Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination
Sample 1

Physics

Higher 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:

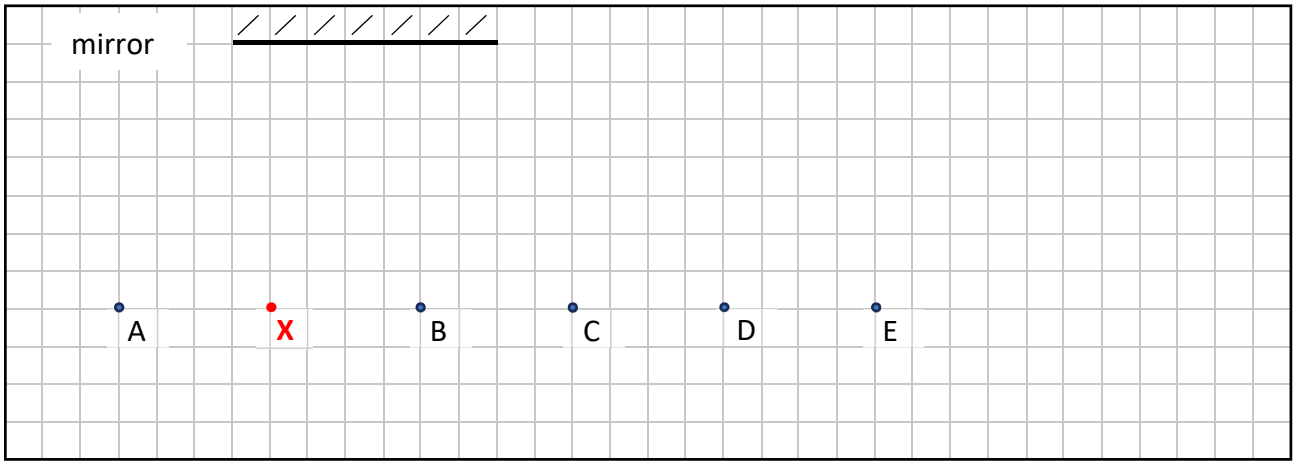
Question 1

(a) The model of light as a wave helped to improve our understanding of mirrors and lenses.

(i) Students labelled A, **X**, B, C, D and E stand in front of a mirror as shown.

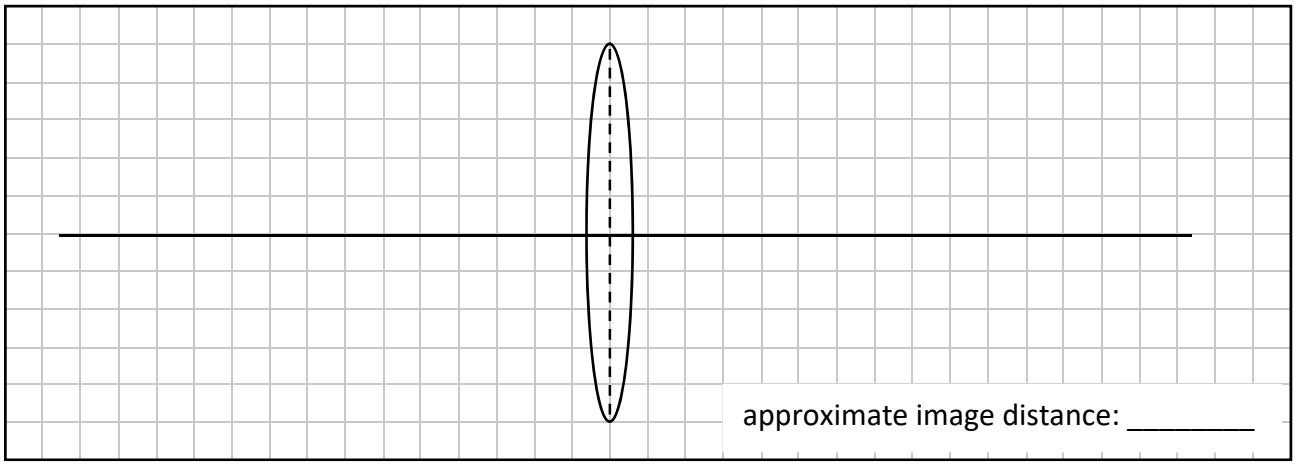
(a) Identify which of these students can be seen reflected in the mirror by student **X**. Draw a circle around each letter that applies.

(b) Justify your answer by drawing the appropriate rays on the diagram.

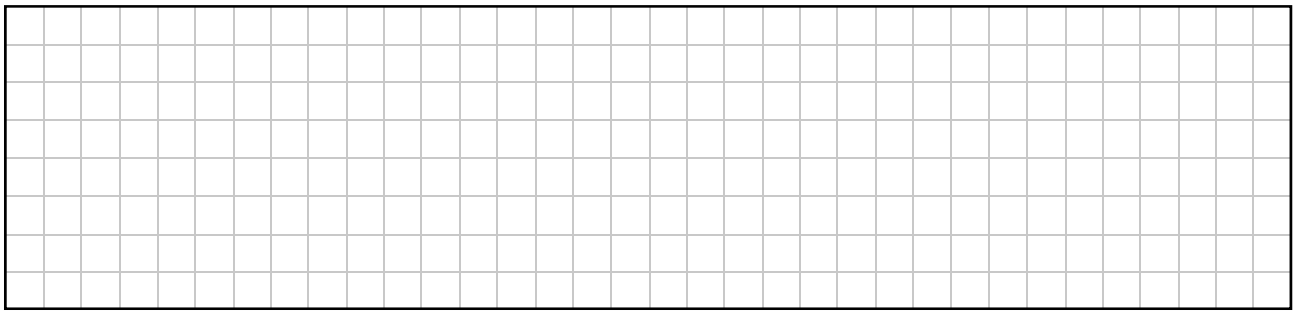


(ii) An object is placed 30 cm in front of a convex lens of focal length 10 cm.

By choosing a suitable scale, draw a ray diagram below to determine an approximate image distance.

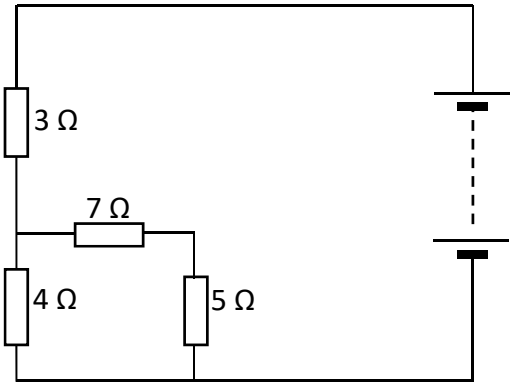


(iii) Identify three changes to the image if the object was placed 5 cm in front of the lens.



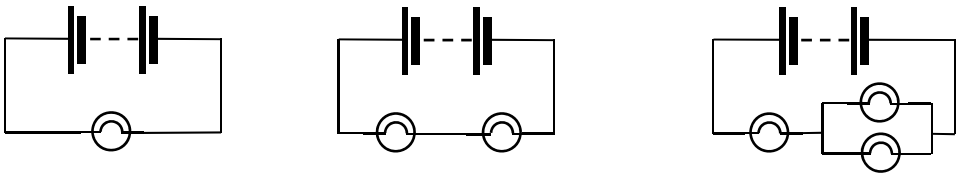
(b) Components in electrical circuits can be arranged in series or in parallel.

(i) Calculate the effective resistance of the arrangement of the resistors shown below.



The following three diagrams show three different circuits. All the bulbs and batteries are identical.

(ii) Circle the bulb(s) that the least amount of current flows through. Justify your answer.

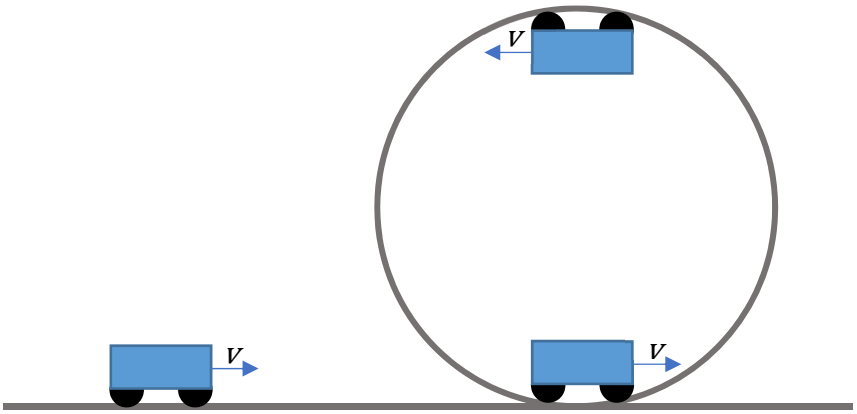


Justification

(c) Vectors are one way to model the forces acting on an object.

(i) Compare vector and scalar quantities by stating one similarity and one difference between them.

The image shows a basic sketch used to model a roller coaster's path as it travels around a vertical loop with a constant speed v.



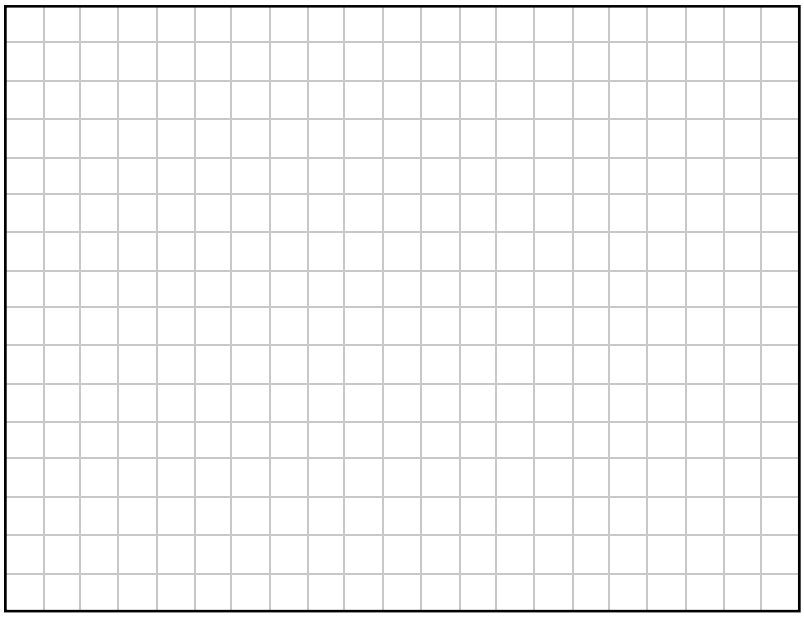
(ii) Ignoring the effects of friction, draw labelled vectors on the diagram to represent the forces acting on the car when it is at

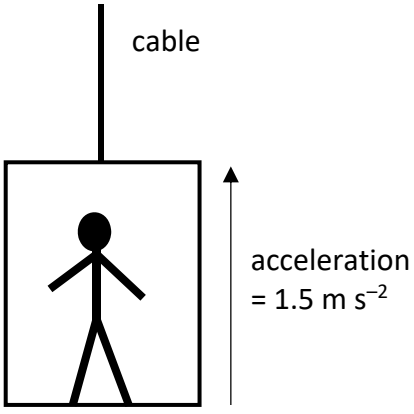
(a) the bottom of the loop,

(b) the top of the loop.

(iii) A person stands in a lift. The total mass of the person and the lift is 800 kg. The lift accelerates upwards at 1.5 m s^{-2}.
Calculate the tension in the cable.

acceleration due to gravity, $g = 9.8$ m s^{-2}





(d) The gravitational field strength g at the surface of the Earth is $g_{surface}$ = 9.81 N kg^{-1}. This is partly due to the radius of the Earth, which is approximately 6378 km.

(i) Calculate the value of the gravitational field strength at a height of 900 km above the surface of the Earth.

(ii) Calculate the escape velocity at this height.

(iii) The mass of a rocket can be over 7×10^5 kg.

(a) Predict how the mass of a rocket affects its escape velocity.

(b) Justify your answer.

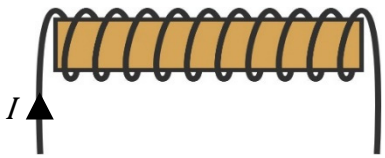
Prediction

Justification

(iv) Rockets are launched at the Kennedy Space Center in Florida, which is roughly at sea level.
Suggest a reason why Kennedy Space Centre was not built at a height of 900 km above the surface of the earth.

(e) The image shows a solenoid which has a direct current entering it in the direction indicated by the arrow.

(i) Sketch, on the diagram below, the magnetic field that will be generated by the current I as it flows in the solenoid.



(ii) Draw a ✓ in one box only to complete the statement.
As the current exits the solenoid its magnitude is

lower ☐ the same ☐ varying ☐ higher ☐

(iii) Identify two ways of increasing the magnetic field around the solenoid.

(f) Given the mass of a Cu–63 nucleus is 1.04471×10^{-25} kg, calculate the binding energy of Cu–63.

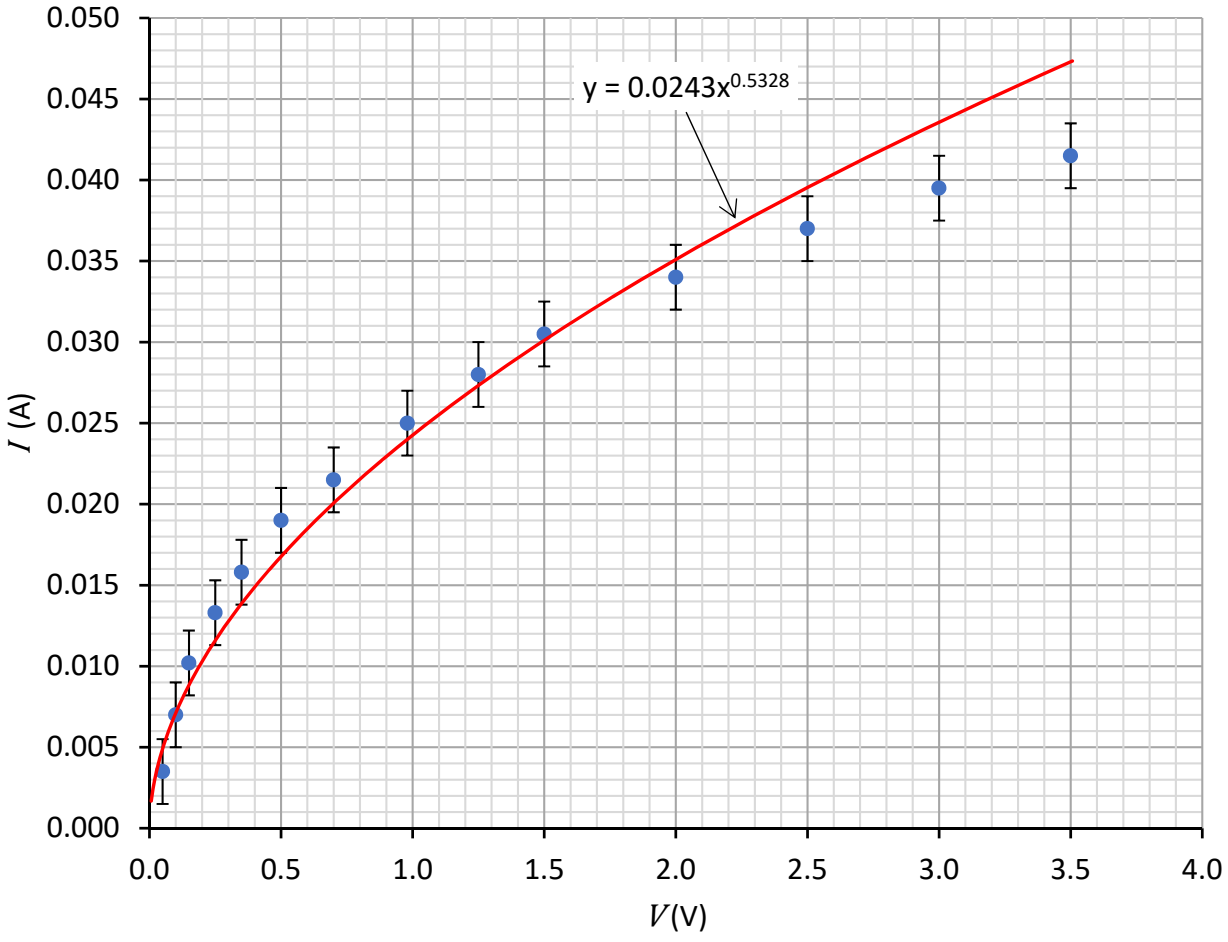
Question 2

(a) A student carried out an experiment to investigate the relationship between the current I flowing through and the voltage V across a filament bulb.

(i) Draw a circuit diagram to show how the student could have recorded the different measurements of current and voltage.

Using graphing software, the student plotted their data points and included error bars to represent the error in the I values. They used the software to develop the following mathematical model of the data and added the curve to the plotted data points.

$$I = 0.0243\ V^{0.5328}$$



(ii) **(a)** Use the student's mathematical model to determine, as accurately as possible, the difference between the value their model predicts for the current at a potential difference of 2.5 V and the actual value the student obtained.

(b) Use the data point and error bar plotted by the student to estimate the range of current values the student would accept when the voltage V is 2.5 V.

In the conclusion of their report the student made the following comment.

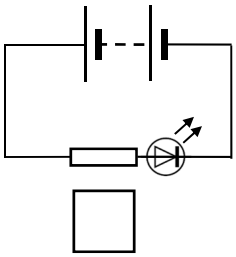
"The mathematical model accurately predicts the current through the filament bulb for voltages from 0 V to 3.5 V."

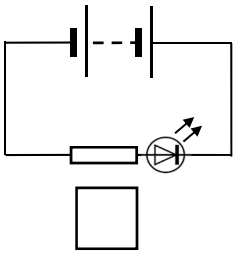
(c) Evaluate this claim by investigating separate data points and comparing them to the values predicted by the student's mathematical model.

(iii) Explain, with reference to the free electrons in the filament, why the current flowing through the wire filament is not directly proportional to the potential difference.
Use diagrams and/or words in your answer.

(b) Light emitting diodes (LEDs) are a more efficient source of light than filament bulbs. They can range from 80% to 90% efficient.

(i) Identify the LED that is in forward bias.
Draw a ✓ in one box only.





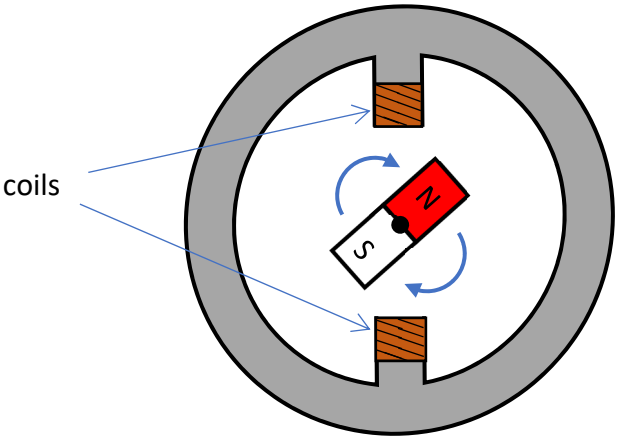
An LED is in forward bias, and energy is emitted as photons of light. This happens as electrons lose energy and fill holes.

A particular LED emits photons of wavelength 650 nm. There is a potential difference of 2.1 V across it and a current of 20 mA flowing through it. The LED has an efficiency of 81%.

(ii) **(a)** Calculate the energy lost by an electron as it fills a hole.

(b) Calculate the number of photons that the LED emits each second.

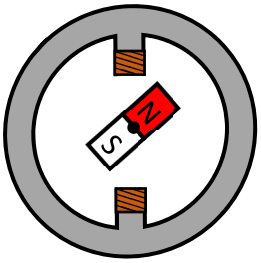
(c) The student decides to use LEDs to make a light for their bicycle. They want to use energy from the rotating wheels to generate the required voltage. The following simplified diagram models the generator they plan to develop.

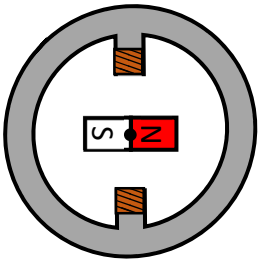


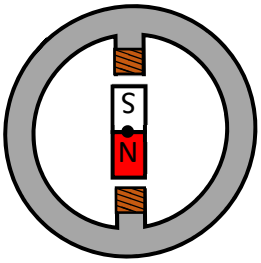
The central magnet is rotated by the bicycle wheel.

(i) Identify when the magnetic flux through the coils is at its greatest.

Draw a ✓ in one box only. Justify your answer.

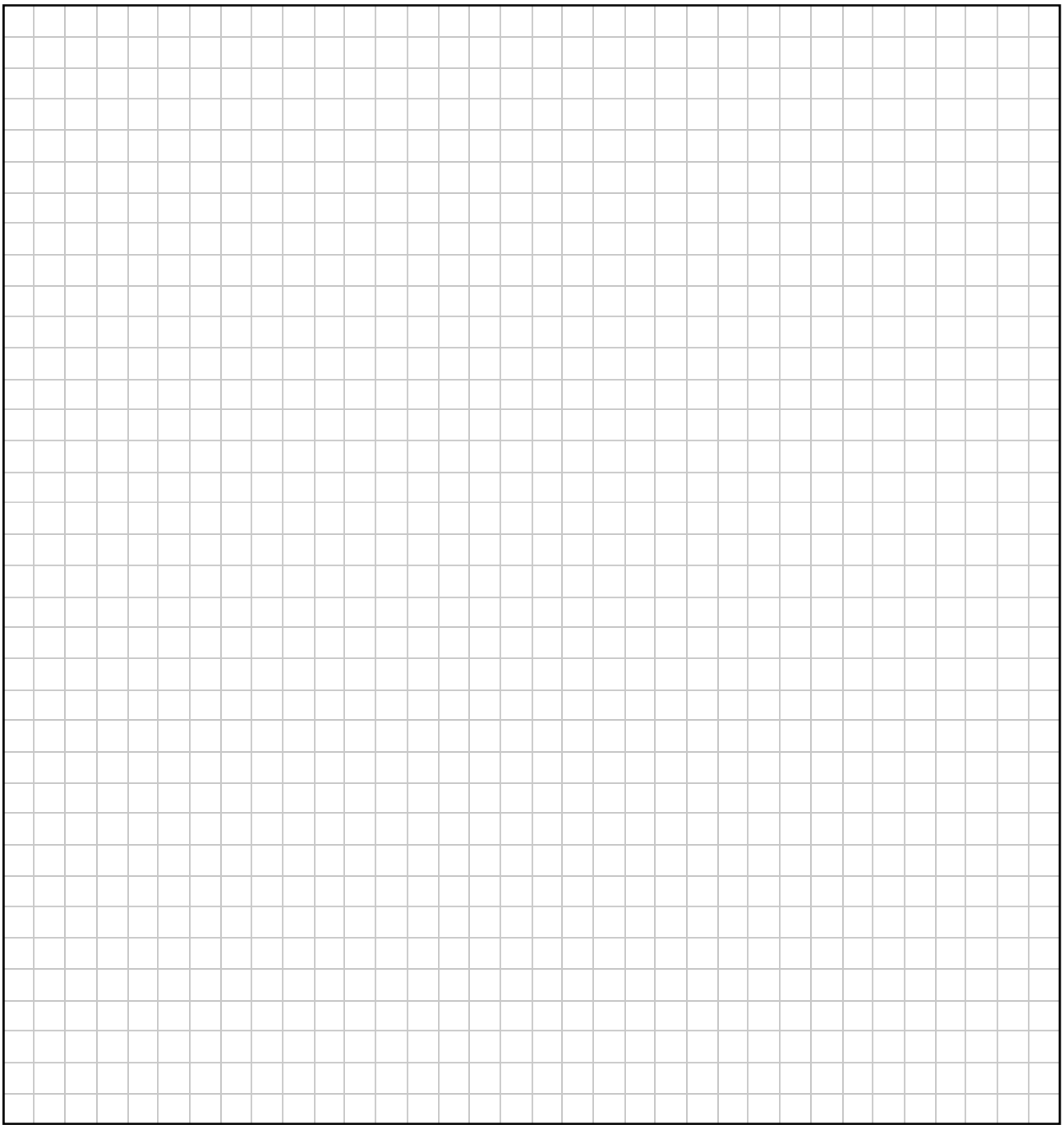






Justification

(ii) The magnetic flux density affecting a coil changes by 0.278 T in 0.017 s. The area of the coil is 225 mm^2. The coil consists of 800 turns of wire.
Calculate the EMF induced in the coil.



Question 3

Sustainability is finding the balance between human needs and nature's resources to ensure a healthy future for all.
On average in Ireland, heating accounts for a large part of a home's utility bills.

(i) State three types of heat transfer.

(ii) Describe how heat could be lost from a building through each method of heat transfer. A diagram may help your answer.

Insulation techniques are used to improve the U-value of a structure.

(iii) Explain what is meant by U-value.

A homeowner follows advice to upgrade both of their external doors. Each door has dimensions 1981 mm × 838 mm. The upgrade changes the average U-value of the doors from a poor U-value rating of 3.03 W m^{-2} K^{-1} to a very good U-value rating of 1.40 W m^{-2} K^{-1}.
The homeowner keeps the internal temperature of the house at a constant 18 °C.

(iv) Calculate the maximum energy that could be saved per hour when the external temperature is –1 °C.

To further reduce energy costs the homeowner installs a system of 10 solar panels with a total area of 3.5 m^2. Each solar panel has a power rating of 300 W.
Electricity supply companies measure energy in kilowatt-hours (kWh). The system generates a total of 4.3 kilowatt–hours of electrical energy over an 8 hour period when the average solar irradiance falling on them is 812 W m^{-2}.

(v) Convert 4.3 kilowatt–hours to joules.

(vi) Calculate the average power per unit area generated by the solar panels over the 8 hour period.

(vii) Calculate the percentage efficiency of the system's ability to convert energy from the sun into electrical energy over the 8 hour period.

(viii) Calculate the maximum mass of water that can be heated from 10 ˚C to 65 ˚C using the energy generated by the solar panels over the 8 hour period.
specific heat capacity of water = 4180 J kg^{-1} K^{-1}

(ix) Suggest two reasons that would explain why the actual mass of water heated could be less than the maximum.

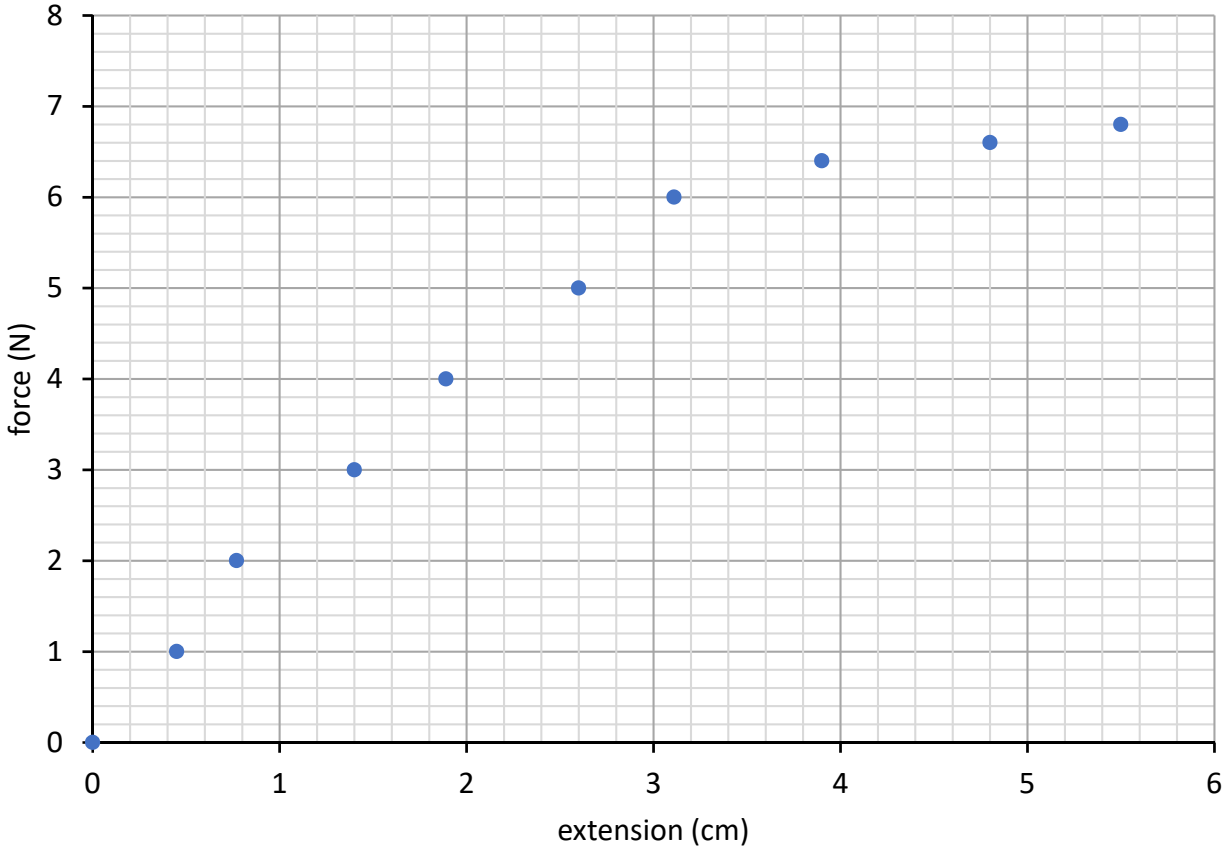
(x) Over the 8 hour period the average solar irradiance value is 812 W m^{-2}.
Draw a ✓ in one box only to complete the statement below.

Over the 8 hour period the actual solar irradiance value is

lower ☐ the same ☐ varying ☐ higher ☐

Question 4

(a) A student conducted an experiment to verify Hooke's law and to investigate the relationship between the force F applied to and the extension s of a spring. They plotted their data as shown.

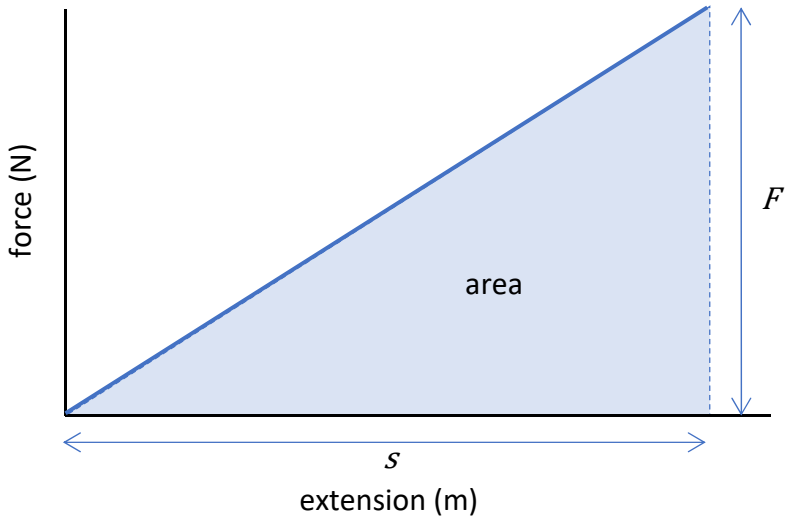


(i) State a limit to the model, developed by Hooke, relating the extension of a spring to the force applied.

(ii) Draw the line of best fit on the graph to show that Hooke's law is verified by the data.

(iii) Using your line of best fit, calculate the spring constant k for the spring.

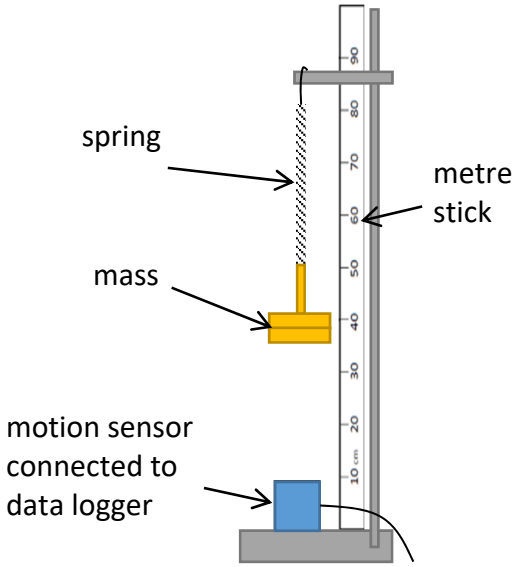
In general, the work done in stretching a spring can be modelled by the area under the best fit line of the graph as shown below.

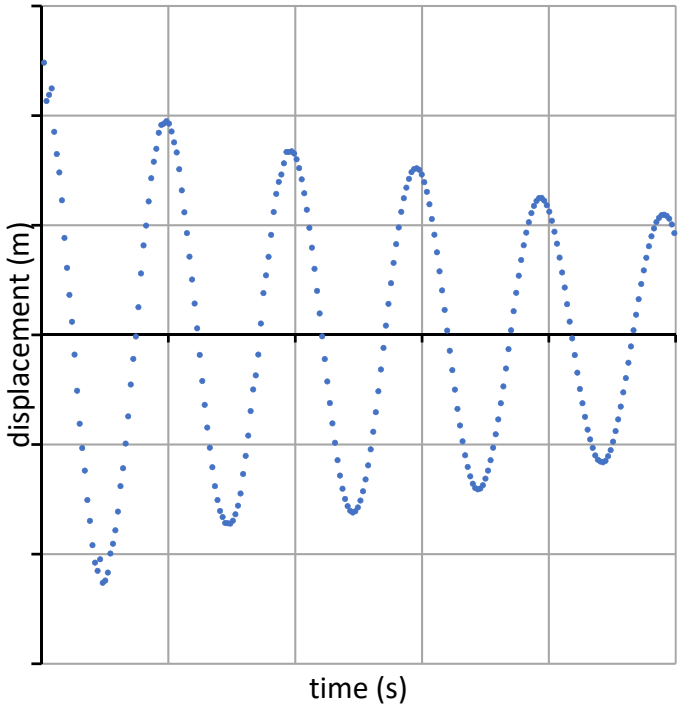


(iv) Deduce a mathematical model relating the work done, in stretching a spring, to the force F and the extension s.

(v) Hence, using Hooke's law, verify that the elastic potential energy of the spring can be modelled, in terms of the spring constant k and the extension s, by the formula $E_p = \frac{1}{2} ks^2$.

The experiment was extended to investigate the compression and extension of a metal spring. A student set up the apparatus as shown below. The equilibrium length of the mass and spring system was recorded. The mass was raised a little and then released. They used data logger software to graph the displacement of the mass against time after it was released as shown.

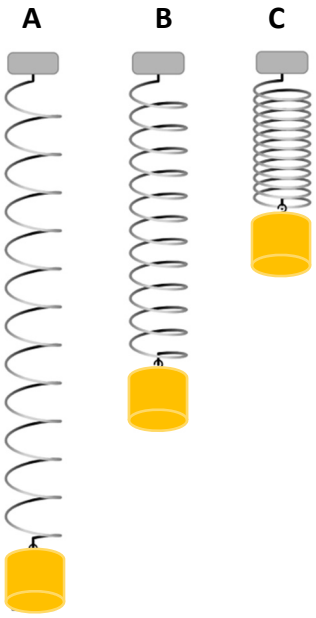




(vi) Suggest a reason that the amplitude decreases over time.

(b) An ideal spring is a theoretical model of a spring that obeys Hooke's law perfectly.

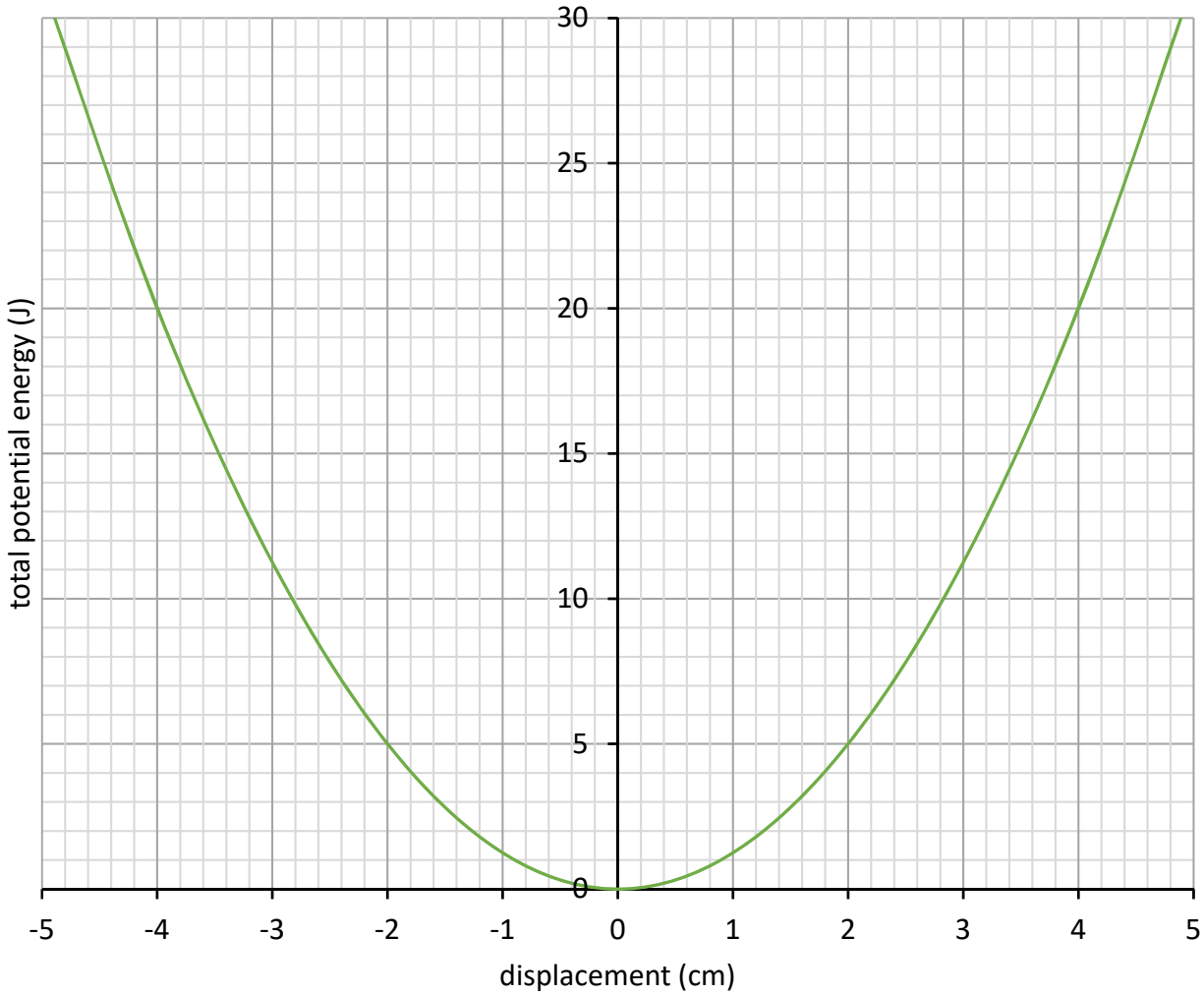
The diagram below shows different positions of a mass which is oscillating vertically at the end of an ideal spring. **B** represents the mass at its equilibrium position. **A** and **C** represent the mass at the maximum displacements from the equilibrium position.



(i) Study the positions **A**, **B** and **C** and the statements in the table below.
Draw a ✓ to identify the position(s) for which each statement is always true for an ideal spring.

Statement	**A**	**B**	**C**
The mass has maximum velocity.			
The mass has maximum acceleration.			
The mass has maximum gravitational potential energy.			
The spring has maximum elastic potential energy.			

The line on the graph below shows how the total potential energy varies with displacement from its equilibrium position for an ideal mass and spring system.



(ii) On the same axes, draw labelled lines to show how

(a) the kinetic energy varies with displacement,

(b) the total energy varies with displacement.

(iii) Using the graph, calculate the spring constant of the spring.

(iv) The magnitude of the mass is doubled and it oscillates with the same amplitude.
Draw a ✓ in one box only to complete the statement below.

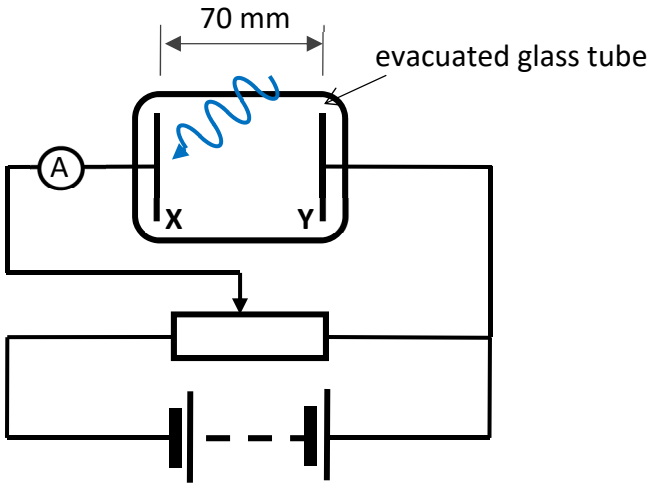
The maximum elastic potential energy stored in the spring will be

lower ☐ the same ☐ varying ☐ higher ☐

Question 5

(a) Physicists studying the photoelectric effect, at the turn of the 20th century, contributed to the understanding of the structure and behaviour of atoms.

The diagram below shows two parallel plates, **X** and **Y**, in an evacuated glass tube connected in a circuit.
Blue light is incident on plate **X**. The separation between the plates is 70 mm.



(i) **(a)** Explain what is meant by the photoelectric effect.
(b) State a practical application of the photoelectric effect.

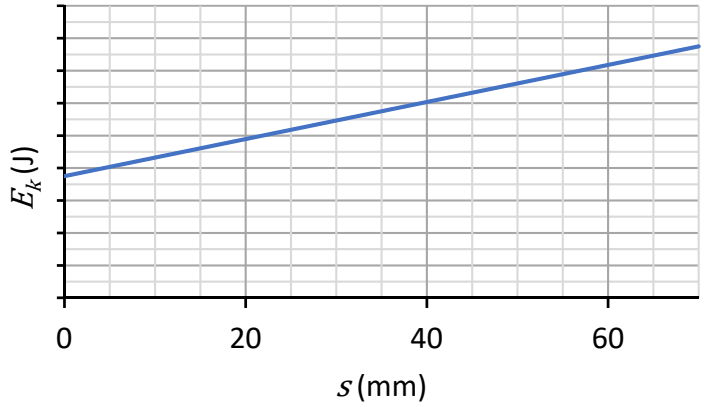
(a)

(b)

(ii) Sketch the electric field created between plates **X** and **Y** on the diagram below.

(iii) The variable resistor is adjusted such that the potential difference across the plates is 0.5 V. Calculate the increase in kinetic energy of the electrons as they move from plate **X** to plate **Y**.

The graph below plots the variation in the kinetic energy E_k of the electrons against the displacement s from plate **X**.



(iv) **(a)** By drawing on the graph, show how the graph can be used to estimate the increase in kinetic energy of the electrons as they move from plate **X** to plate **Y**.

(b) Explain the significance of the intercept value on the graph.

The blue light incident on plate **X** has a frequency of 630 THz. Plate **X** has a work function of 2.14 eV, where 1 eV = 1.602×10^{-19} J.

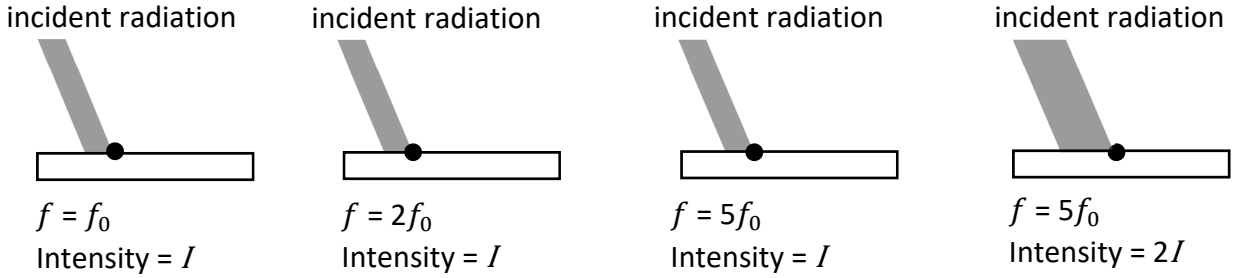
(v) Calculate the maximum kinetic energy of the electrons in the glass tube.

The terminals of the battery are reversed, and the variable resistor is adjusted until the ammeter has a reading of 0 A. The blue light is still incident on plate **X**.

(vi) Predict the effect, if any, on the path of the electrons in the glass tube.

(b) A metal plate with threshold frequency f_0 has electromagnetic radiation of frequency f incident on it. The frequency f and the intensity I of the radiation landing on the plate can be varied.

(i) Draw velocity vectors on the diagrams below, if appropriate, to represent the approximate relative magnitude of the electrons' velocities. The electrons are represented by ●.



$f = f_0$
Intensity = I

$f = 2f_0$
Intensity = I

$f = 5f_0$
Intensity = I

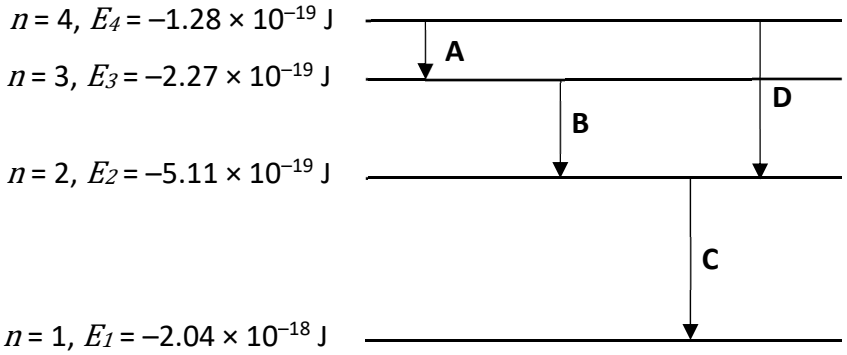
$f = 5f_0$
Intensity = $2I$

(c) Models of the atom were modified as research progressed. Thompson, Rutherford and Bohr each proposed a new model of the atom based on experimental results.

(i) Compare, with the aid of labelled diagrams, two differences between Thompson's model and Rutherford's model.

Bohr's model built on Rutherford's to explain emission line spectra.

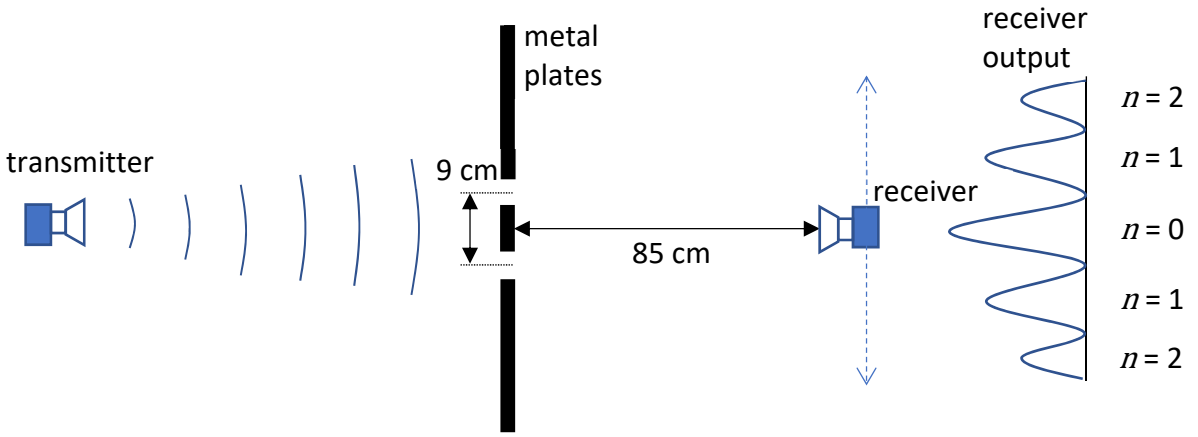
The energy values of the first four energy levels in a hydrogen atom are given below, and four electron transitions are shown labelled **A**, **B**, **C** and **D**.



(ii) Rank each transition from the shortest to the longest wavelength λ of photons emitted, by writing the appropriate letter **A**, **B**, **C** or **D** in each box.
Diagram is not drawn to scale.

Question 6

(a) The diagram below shows a microwave transmitter and receiver apparatus used to study many aspects of wave behaviour. This particular arrangement is a modern reproduction of the famous Young's slits experiment carried out at the start of the 19th century.



(i) Explain what is meant by diffraction.

(ii) Explain how the microwaves produce the output recorded by the receiver as it is moved along the dashed path. Use diagrams and/or words in your answer.

The wavelength of the microwaves is 29.98 mm and the distance between the centres of the two gaps between the metal plates is 9 cm.

(iii) Calculate the distance between the two second order ($n = 2$) peaks shown in the diagram.

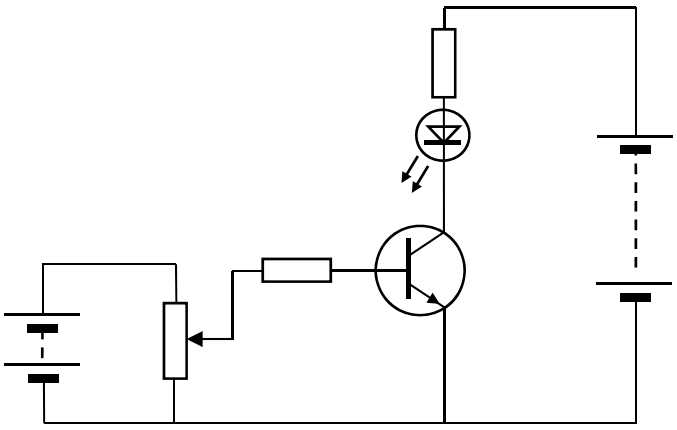
(iv) Calculate the maximum number of peaks that microwaves of this wavelength could generate.

The metal plates are removed and the wire grids shown are put in between the transmitter and receiver.
When both wire grids are aligned vertically, the meter registers a reading.

However, if one of the wire grids is rotated until the bars are horizontal, then the meter does not register a reading.

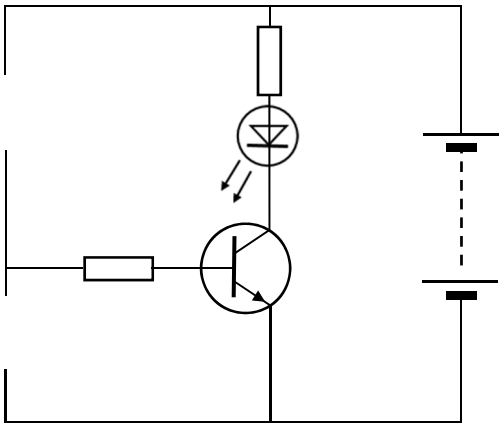
(v) Suggest one possible reason for this.

(b) The following circuit is used to demonstrate the action of a transistor as a switch.

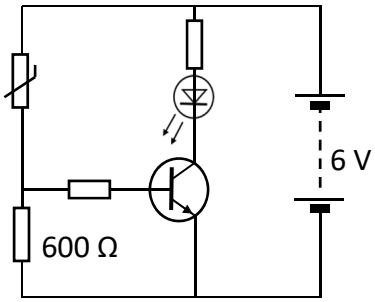


(i) Describe how the circuit can be used to demonstrate how the transistor can act as a switch to turn on and off the LED.

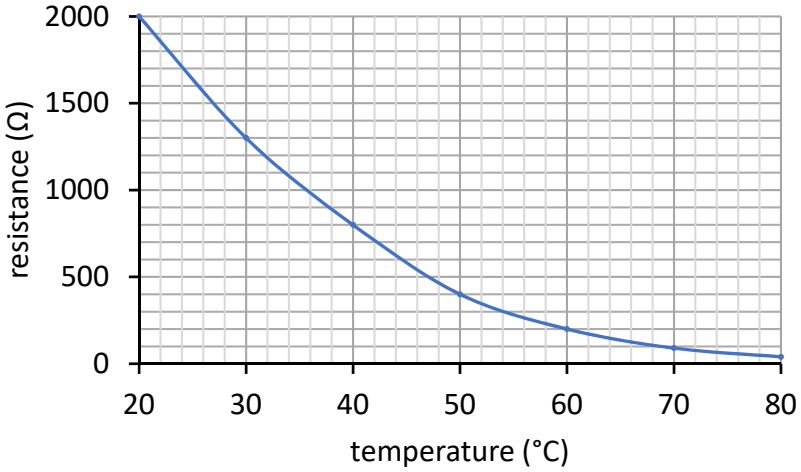
(ii) A student wants to use a transistor, fixed resistors and an LDR to create a circuit so that an LED switches on when the LDR is in the dark.
Complete the circuit below by drawing appropriate circuit symbols in the spaces provided.



In the circuit below the LED does not switch on until the voltage drop across the cold thermistor is 2 V.



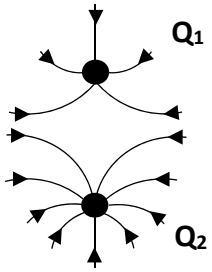
Graph showing resistance against temperature for the thermistor



(iii) Use the circuit diagram and the graph provided to estimate the minimum temperature at which the LED switches on.

Question 7

(a) The following diagram models the electric field surrounding the two point charges, Q_1 and Q_2.



(i) Explain what is meant by an electric field.

(ii) Identify the type of charges on each by drawing a ✓ in the appropriate boxes.

Q_1: negative ☐ Q_1: positive ☐ Q_2: negative ☐ Q_2: positive ☐

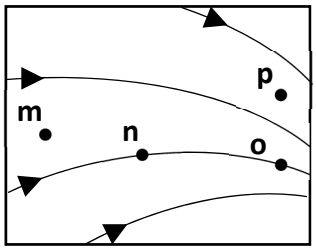
(iii) Which charge Q_1 or Q_2 has the largest magnitude? Justify your answer.

Answer

Justification

The following diagram is a magnified section of the field near Q_2.

(iv) Insert the letters of the points into the boxes below to rank, from weakest to strongest, the electric field at the points labelled **m**, **n**, **o** and **p**.



weakest ☐ ☐ ☐ ☐ strongest

(v) The force on the charge $\mathbf{Q_1}$ has a magnitude F.

The magnitude of the charge, $\mathbf{Q_2}$, is doubled and the distance between the charges is tripled.

Identify which of the following expressions gives the magnitude of the new force on $\mathbf{Q_1}$. Draw a ✓ in one box only.

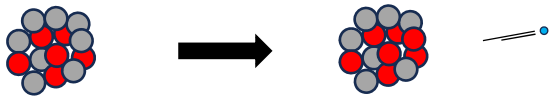
$\frac{2F}{9}$ ☐ $\frac{F}{3}$ ☐ $\frac{4F}{9}$ ☐ $\frac{2F}{3}$ ☐ $\frac{4F}{3}$ ☐ $2F$ ☐

(vi) Describe, with the aid of a labelled diagram, how an insulated metal sphere can be given a positive charge by induction.

(vii) Two identical metal spheres with a diameter of 7 cm are oppositely charged with a magnitude of 6 nC each. They are held so that the electric field strength mid-way between the two spheres is 5 kN C^{-1}.

Calculate the minimum distance between the surfaces of the two spheres.

(b) During a beta decay, a neutron decays into a proton and an electron. The electron is emitted at high speed from the nucleus, and the proton stays in the nucleus. An example of this is when a carbon–14 (C–14) nucleus decays into a nitrogen–14 (N–14) nucleus.



(i) Write a nuclear equation to represent this beta decay of C–14.

Assume that the carbon nucleus is at rest the instant that the beta decay process begins.

(ii) State why the electron travels at a higher speed than the nitrogen nucleus.

Radio-carbon dating can be used to approximate the age of historical finds. A skeleton is found to have 3.125% of its original amount of carbon–14 remaining.
The half-life of C–14 is 5730 years.

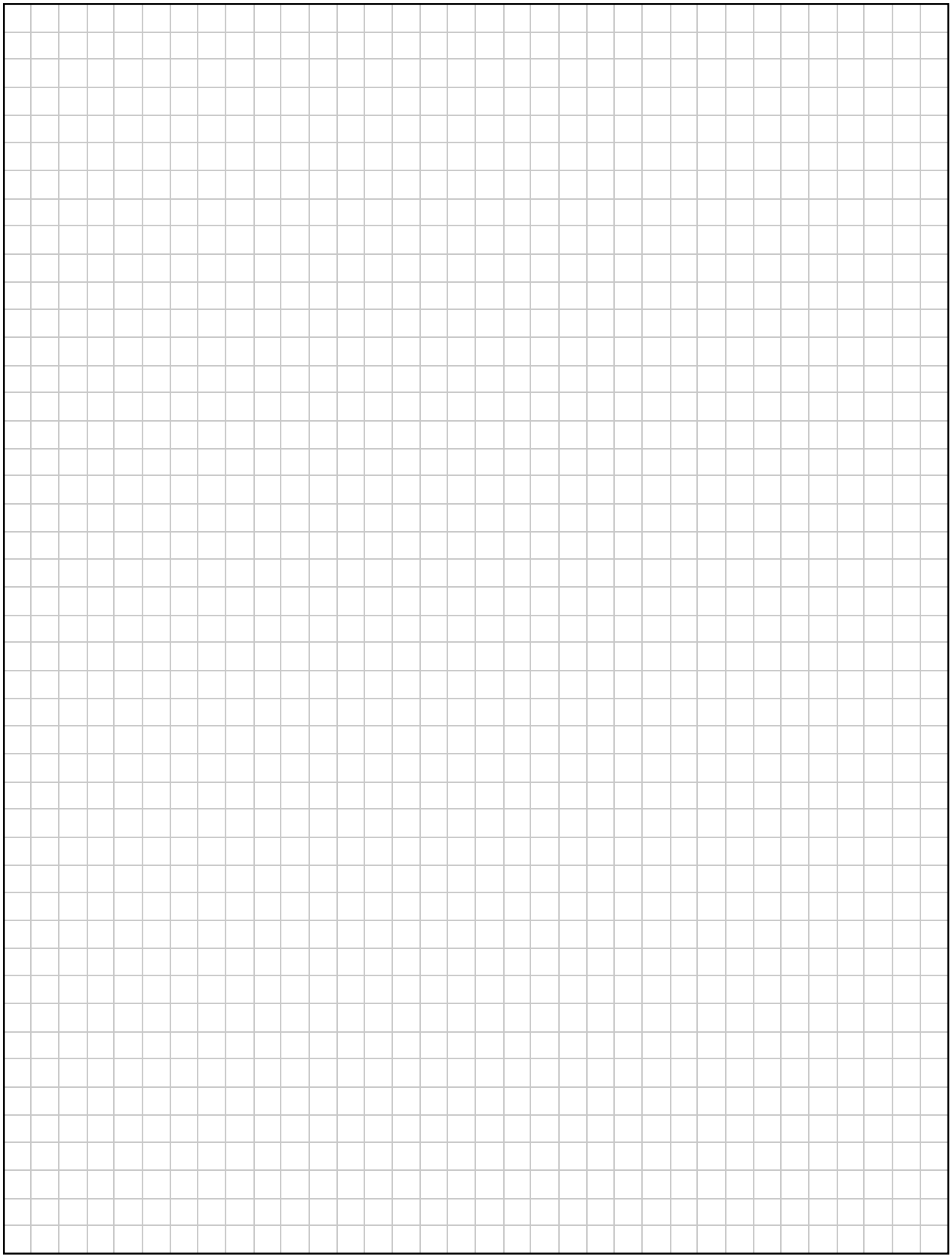
(iii) Calculate the approximate age of the skeleton that was found.

The activity of the C–14 in the skeleton is 115 Bq.

(iv) Calculate the number of C–14 nuclei undecayed in the skeleton.

Page for extra work.

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



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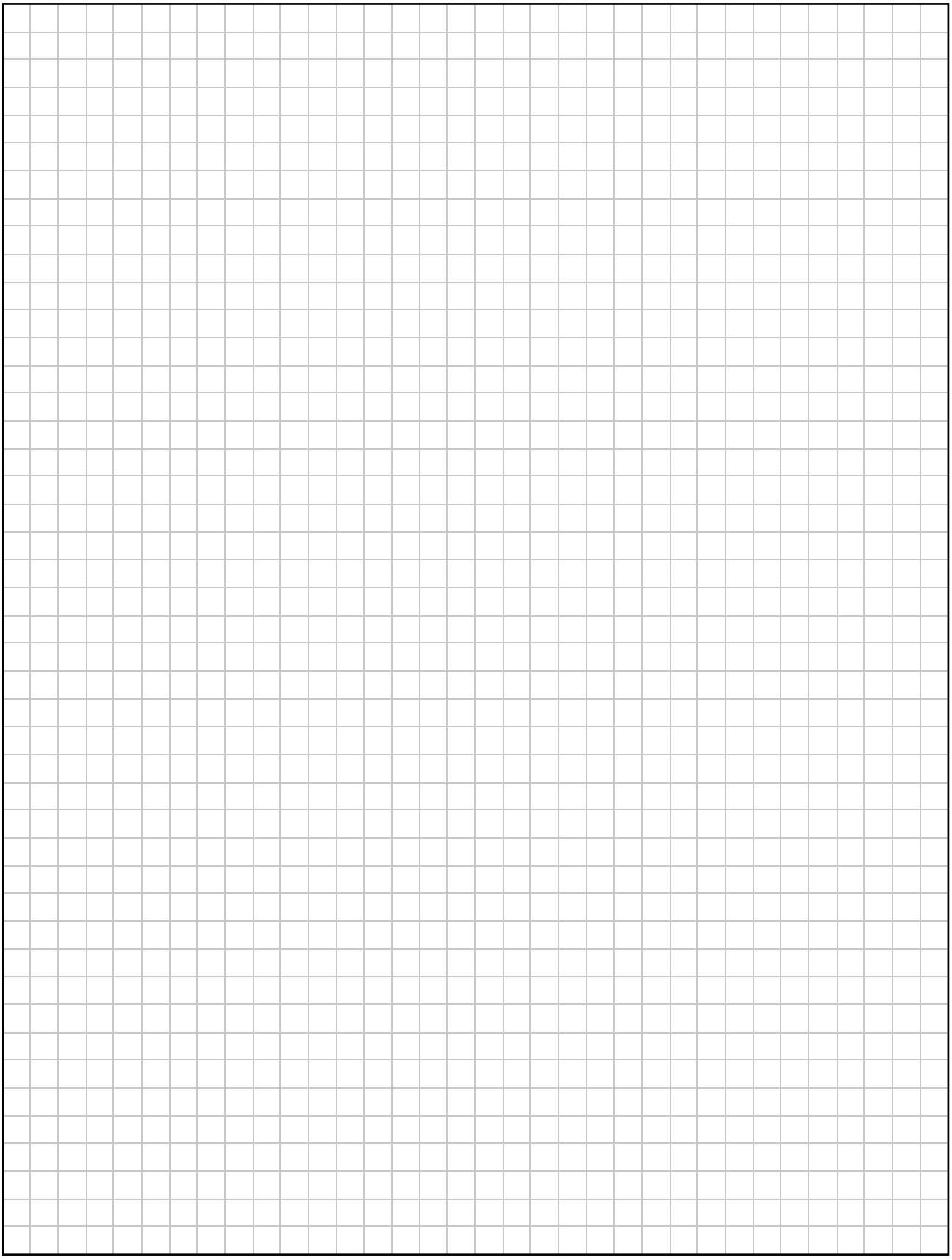

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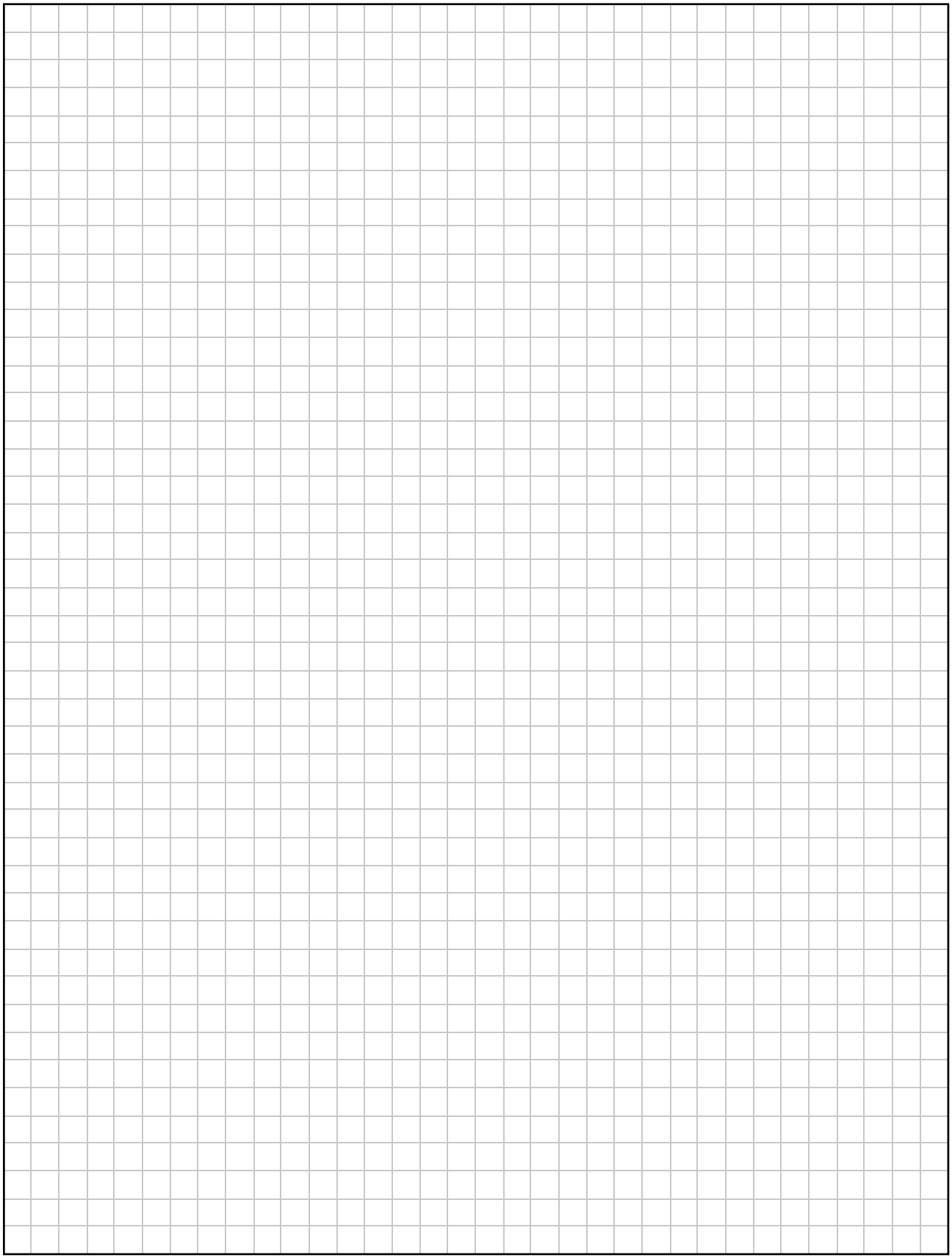

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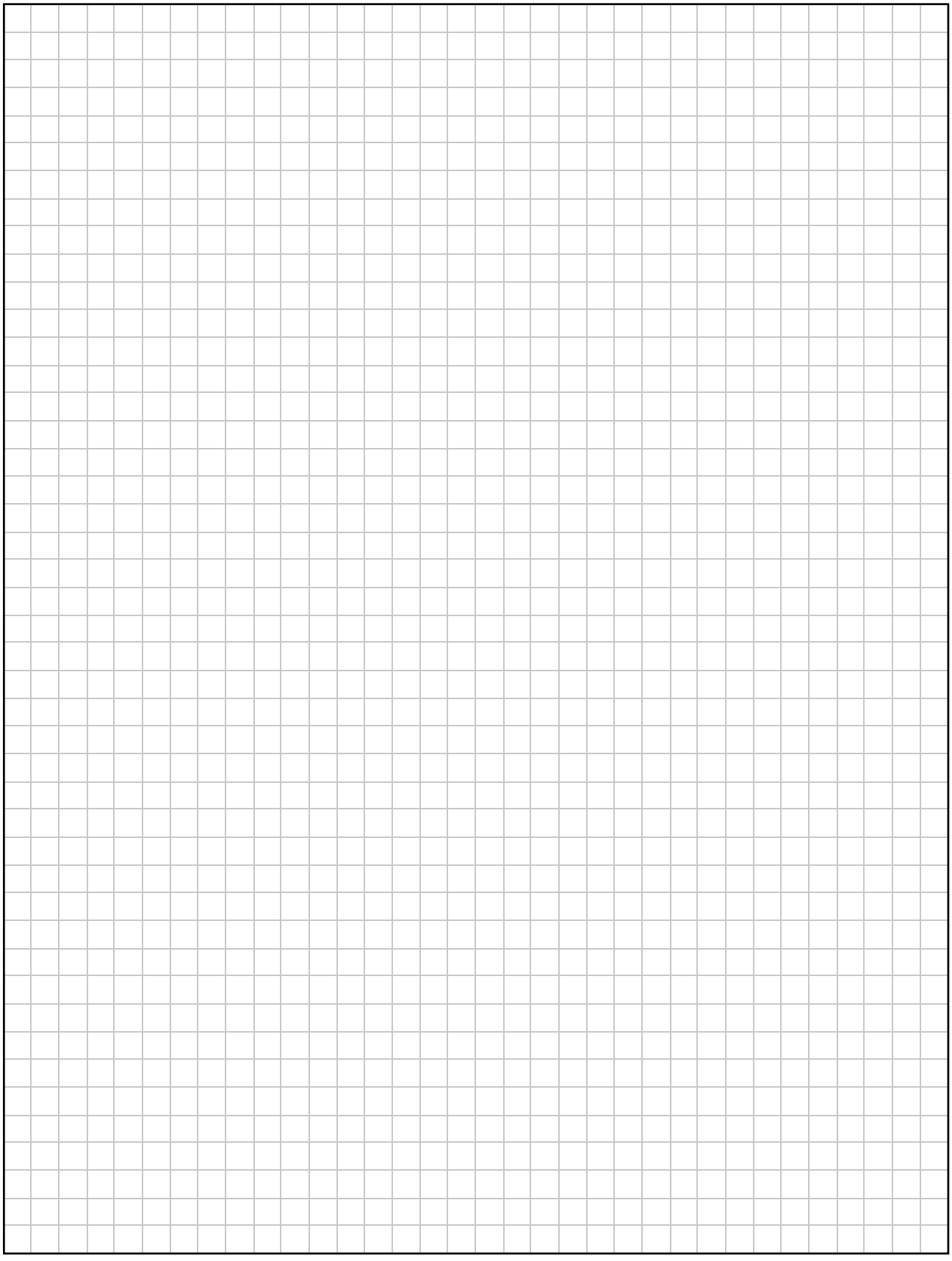

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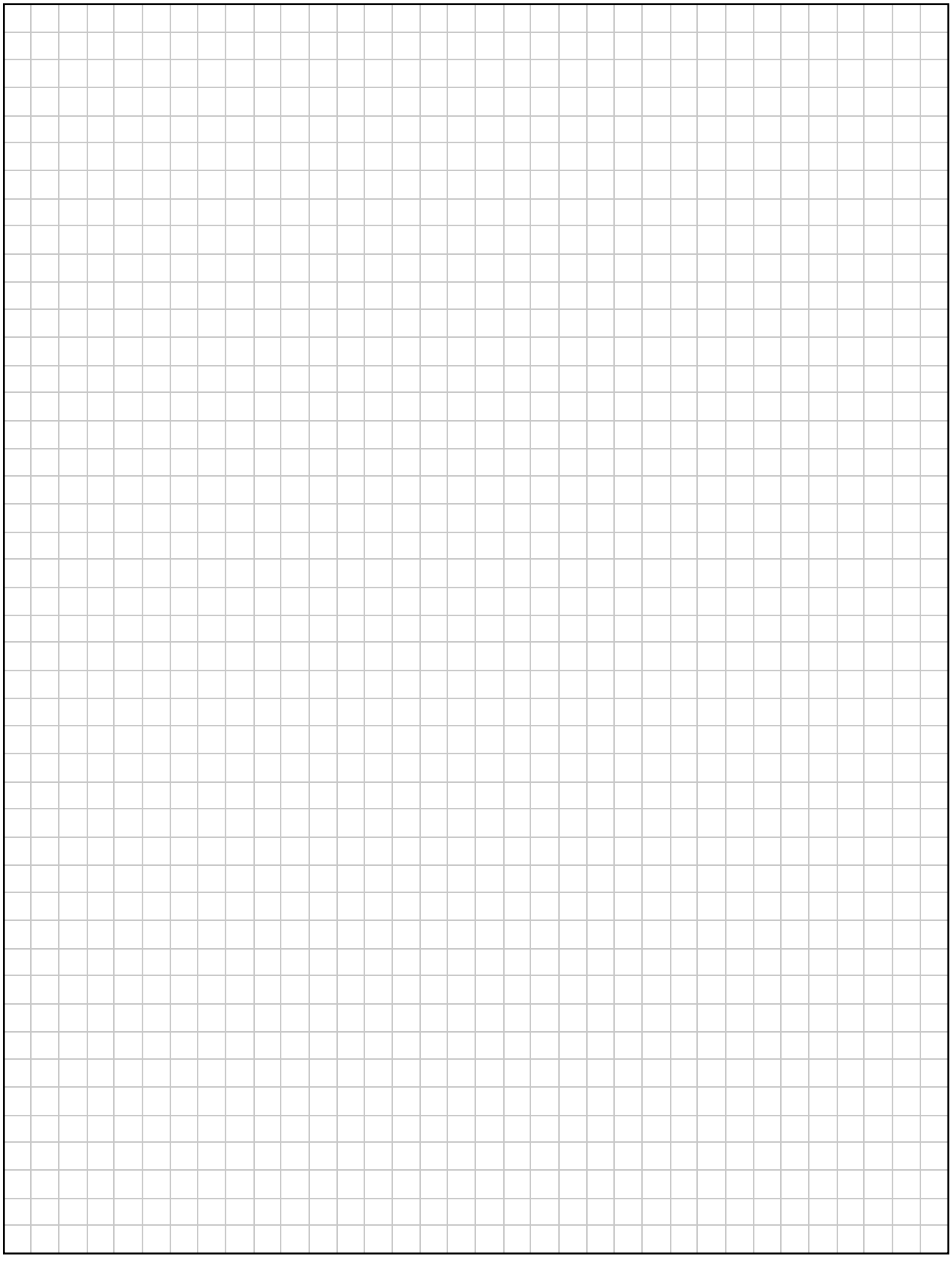

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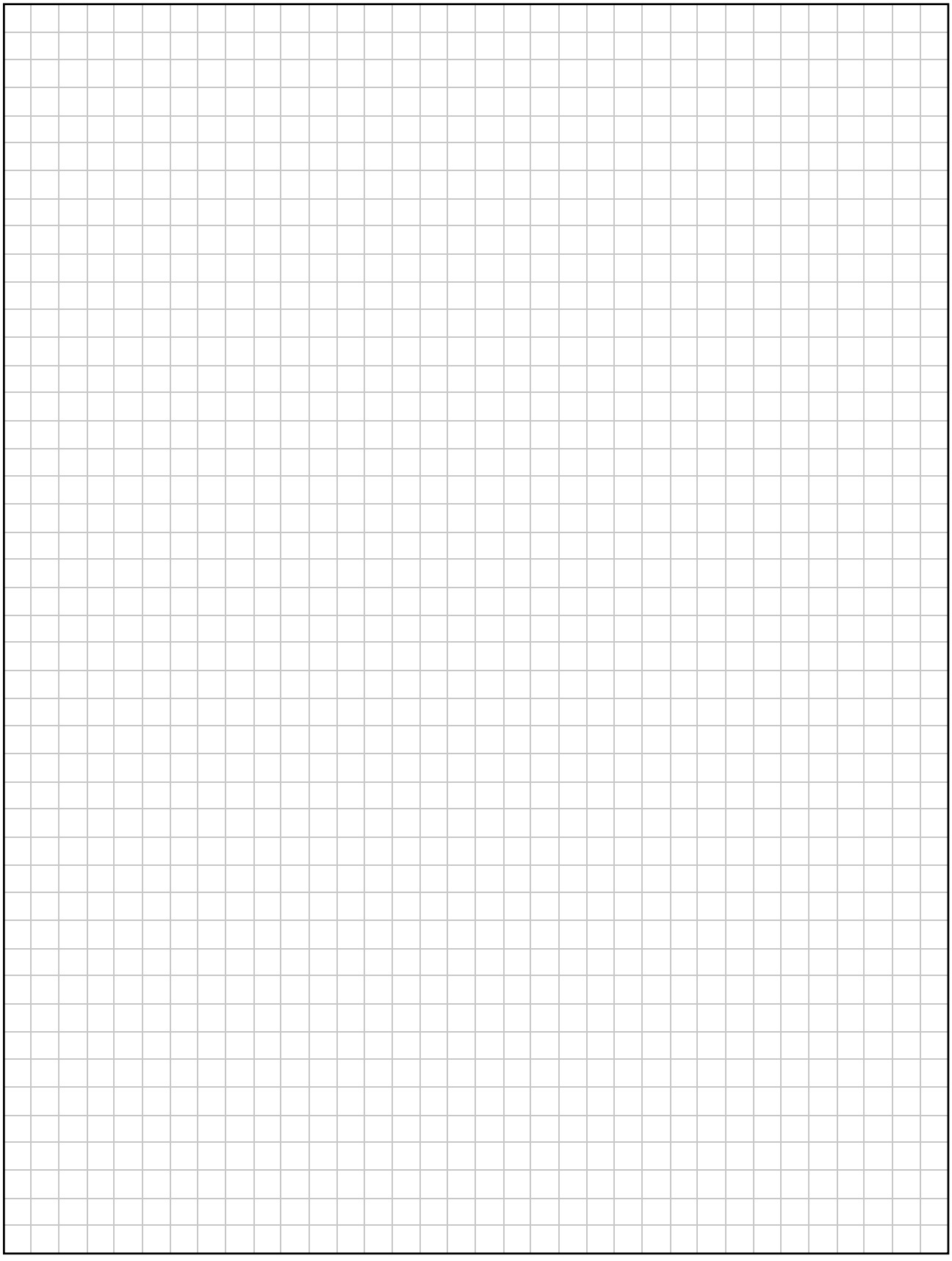

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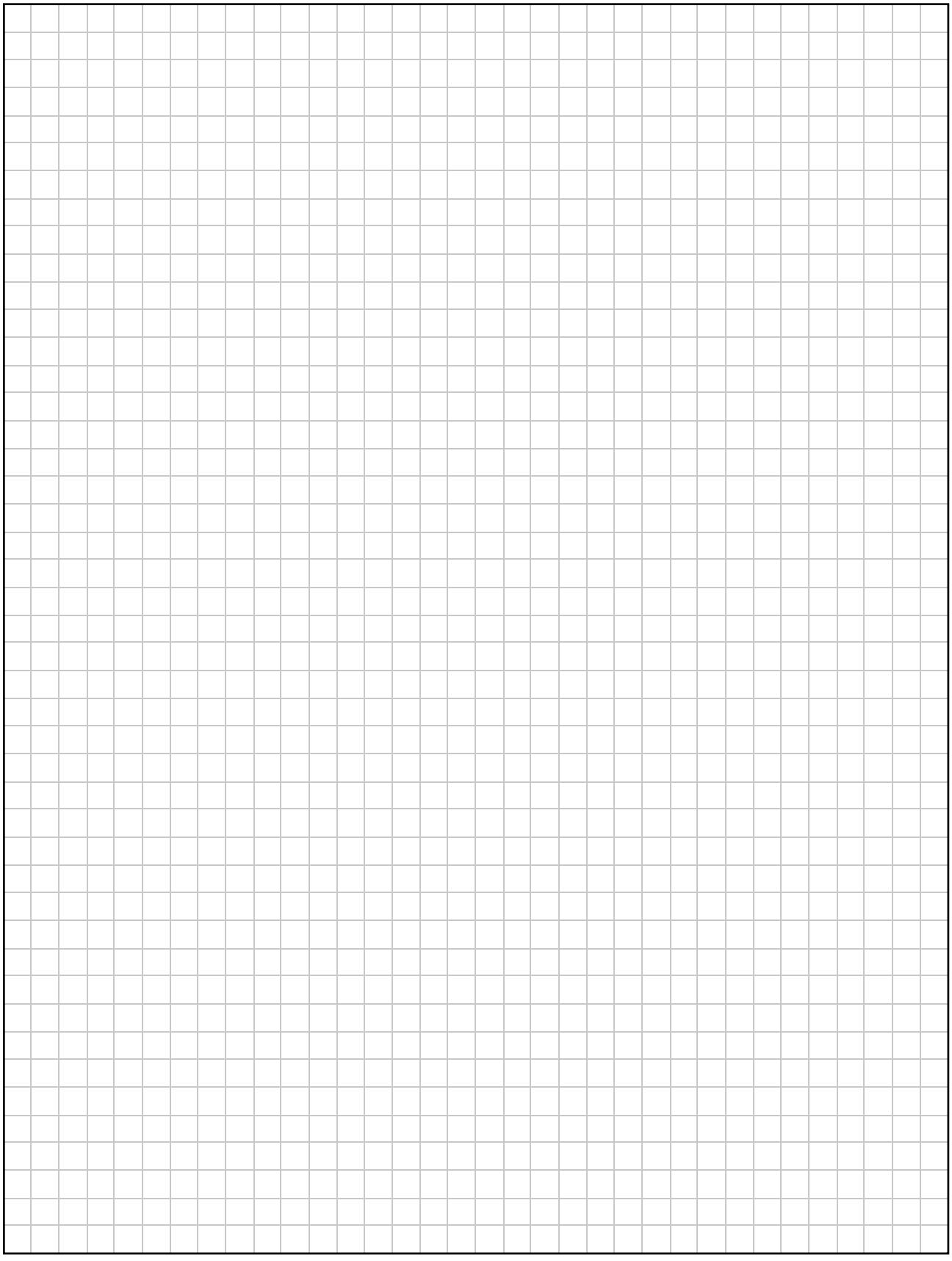

Acknowledgements

Images

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Leaving Certificate Examination – Higher Level

Physics

Sample 1

2 hours 30 minutes