =) 3.4×10^5 (J kg ⁻¹)	C1 A1	
	(b)	(iii)	Longer time to heat water (through the same temperature) / shorter time to heat (ice) through same temperature / gradient of graph is greater for ice / gradient of graph is smaller for water/AW Water has greater specific heat capacity	M1 A1	Allow calculation of gradients
		(i)	Molecules in X vibrate about fixed positions /AW Molecules in Z are free to move/random/AW	B1 B1	Allow references to ice for X and water / liquid for Z Allow one correct for B1 from: • Molecules in X have lower <u>KE</u>/speed/velocity • Speed/velocity of molecules increases with temp/time • Amplitude or frequency increases with temp/time in X

		(ii)	<table><tr><th>Region</th><th>Physical quantity, or quantities, that increase as time increases</th><th>Physical quantity, or quantities, that remain constant as time increases</th></tr><tr><td>X</td><td>K</td><td>P</td></tr><tr><td>Y</td><td>P</td><td>K</td></tr><tr><td>Z</td><td>K</td><td>P</td></tr></table>	Region	Physical quantity, or quantities, that increase as time increases	Physical quantity, or quantities, that remain constant as time increases	X	K	P	Y	P	K	Z	K	P	B1×3	Note that each B1 mark is for a correct row Allow KP/- for both X and Z
Region	Physical quantity, or quantities, that increase as time increases	Physical quantity, or quantities, that remain constant as time increases															
X	K	P															
Y	P	K															
Z	K	P															
		(iii)	Absolute zero / 0 <u>K</u> / - 273 <u>°C</u>	B1													
			Total	13													

20	a	i	Internal energy (of an ideal gas) is the sum of the (randomly distributed) kinetic energies of the particles	B1	Allow use of KE or E_k and atoms/molecules for particles. Ignore reference to PE (of particles)
		ii	evidence of $NkT = \frac{1}{3}Nm\overline{c^2}$ Manipulation to insert $\frac{1}{2}$ to give $\frac{1}{2}mc^2 = \frac{3}{2}kT$	M1 A1	
	b	i	(r.m.s. speed =) $\sqrt{\frac{310^2+370^2+440^2+550^2}{4}}$ r.m.s. speed evaluated as 427 (m s ⁻¹)	M1 A1	Not arithmetic mean 418. Treat as XP. Allow 729100 as evidence of summation of squares Allow mean squared speed = 182275 (m ² s ⁻²) Allow any candidate evaluation that rounds to or is 427 i.e. 426.93...
		ii	$\frac{1}{2}mc^2 = \frac{3}{2}kT$ $\frac{1}{2}m \times 430^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ (molar mass = $6.02 \times 10^{23} \times 6.49 \times 10^{-26}$) molar mass = 0.039 (kg mol ⁻¹)	C1 C1 A1	allow $\frac{1}{2}Mc^2 = \frac{3}{2}RT$ allow any valid rearrangement allow $\frac{1}{2}M \times 430^2 = \frac{3}{2} \times 8.31 \times 290$ allow $m = 6.5... \times 10^{-26}$ (kg) or $m = 6.7 \times 10^{-26}$ (kg) Using 427 m s ⁻¹ gives 0.0396 i.e. 0.040
	c	i	Energy transferred from electrical (energy) to internal (energy) or thermal (energy) of filament	B1	Allow power supply doing electrical work on filament



Question			Answer	Mark	Guidance
			Energy transferred from filament to internal energy of gas	B1	Allow heating of gas by conduction Allow description of Newton's Law of Cooling Allow heating of gas by radiation
			(because) the (rate of) energy lost to the surroundings = the (rate of) energy transfer gained (by filament)	B1	Allow reference to thermal equilibrium of any part or whole of lamp structure
		ii	$(P/T = \text{constant}) \frac{120}{2400} = \frac{p}{290}$	C1	
			pressure = 14.5 (kPa)	A1	Allow 15 Allow 14
			TOTAL	13	

Question	Answer	Mark	Comments
5	(i) sin or cos wave with 1.5 wavelengths (between C and R) y-axis showing scale ,i.e. (amplitude) 2.0×10^{-6} (m) correct scale on x-axis showing $\lambda = 0.2$ (m) X and Y labelled at adjacent intercepts on x-axis	B1 B1 B1 B1	unit must be present, e.g 10^{-6} m NOT if axis labelled time
	(ii)1 $v = A\omega$ or $2\pi fA$ $v = (2 \times 10^{-6} \times 2 \times 3.14 \times 1.7 \times 10^3 \Rightarrow) 2.1 \times 10^{-2}$ (m s ⁻¹ .) (ii)2 $\frac{1}{2}Mv^2 = \frac{3}{2}RT$ and $T = 290$ $v = \sqrt{(3 \times 8.31 \times 290/0.029)}$ $v = 5(.0) \times 10^2$ (m s ⁻¹ .)	C1 A1 C1 A1	 or $\frac{1}{2}mv^2 = \frac{3}{2}kT$ so $v^2 = 3 (k/m) 290$ N.B. remember to record a mark out of 4 here
	(b) see page 14	B1 x 6	
	Total	14	

Question		Answer	Marks	Guidance
5	(b)	Level 3 (5 - 6 marks) Clear description and explanation for both experiments and some discussion of uncertainty <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.</i> Level 2 (3 – 4 marks) Some description and explanation for both experiments or clear description and explanation for one experiment and some discussion of uncertainty <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited description and explanation for one experiment <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: Description and explanation Experiment (a) • Coherent signals/(sound) waves • Interference / superposition • Maximum signal / minimum signal • Idea of how wavelength is determined (e.g. distance between adjacent max positions = λ) • $v = f \times \lambda$ Experiment (b) • Stationary/standing wave produced • Superposition of waves travelling in opposite directions • Nodes / antinodes • Idea of how wavelength is determined (e.g. distance between adjacent nodes = $\lambda/2$) • $v = f \times \lambda$ Uncertainty • Measure multiples of λ • to reduce % uncertainty (by factor n) • move from minimum signal to minimum signal • so can increase sensitivity of scope to get better fix on each minimum position/ increase loudness from speaker • Lower frequency from signal generator • so increases λ with (%) uncertainty reduced • Do experiment outside • to reduce background reflections from room (so that sharper minima should be observed)

20	(a)		$pV=nRT$ mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	Not n=1 Not n=1
	(b)	(i)	$\rho = \frac{100,000 \times 0.029}{8.31 \times 293}$ =1.19 kg m ⁻³	M1 A0	Accept R for 8.31, T = 293.1(5) Reject 20 for T.
		(ii)	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	Accept all answers that round to 140 000 N, eg 140210, 141264
		(iii)	<u>Upthrust</u> = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified “Archimedes’ principle” Not water for fluid

Question			Answer	Mark	Guidance
		(iv)	Two from • (Greater pressure) would increase the density/mass/weight of the helium • (increased pressure but) no change in volume therefore no more upthrust. • If the volume goes up then the upthrust will increase / ORA • Pressure only needs to be large enough to inflate the gasbag • (increased pressure difference or volume) may cause structural failure • (higher pressure means) more collisions of helium atoms with walls so more leakage of helium	B1 x 2	

Question			Answer	Mark	Guidance
20	(c)	(i)	$F = ([\text{delta mass} \div \text{delta time}] \times \text{speed}) = 7.8 \times 45$ $= 350\text{N}$	C1 A1	reject 'F=ma = 7.8 x 45' score zero annotate XP
	(d)		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced. There is less drag/resistive force on the airship.	B1 B1	
			TOTAL	14	

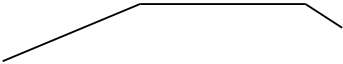


17	(a)		Use a thermometer (with $\pm 1^\circ\text{C}$) Stir water bath / avoid parallax (for glass thermometer)	B1 B1	Allow 'temperature sensor/gauge' Allow 'avoid touching sides of water bath with thermometer' Allow 'take temperature in several places/times and average' Allow idea of 'leave thermometer for long time (to reach thermal equilibrium)' Not idea of 'use thermometer with finer resolution'
	(b)	(i)	Smaller (spacing between) divisions / increments (AW)	B1	Ignore any reference to accuracy or precision Allow 'less uncertainty' Allow better or smaller or greater or higher resolution
		(ii)	$p = 37.0 \times 4.448 / (1000 \times 0.0254^2)$ 255 (kPa) uncertainty = 3 (kPa)	B1 B1	Allow clearly identified correct answer in table or in working area. Must be 3sf Must be 1sf Allow 255.1 ± 3.4 scores mark 1
	(c)	(i)	Point plotted at (44, 255)	B1	ECF from (b)(ii) Plot to with $\pm$ half a small square Ignore checking error bars

		(ii)* Level 3 (5–6 marks) Clear explanation, description and determination <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some explanation, description and determination Or Some explanation and clear determination <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation or description or determination <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1× 6	Indicative scientific points may include: Explanation and Description • Absolute zero is the minimum possible temperature / at absolute zero KE is zero • At absolute zero p is zero • At absolute zero, the internal energy is minimum (allow 0) • Absolute zero should be (about) $-273\text{ }^{\circ}\text{C}$ • Reference to $pV = nRT$ or $pV = NkT$ or $p \propto T$ • A graph of p against θ is a straight line / straight line drawn on graph • Intercept of straight line with x- axis or θ-axis is absolute zero calculated by using $y = mx + c$ Determination • Gradient in the range 0.7 to 0.9 (kPa K^{-1}) • $y = mx + c$ used to determine the intercept c or absolute zero • Absolute zero in the range $-320\text{ }^{\circ}\text{C}$ to $-240\text{ }^{\circ}\text{C}$ Use only L1, L2 and L3 in RM Assessor.
--	--	---	---------------------	--

	(d)	Draw the worst fit line (through all the error bars) (AW). Determine the new value for absolute zero and find the <u>difference</u> between the value in (c)(ii) and this new intercept. (AW)	B1 B1	
	(e)	Cooling gas value of absolute zero is lower than (c)(ii) (Whilst cooling, the) temperature of gas lags behind the temperature of water (AW, ORA) Graph is shifted to the left Stir water / <u>wait</u> for temperatures to be the same / attempt at measuring temperature of gas directly (AW)	B1 B1 B1 B1	Allow: gradient is too shallow Allow: p measured is higher than expected for incorrect measurement of T (so affects the graph) (AW, ORA) Not insulation of water bath Not heat losses
		Total	18	

6	(a)		$P = V^2 / R$ $R = 12^2 \div 40 =$ 3.6 (Ω)	C1 A1	Allow $I = P/V$ ($= 3.3A$) and $R = V/I$ Correct to at least 2sf
	(b)	(i)	Either (thermal/heat) energy required per unit mass to change solid to liquid <u>at constant temperature</u> or (thermal/heat) energy released per unit mass when liquid changes to solid <u>at constant temperature</u>	B1 (B1)	Ignore $L = E/m$ unless letters are defined Allow energy per kg /energy of 1kg for energy per unit mass Allow energy required to melt unit mass at constant temperature Allow energy released when unit mass solidifies at constant temperature
		(ii)	(Energy =) $Pt = mL$ $m = \frac{40 \times 60}{9.4 \times 10^4} =$ 2.6×10^{-2} (kg)	C1 A1	Allow $E = Pt$ and $E = mL$ seen separately Formulae may be implied from subsequent calculation Correct to at least 2sf 2.553×10^{-2} to 4sf so annotate 2.5×10^{-2} as AE

Question			Answer	Mark	Guidance
6	(b)	(iii)	Any two from - not all the heat / energy is used to melt the PLA or some heat / energy is 'lost' (to environment / surroundings) - some heat / energy / time is used to raise temperature of PLA up to or above its melting point / 160°C (PLA not all applied to same spot so) PLA needs (time) to move from one place to another - PLA needs (time) to solidify	B1 × 2	For environment, allow printer or any named part of printer (e.g. nozzle, print head, print bed, build plate, hot-end, cables) Allow energy transfer is not 100% efficient Not energy is lost through sound or light Not PLA needs time to melt
		(iv)	a single line (or curve) starting at A which gradually and continuously rises to 160°C followed by an initial flat section at 160°C after a flat section at 160°, the line (or curve) rises and then falls back to 160°C a second flat section at 160°C followed by a single line (or curve) which gradually and continuously falls, ending at B	B1 B1 B1	Note: this flat-topped shape gains the first and third marks 

Question			Answer	Mark	Guidance
6	(c)	(i)	Any two points from the following: (high-energy X-ray) photon interacts with nucleus / travels close to nucleus / disappears - Positron is the antiparticle of an electron - energy (of X-ray photon) is transformed into matter and antimatter - particle and antiparticle pair produced / (mechanism known as) pair production occurs	B1 x 2	Ignore references to scattering, Compton effect and photoelectric effect Not - atom instead of nucleus - approaches instead of travels close to - two photons annihilate - photon annihilates - electron and positron annihilate Allow photon is absorbed by nucleus Allow electrons and positrons are antiparticles (of each other) Allow energy (of photon) is transformed into mass Ignore electron positron pair (this is a rewording of the stem which states that X-ray photons produce electrons and positrons) Allow pair creation

6	(c)	*(ii) Level 3 (5–6 marks) Clear explanation of both scans and Clear discussion (compares the risks of either having a scan to fit a bolus or not, to a patient undergoing radiotherapy for skin cancer) <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Limited explanations of both scans or clear explanation of one scan and Basic discussion (e.g. compares the risks of one scan to the other) <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation for example • CAT scan only • PET scan only • both scans attempted but with several errors or Limited discussion (eg compares advantages and disadvantages of having a CAT scan) <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1 × 6 Use the annotations (for example) L2 for 4 marks, L2^ for 3 marks etc. Place the appropriate number of ticks below the annotation. Indicative scientific points may include: Explanation <u>CAT scan</u> • Thin fan-shaped beam of X-rays • Ring of detectors rotate around patient • Images of slices produced • Instruments move along patient to take several 2D images • Software produces 3D image <u>PET scan</u> • Positron-emitting tracer injected • Positron annihilates electron producing two gamma photons • Gamma photons travel in opposite directions • Ring of gamma detectors around patient • Delay time between arrival of photons locates annihilation • Software produces 3D image Discussion - balance of benefits and risks of having the scan • Both types of scan deliver radiation dose to healthy tissue but • a bolus would mean a lower dose is needed during radiotherapy • Both types of scan are expensive / use NHS resources • but radiotherapy also costly and less would be needed with bolus • Scans can be long / scary / cause discomfort • but the same is true of radiotherapy and less would be needed • Both types of scan are risky but with a bolus the • improved effectiveness of radiotherapy may save a patient's life
		Total	18

