2027.M35S1

2027L021G1ES1

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination
Sample 1

Physics

Ordinary Level

2 hours 30 minutes

300 marks

Examination Number

Date of Birth ☐☐/☐☐/☐☐

For example, 3rd February 2005 is entered as 03 02 05

Centre Stamp

Instructions

There are seven questions on this examination paper. Each question carries 50 marks.

Answer **Question 1** and any **five other** questions.

Write your Examination Number and your Day, Month and Year of Birth in the boxes on the front cover.

Write your answers in blue or black pen. You may use pencil for sketches, graphs and diagrams only.

This examination booklet will be scanned and your work will be presented to an examiner on screen. All of your work should be presented in the answer areas, or on the given graphs, or diagrams. Anything that you write outside of the answer areas may not be seen by the examiner.

You are not required to use all the space provided. There is space for extra work at the back of the booklet. If you need to use it, label any extra work clearly with the question number and part.

The superintendent will give you a copy of the *Formulae and Tables* booklet. You must return it at the end of the examination. You are not allowed to bring your own copy into the examination.

Data from the *Formulae and Tables* booklet, including but not limited to fundamental physical constants, particle physics data and electrical circuit symbols should be used wherever necessary.

You may lose marks if your solutions do not include relevant supporting work.

You may lose marks if the appropriate units of measurement are not included, where relevant.

Write the make and model of your calculator(s) here:

Question 1

(a) Waves are a way of transferring energy.

(i) Write one of the following labels in the box below to identify a type of electromagnetic radiation with a lower frequency than that of red light.

gamma rays **radio-waves** **ultraviolet** **X-rays**

(ii) Electromagnetic waves all travel at the same speed c in a vacuum. Using the *Formulae and Tables* booklet, or otherwise, state this value of c.
Round the value to four significant figures.

(iii) A mechanical wave has a frequency of 30 Hz and a wavelength of 900 m.
Estimate the speed of the wave by calculation or otherwise.

Draw a ✓ in one box only.

30 Hz ☐

30 m s^{-1} ☐

27 000 Hz ☐

27 000 m s^{-1} ☐

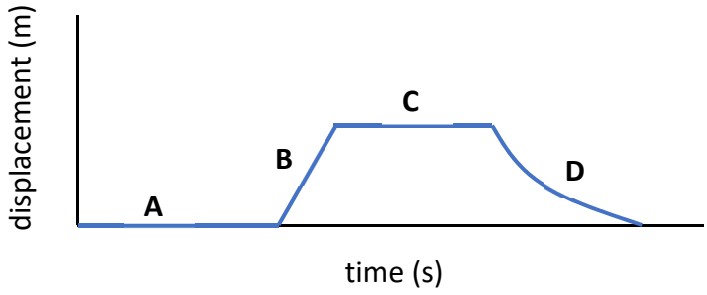
(b) Displacement–time graphs and velocity–time graphs are useful ways to model an object in motion.

(i) Are displacement and velocity examples of scalar or vector quantities?

Draw a ✓ in one box only.

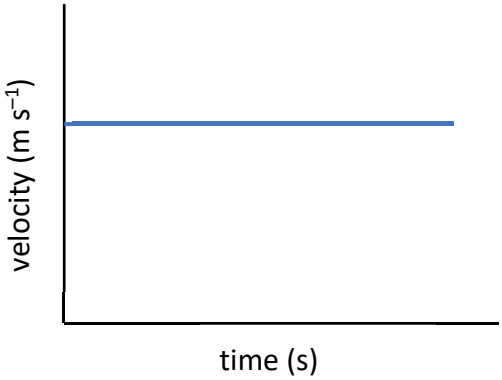
scalar quantities ☐ vector quantities ☐

(ii) Identify the section(s) of the displacement–time graph below that show an object moving with a constant velocity.
Circle one or more of the letters **A, B, C** and **D**.



(iii) Describe the motion of an object modelled by the velocity–time graph below.

Draw a ✓ in one box only.



constant velocity ☐

slowing down ☐

speeding up ☐

stopped ☐

(c) Explain what is meant by latent heat.

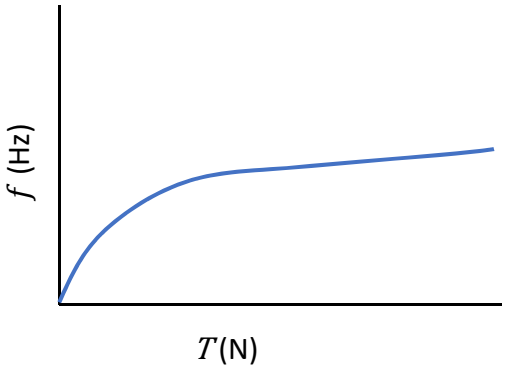
(d) **(i)** Draw a labelled diagram of the apparatus that you could use to verify the following mathematical model for the frequency f of a stretched string.

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

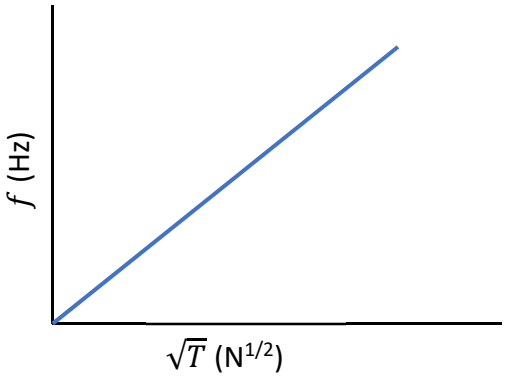
(ii) Identify, with reference to your diagram, how to determine a value for the frequency f and a value for the tension T.

A student drew the following two graphs.

A



B



(iii) The student wants to show that frequency is proportional to the square root of the tension, $f \propto \sqrt{T}$.

Which graph, **A** or **B,** would you advise the student to use? Justify your answer.

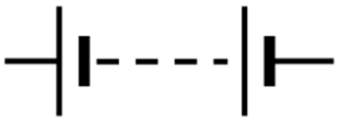
Draw a ✓ in one box only.

A ☐ **B** ☐

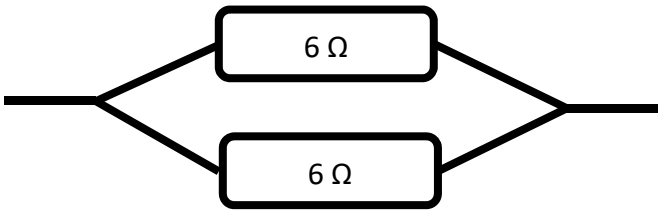
Justification

(e) A student builds a circuit to model resistances in parallel in a school laboratory.

(i) Indicate the battery's positive and negative ends by drawing on the circuit symbol.



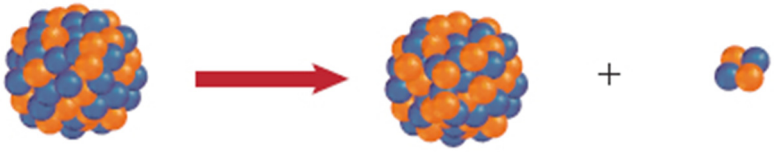
(ii) The diagram shows two resistors connected in parallel. Calculate the combined resistance.



(iii) Suggest a reason why a miniature circuit breaker (MCB) is not usually used when students build circuits in a school laboratory.

Question 2

(a) Radon–222 (Rn–222) is a naturally occurring radioactive gas which is colourless and odourless. A Rn–222 nucleus decays to Polonium (Po) by emitting an alpha particle.



Rn Po α

(i) Complete the following definition of radioactivity.

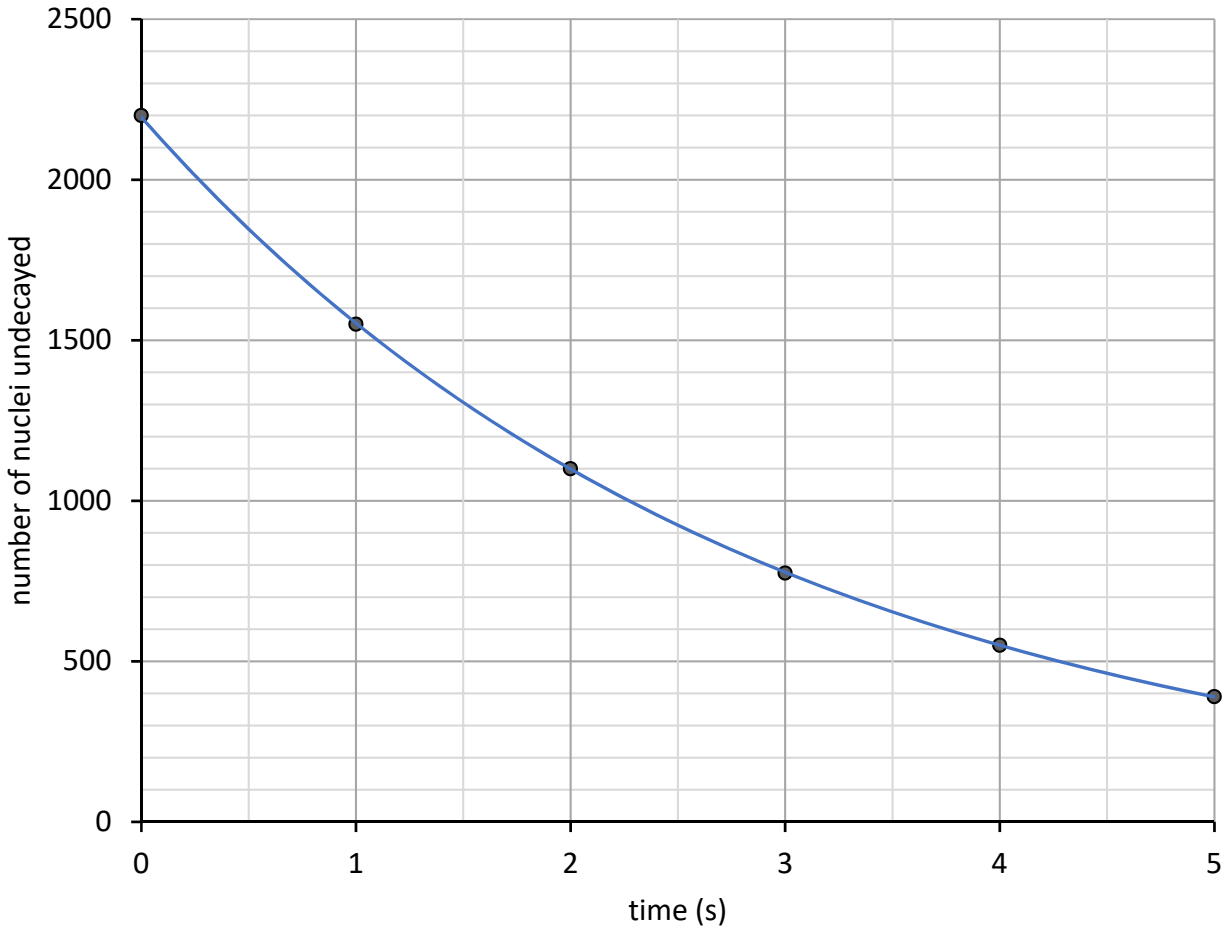
Radioactivity is the spontaneous emission of _____

from the _____ of an atom.

(ii) Use the periodic table on page 79 of the *Formulae and Tables booklet*, or otherwise, to complete the nuclear equation for the reaction.

$$^{222}_{\square}\text{Rn} \rightarrow {}^{\square}_{84}\text{Po} + {}^{\square}_{\square}\alpha$$

The graph below models radioactive decay.



(iii) Estimate the number of nuclei undecayed after 1.5 s.

(iv) Estimate the length of time it takes for half of the nuclei to decay.

Working with radioactive substances can be dangerous.

(v) State one safety precaution that you should take when working with radioactive substances.

(b) The Lightyear 0 is a partly solar-powered car. The car has a compact battery which can recharge each day thanks to the panels of photocells spread across its roof and bonnet.

(i) Fill in the spaces below to describe an energy conversion that takes place in a solar-powered car.

Energy before → Energy after

_____ → _____

(ii) Would you consider a car of this type to be a sustainable option? Justify your answer.

Answer

Justification

(iii) The total power from the Sun incident on an area of 5 m^2 of the panels is 2740 W.

(a) Calculate the solar irradiance on the panels.

(b) The efficiency of the panels is 20%.
Calculate how much energy in total is available for use in one second.

When the brakes are applied, the kinetic energy of the car is converted to electrical energy in a generator.
The electrical energy produced by a generator can be calculated using the following formula.

$$\text{energy} = \text{voltage} \times \text{current} \times \text{time}$$

A voltage of 900 V causes a current of 40 A to flow for 10 seconds.

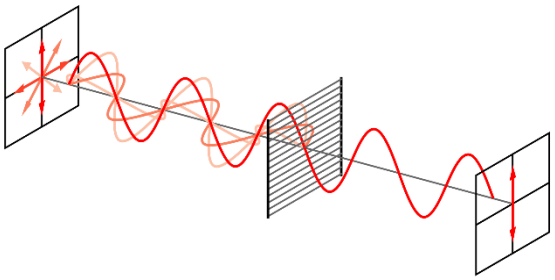
(iv) Calculate the electrical energy produced.

(v) Describe one difference between a DC generator and an AC generator.

A labelled diagram may help your answer.

Question 3

Luminous objects, from lamps to stars, are objects that give off light waves. These light waves vibrate in different planes. This jumble of waves is known as unpolarised light. Polarised light, on the other hand, is unjumbled, its waves all vibrate in the same plane.



Polarisation is the process of turning unpolarised light into polarised light. Light can be polarised because it is a transverse wave. There are a few ways this can happen.

Light can become polarised when it is reflected off a surface.

Another way to polarise light is to pass it through a polarising filter. This only allows light waves vibrating in specific planes to pass through. For example, some sunglasses contain polarising filters that help reduce the amount of reflected light (glare) that reaches a wearer's eyes.

Light can also become polarised when it undergoes refraction.

adapted from an article at snexplores.org

(i) Explain what is meant by a luminous object.

Waves are classified as transverse or longitudinal.

(ii) Is light an example of a transverse wave or a longitudinal wave?

Draw a ✓ in one box only.

longitudinal ☐ transverse ☐

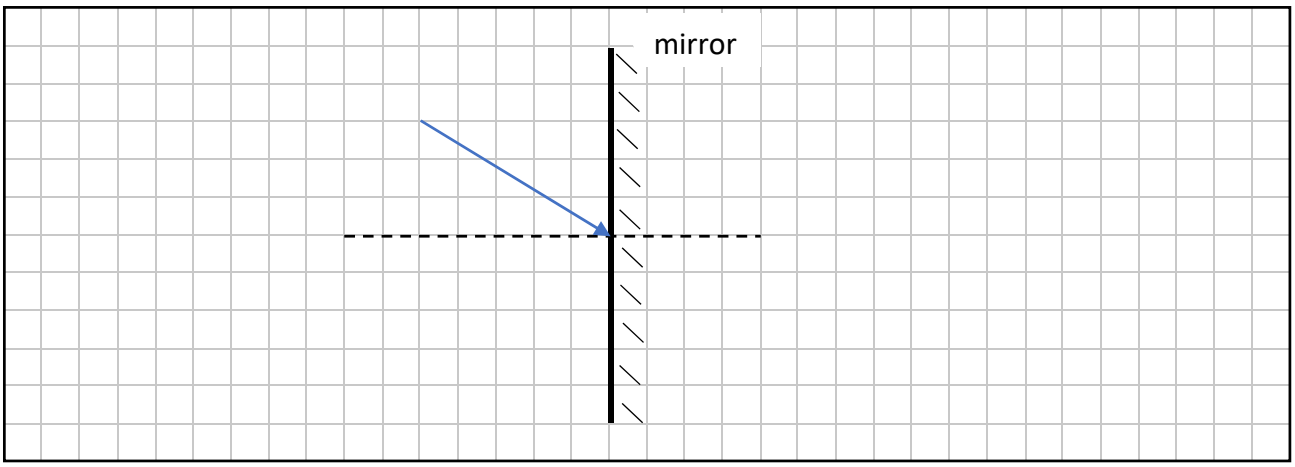
(iii) Light waves can be polarised. Can all waves be polarised? Justify your answer.

Answer

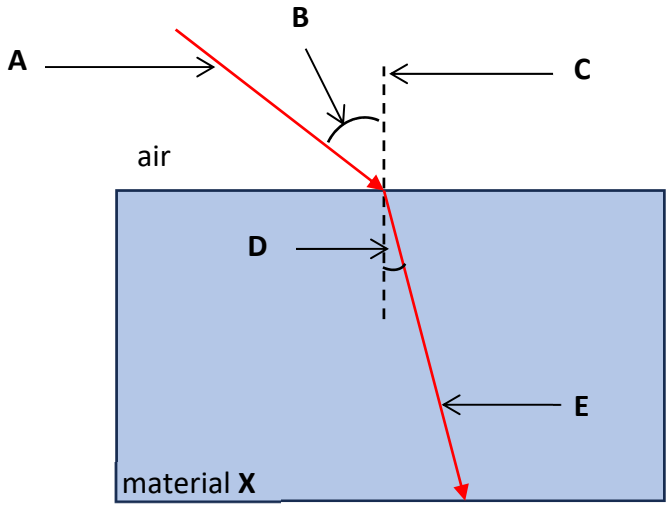
Justification

(iv) Light waves can be polarised by reflection. Explain what is meant by reflection.

(v) Complete the diagram below by drawing the reflected ray.



(vi) Light waves can also be polarised by refraction. The diagram below models refraction through a material **X**. Match the letters **A**, **B**, **C**, **D** and **E** to the descriptions in the table.



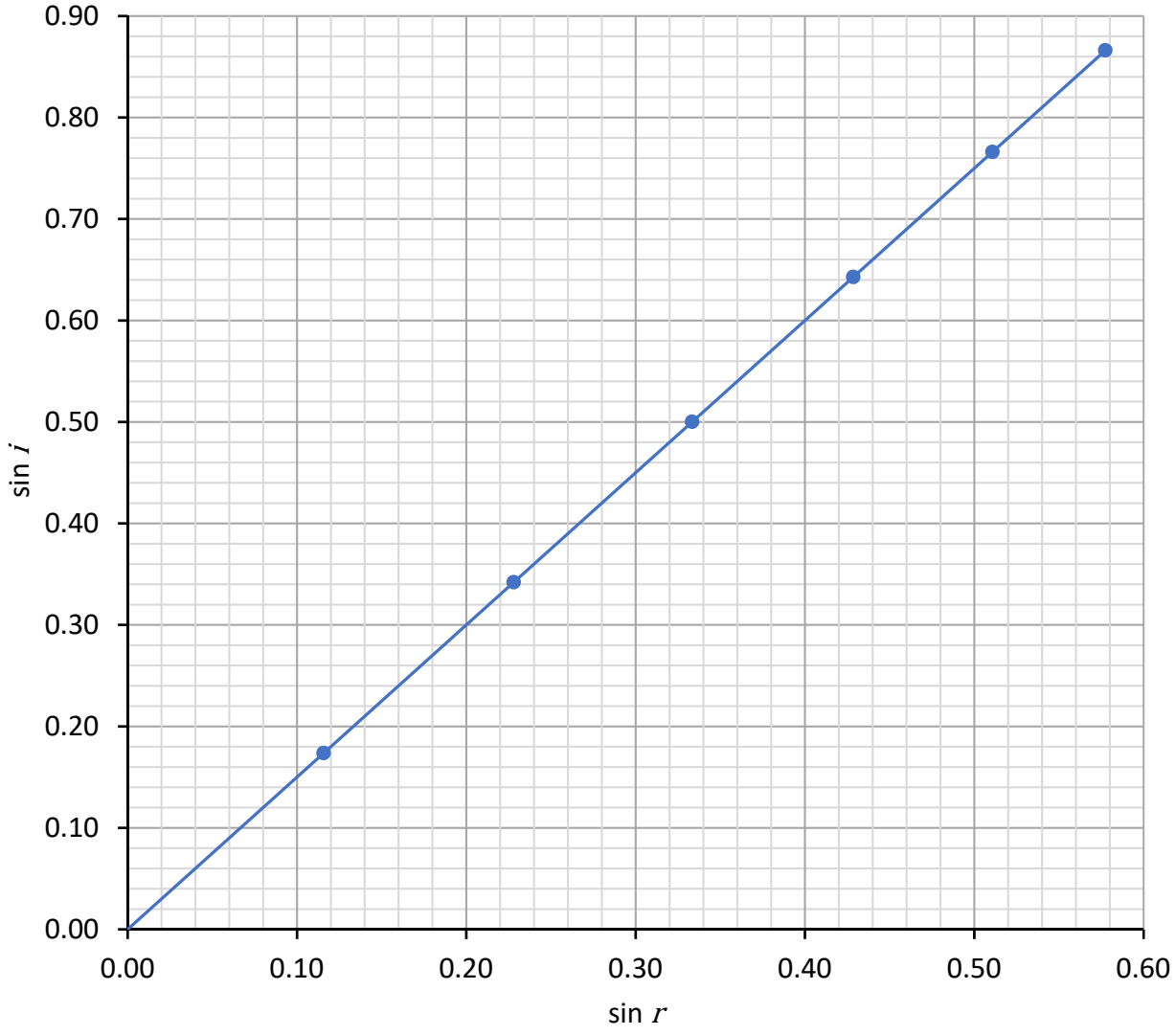
Descriptions	**A, B, C, D or E**
incident ray	
refracted ray	
normal	
angle of incidence	
angle of refraction	

Refraction of light is modelled by Snell's law. Snell's law states that $\frac{\sin i}{\sin r} = n$, where n is the refractive index. A student carries out an experiment to investigate Snell's law and the refractive index of material **X**.

The student gathered the following data.

sin i	0.17	0.34	0.50	0.64	0.77	0.87
sin r	0.12	0.23	0.33	0.43	0.51	0.58

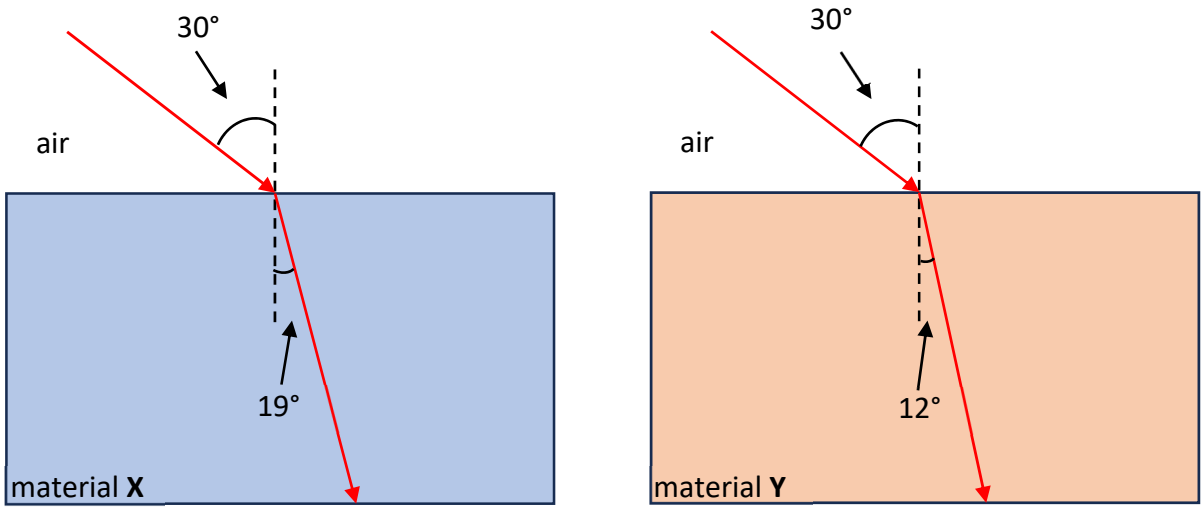
Below is the student's graph of sin i against sin r.



(vii) State the relationship between sin i and sin r.

(viii) Calculate an average value for the refractive index n using either the table or the graph.

This diagram shows material **X** alongside another material.



(ix) Predict which material has the greater refractive index. Justify your answer.

Draw a ✓ in one box only.

material **X** ☐ material **Y** ☐

Justification

Question 4

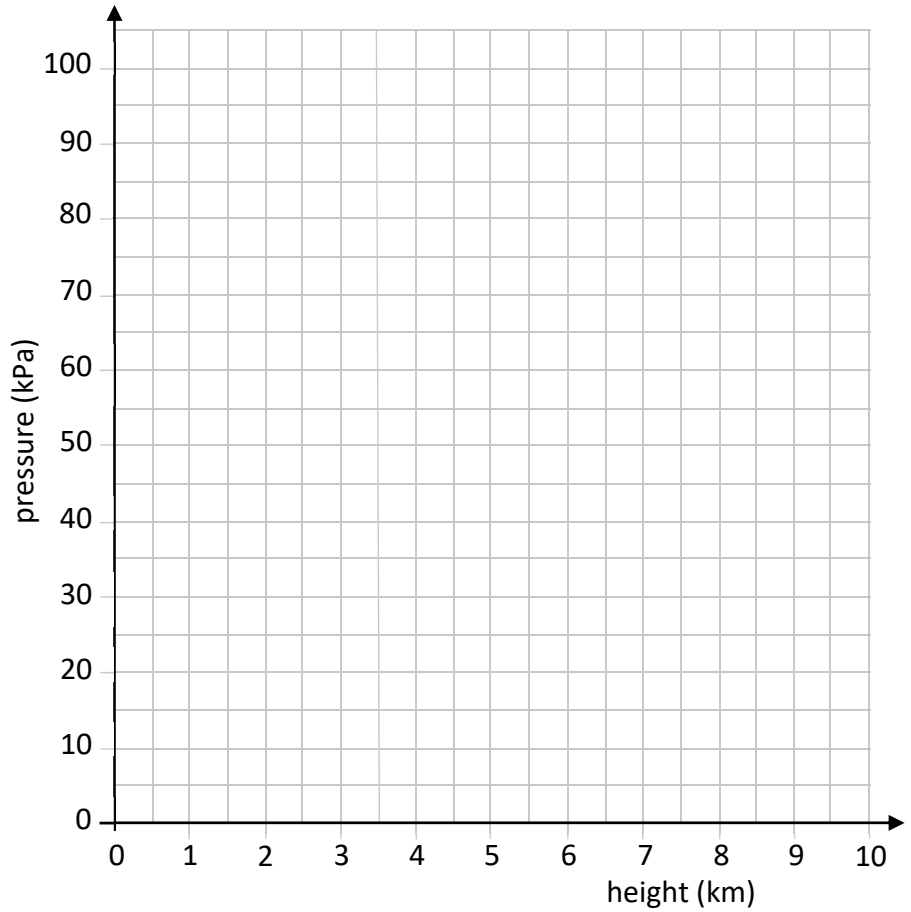
The atmosphere is a mixture of gases that extends from sea level up to a height of several hundred kilometres. This creates the phenomenon we call atmospheric pressure. Atmospheric pressure values change continuously giving us our constantly changing weather.

A student conducted research into atmospheric pressure values and found the following data for atmospheric pressure at different heights.

height (km)	0	2	4	6	8	10
pressure (kPa)	101.3	79.5	61.6	47.1	35.6	26.4

Küpper, Milledge, et al 2015

(i) Draw a graph to show the relationship between atmospheric pressure and height.



(ii) K2 is the world's second highest mountain. The atmospheric pressure at the top of K2 is 32 kPa.

Use your graph to estimate the height of K2.

height of K2 = _____ km

A mercury barometer is a device that measures atmospheric pressure.

To determine a value for atmospheric pressure p_{atm}, the height $h_{mercury}$ of a column of mercury can be calculated using the following formula.

$$p_{atm} = \rho\, g\, h_{mercury}$$

(iii) Fill in the blank spaces in the table below to identify the quantity and unit of measure for each symbol in this formula.

symbol	quantity name	unit
p_{atm}	atmospheric pressure	
ρ		
g		
$h_{mercury}$	height of the column of mercury	

(iv) At sea level, the average height of the column of mercury is 760 mm.
Convert 760 mm to metres.

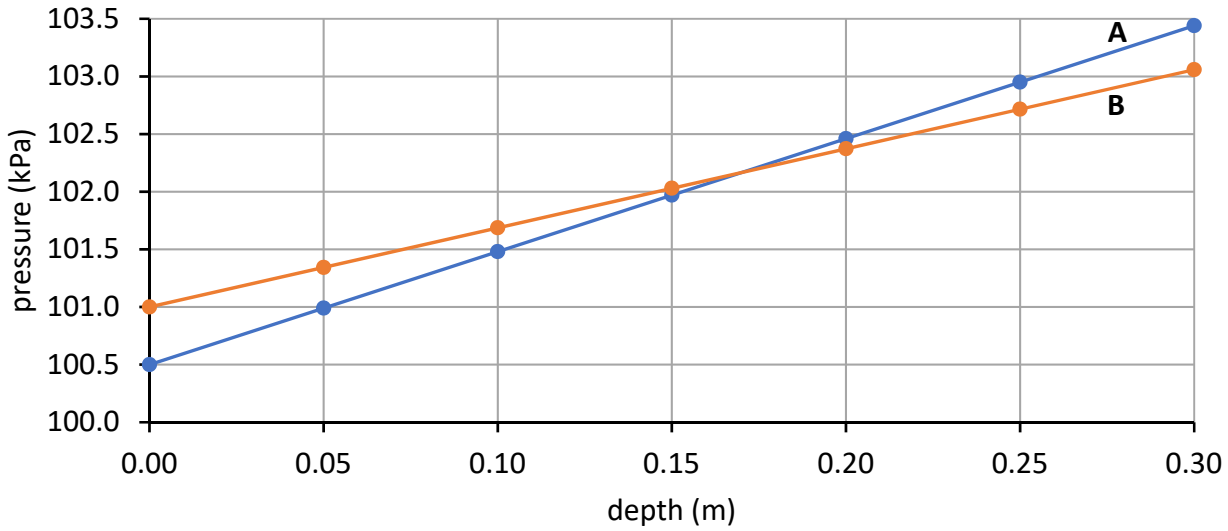
(v) Use the formula to calculate atmospheric pressure p_{atm}, at sea level.
density of mercury = 13 546 kg m^{-3}; acceleration due to gravity = 9.8 m s^{-2}

(vi) Calculate $h_{mercury}$ if the barometer reads an atmospheric pressure of 32 kPa.

Climbers have discovered that black tea does not brew well at rest points high in the mountains due to the lower boiling point of water.

(vii) Pose a testable hypothesis to explain this lower boiling point.

The change in pressure with depth in a liquid can be demonstrated by lowering a pressure sensor into a tall graduated cylinder of the liquid. Using this technique, data were collected for water and for a less dense liquid.
The graph below represents the data collected.



(viii) Predict which of the lines represents the data collected for the less dense liquid.
Draw a ✓ in one box only.

line **A** ☐ line **B** ☐

Pressure at a depth in a liquid is due to both the pressure of the liquid and the pressure of the atmosphere, at a given time, acting on the surface of the liquid.
The intercepts on the pressure axis, when the depth is 0 m, are equal to the atmospheric pressure.

(ix) Analyse the data to determine if the data for the water and the other liquid were collected at different times or the same time. Justify your answer.
Draw a ✓ in one box only.

different times ☐ same time ☐

Justification

Question 5

An airplane started from rest and accelerated to 260 km h^{-1} in 14 seconds.

(i) Convert the speed 260 km h^{-1} into m s^{-1}.

(ii) Identify which formula the student should use to calculate the acceleration of the airplane. Draw a ✓ in one box only.

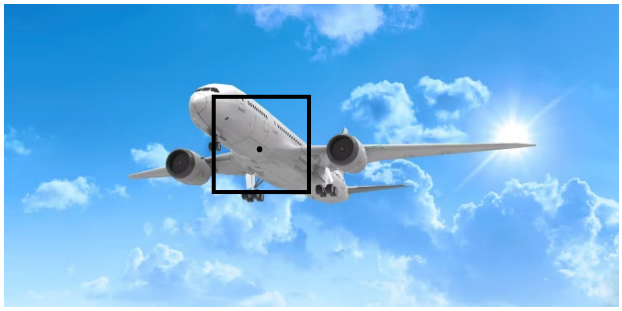
$s = ut + \frac{1}{2}at^2$ ☐ $v = u + at$ ☐ $v^2 = u^2 + 2as$ ☐

(iii) Calculate the airplane's acceleration.

Once the airplane is at the appropriate height, it travels at a constant speed.

(iv) The box below is used to model the airplane. The central dot shows its centre of mass.

Draw labelled vector arrows in the enlarged box below to show four forces acting on the airplane when it is travelling at a constant speed.

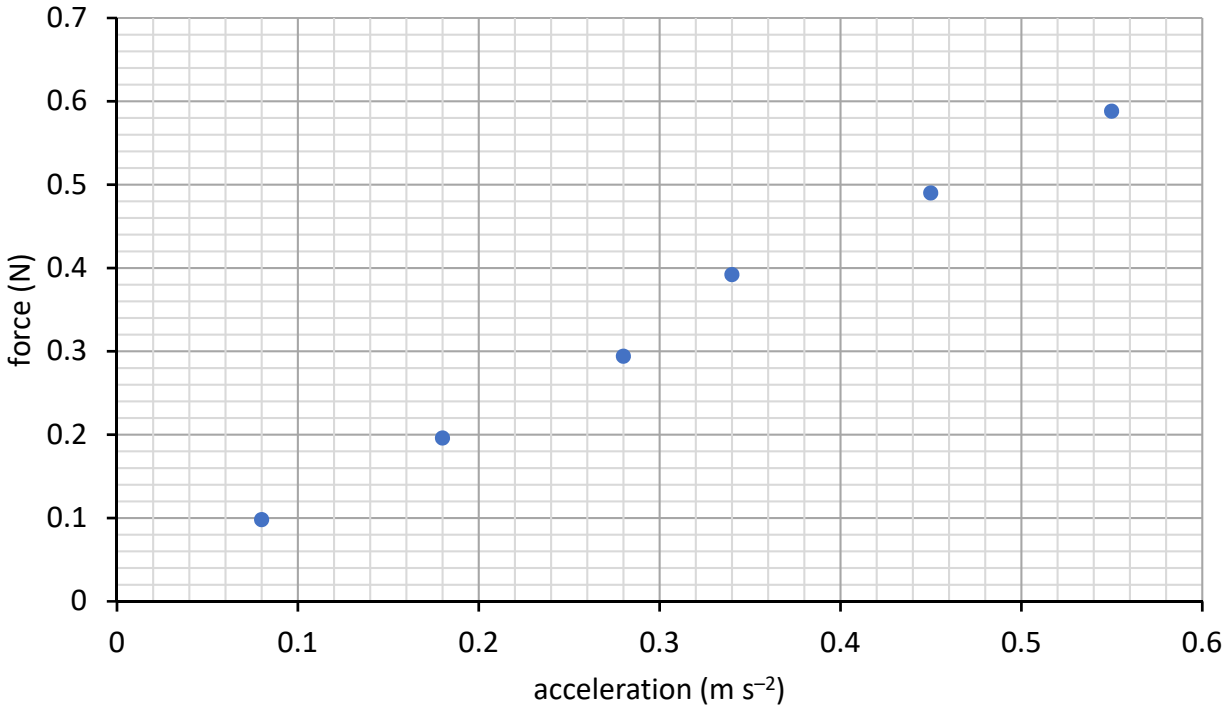


If the airplane needs to accelerate during flight, the pilot uses the engines to provide a net forward force. The magnitude of the acceleration is proportional to the net force.

A student carried out an experiment to investigate the relationship between force and acceleration.

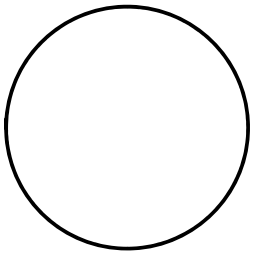
(v) Draw a labelled diagram of the arrangement of the apparatus that could be used in this experiment.

(vi) The student plotted the following graph based on their collected data. Complete the graph below by drawing the best fit line.



(vii) Calculate the slope of the graph to determine the mass of the system.

Positive static charge builds up on an airplane as it flies. The airplane can be modelled as an insulated metal sphere as shown below.



(viii) Add positive (+) symbols to the diagram above to show the distribution of positive charge on an insulated metal sphere.

The airplane can also be modelled as a positive point charge as shown below.

(ix) Sketch the electric field lines around the positive point charge shown.

The diagram below models two airplanes as two positive point charges.

(x) Sketch the electric field lines around these two positive point charges.

(xi) When an airplane lands, it is important to remove the charge safely.
Suggest a method of removing the charge from the airplane.

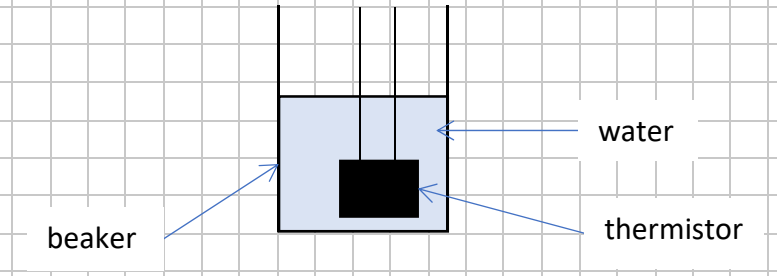
Question 6

(a) Thermometers use a thermometric property of a substance to measure temperature.

(i) Explain what is meant by a thermometric property.

A student set up an experiment to investigate the suitability of a thermistor for use as a thermometer. The resistance of the thermistor was measured at different temperatures.

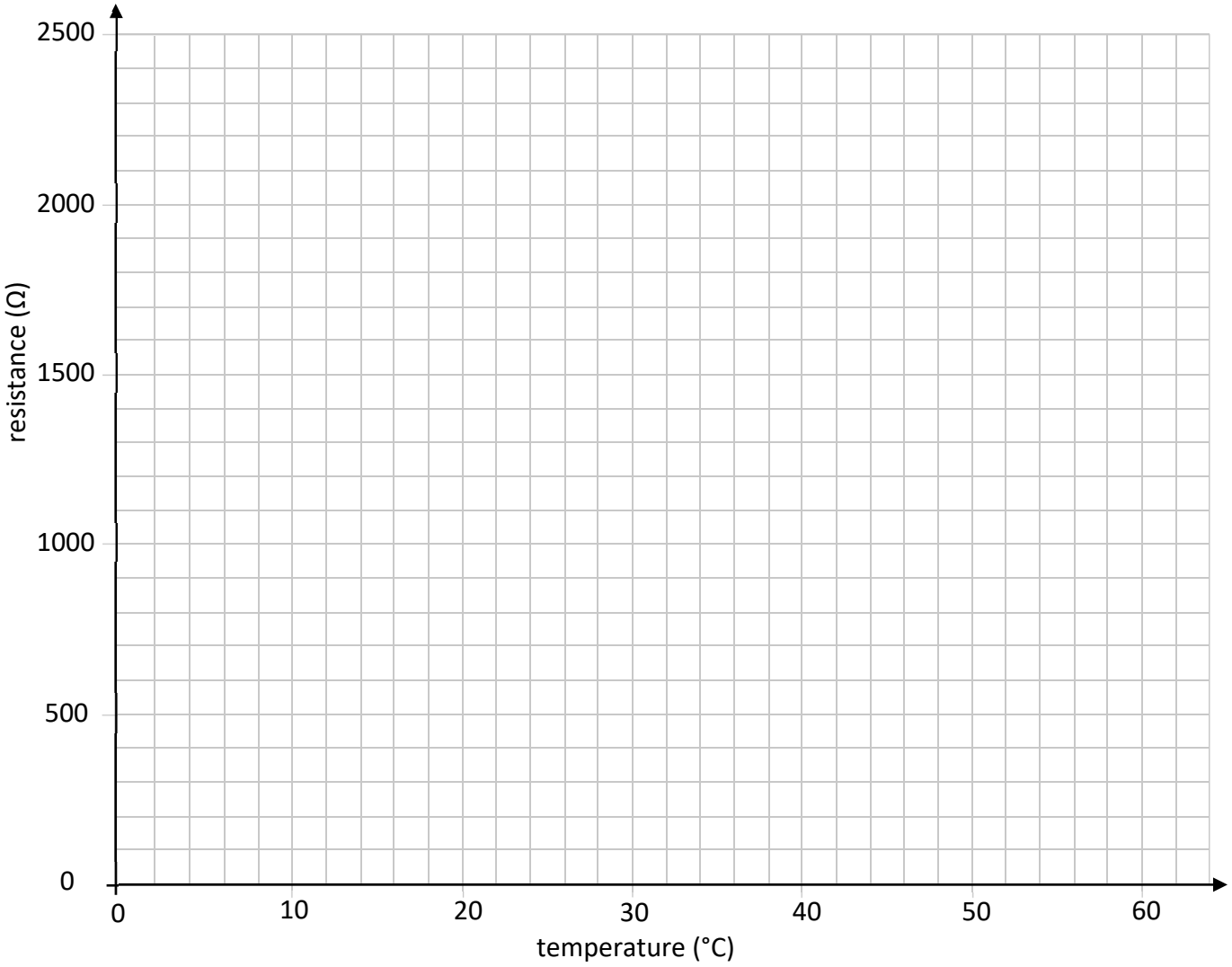
(ii) Complete the diagram below to show the equipment needed to take the measurements for this experiment.
Include labels for the equipment.



The following data were collected during the experiment.

temperature (°C)	10	20	30	40	50	60
resistance (Ω)	2400	1600	1000	600	400	200

(iii) Draw a graph, on the axes provided, to show the relationship between temperature and resistance.

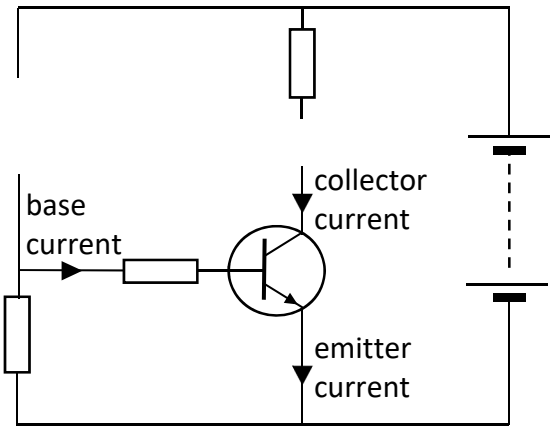


(iv) Use your graph to estimate the temperature when the value of the resistance is 800 Ω. Show your work on the graph and write your answer in the space provided.

temperature = _____ °C

(b) A thermistor can be used as part of a circuit when building a heat sensitive switch.

The diagram shows a transistor as a switch being used to build a heat sensitive alarm.
Note: There are components missing.



(i) Using the symbols from pages 72–78 of the *Formulae and Tables* booklet, draw in the symbols for the thermistor and a light source to complete the circuit diagram.

(ii) Complete the following sentence by writing the appropriate terms from the list below.

base current **collector current** **emitter current**

When a transistor acts as a switch, the _____ switches on the _____.

(iii) At room temperature, the alarm does not light up.

What is observed if the temperature is raised significantly? Justify your answer.

Draw a ✓ in one box only.

alarm lights up ☐ alarm does not light up ☐

(c) A heat sensitive switch can be used to automatically switch off an electric kettle when it reaches a set temperature.

(i) A kettle supplies heat energy ΔE of 472 500 J to a mass m of 1.5 kg of water. Calculate the change in temperature $\Delta\theta$ of the water.

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

The total energy used by the kettle is 600 000 J.

(ii) Calculate the percentage efficiency of the kettle.

(iii) Suggest a way to increase the efficiency of a kettle.

Question 7

(a) Doppler ultrasound is a non-invasive test that can be used to measure the blood flow through your blood vessels. It works by bouncing high-frequency sound waves off red blood cells that are in the bloodstream.

(i) Explain what is meant by the Doppler effect.

The following data show the apparent frequency f detected using a Doppler ultrasound in three patients.
The formula below is used to calculate the blood flow velocity v.

$$v = 2.2 \times 10^{-4} \times f$$

Patient	f (Hz)	v (m s^{-1})
1	1750	
2	900	0.198
3	140	

(ii) Complete the table above by calculating the blood flow velocity for patients **1** and **3**.

(iii) A healthy patient has a blood flow velocity between 0.3 m s^{-1} and 0.4 m s^{-1}.

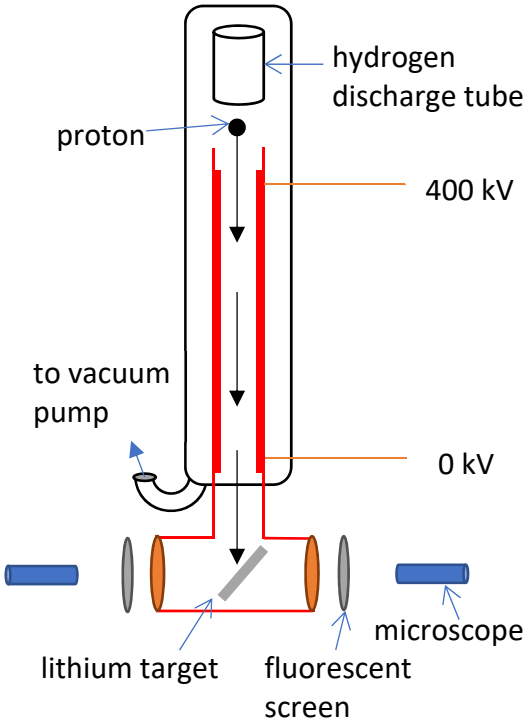
Identify which of the data above was taken from a healthy patient.

Draw a ✓ in one box only.

patient **1** ☐ patient **2** ☐ patient **3** ☐

(b) In 1932, the English physicist John Cockcroft and the Irish physicist Ernest Walton produced a nuclear disintegration by bombarding lithium with artificially accelerated protons.

The positive protons were accelerated to high speeds and collided with the positive lithium nuclei.



(i) Suggest a reason that protons were used instead of neutrons.

(ii) Identify why it was necessary to accelerate the protons to high speeds for the collision to happen.

The products of the reaction are alpha particles.

(iii) Describe how the products can be detected.

The reaction that took place in this experiment is shown below.

$$^{7}_{3}\text{Li} + ^{1}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + ^{4}_{2}\text{He} + \text{energy}$$

Reactants		**Products**	
mass of Li	$1.1650358 \times 10^{-26}$ kg	**mass of He**	$6.6464832 \times 10^{-27}$ kg
mass of H	$1.6735339 \times 10^{-27}$ kg	**mass of He**	$6.6464832 \times 10^{-27}$ kg
total mass	$1.3323892 \times 10^{-26}$ kg	**total mass**	$1.3292966 \times 10^{-26}$ kg

(iv) Use the table above to calculate the difference in mass m between the total mass of the reactants and the total mass of the products to four significant figures.

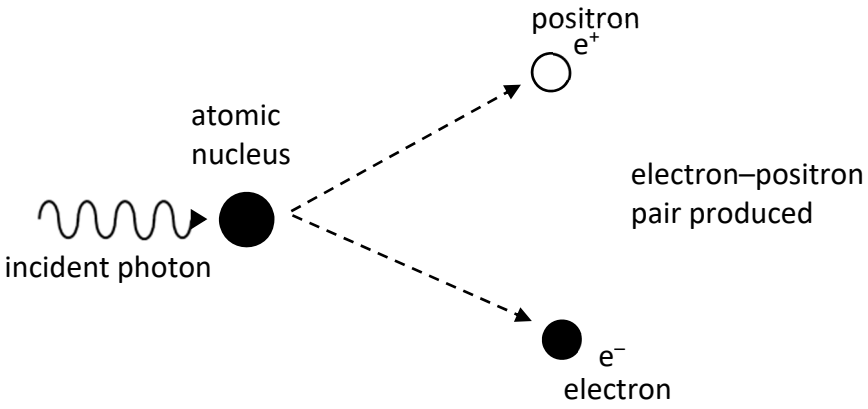
This experiment won the Nobel prize in Physics in 1951 and it was the first experimental verification of Einstein's famous formula, $E = mc^2$.

(v) Use this formula to calculate the energy released in this nuclear reaction.

Take the following value for the speed of light $c = 3 \times 10^8$ m s^{-1}.

(c) In the Cockcroft and Walton experiment, mass is converted into energy.

Energy can also be converted into mass as shown below.



An electron and its antiparticle are produced during this process.

(i) Using the *Formulae and Tables* booklet, or otherwise, identify the type of particles that are produced.

Draw a ✓ in one box only.

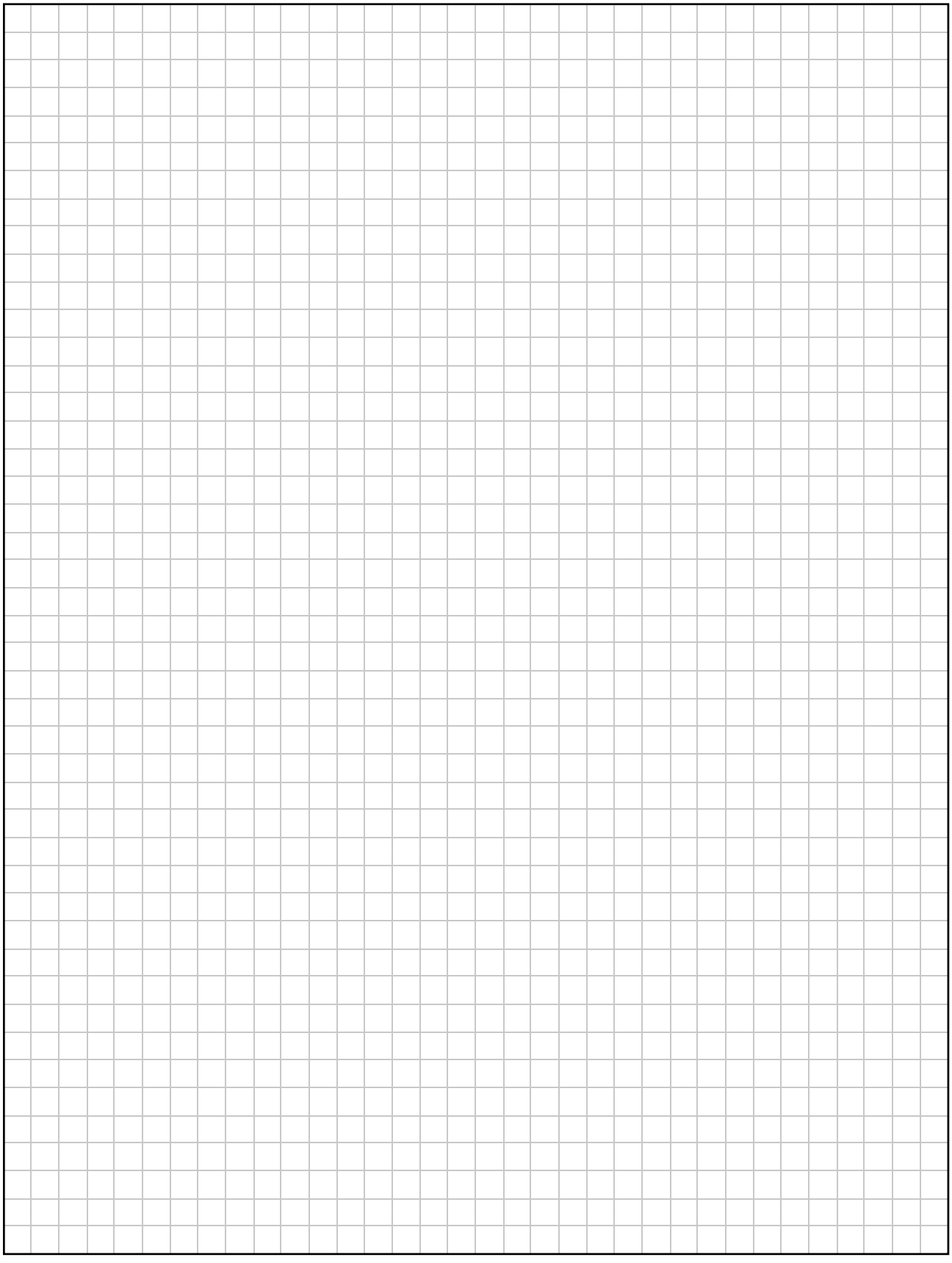
bosons ☐ leptons ☐ quarks ☐

(ii) What is the antiparticle of the electron called?

(iii) Identify one difference between an electron and its antiparticle.

Page for extra work.

Label any extra work clearly with the question number and part.



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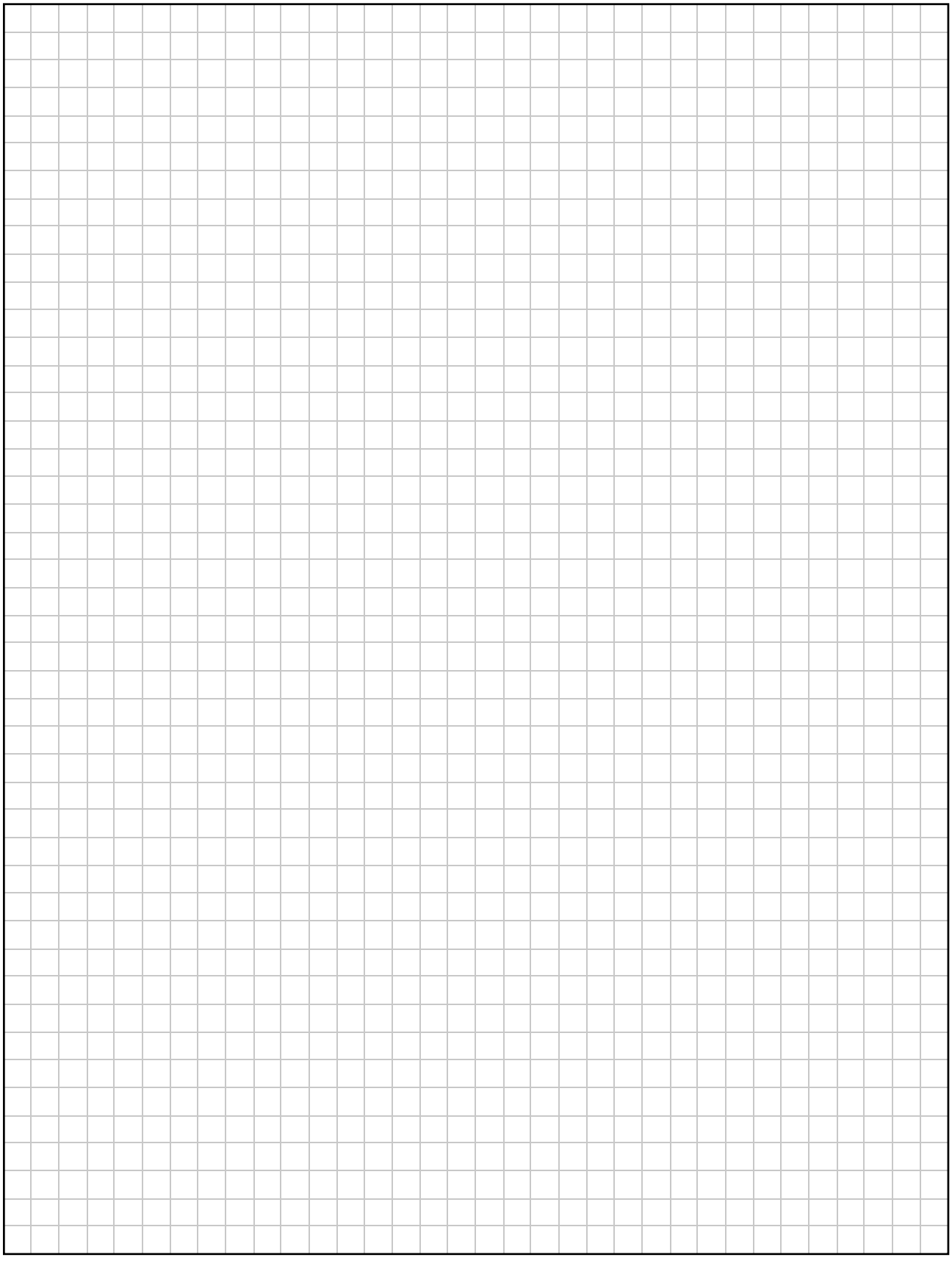
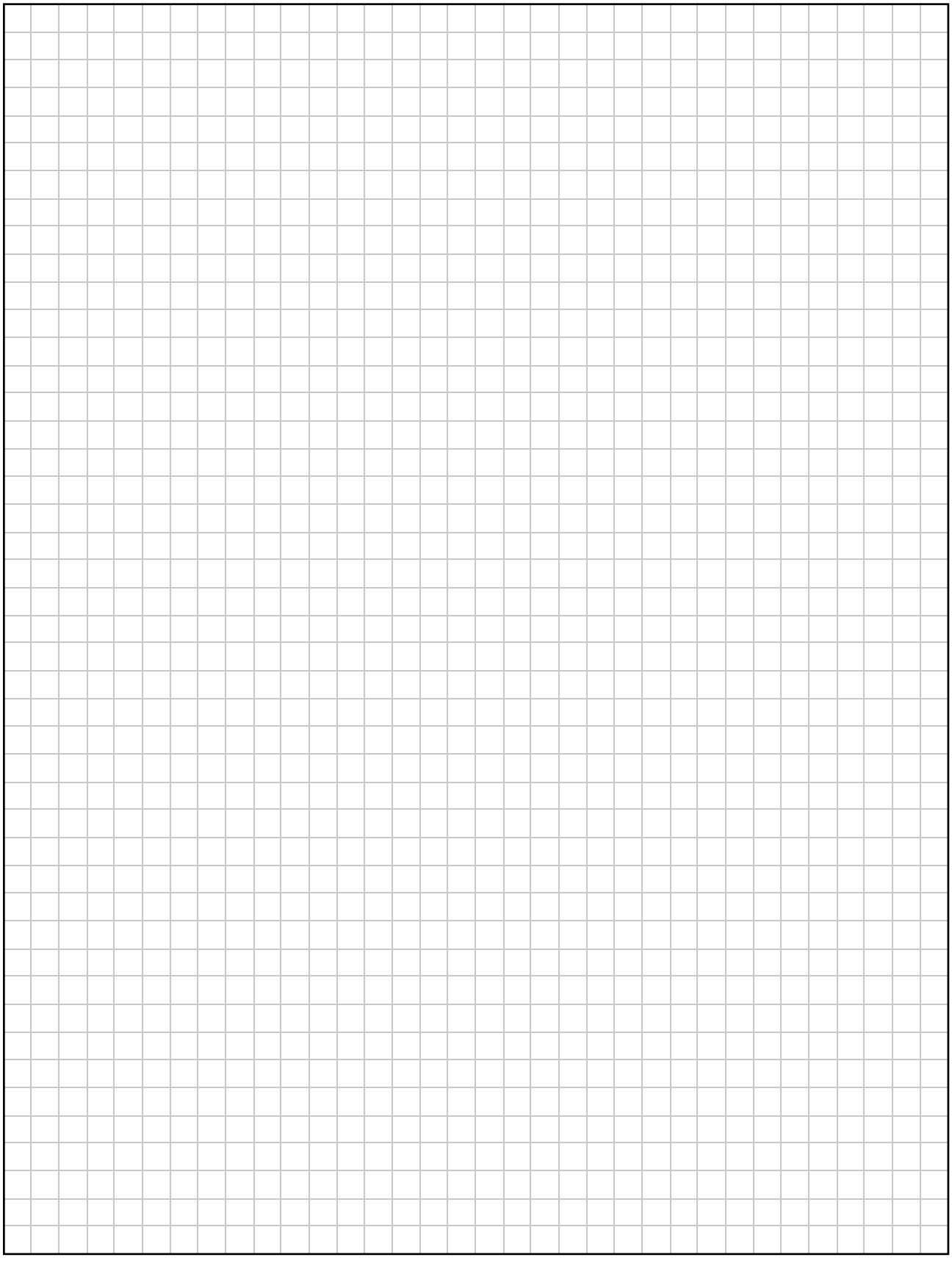


Page for extra work.

Label any extra work clearly with the question number and part.



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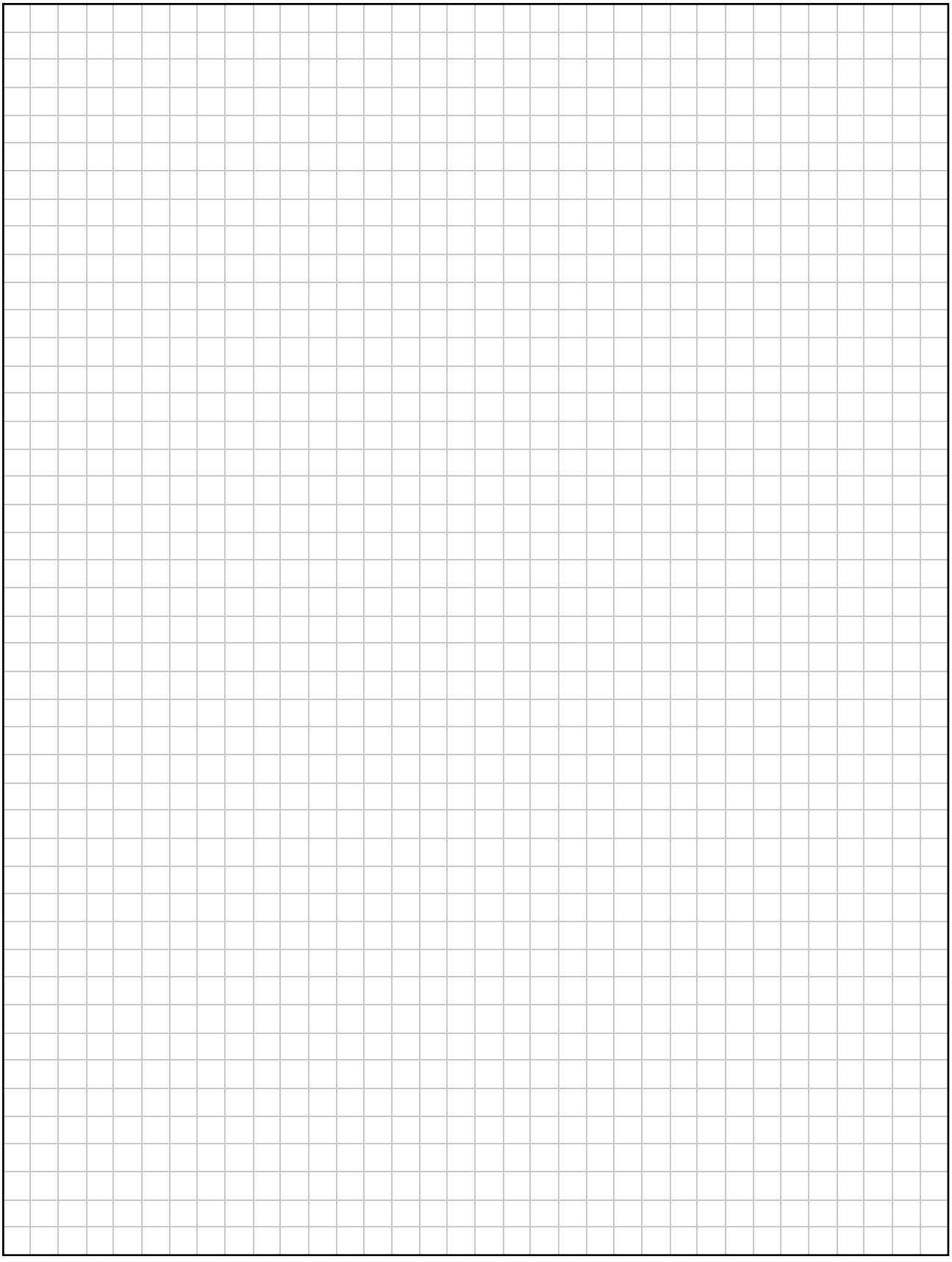

Acknowledgements

Images

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Leaving Certificate Examination – Ordinary Level

Physics

Sample 1

2 hours 30 minutes