EXAM PAPER

Physics Unit 3 & 4 — Practice Exam 1

Reading time: 15 minutes (no writing)
Writing time: 150 minutes
Total time: 165 minutes

SECTIONS IN THIS PAPER

- Section A — multiple choice — 25 min (calculator allowed) — 20 questions, 20 marks
- Section B — short answer — 125 min (calculator allowed) — 15 questions, 100 marks

A formula sheet is printed at the end of this paper.

INSTRUCTIONS

You are not permitted to write during reading time — you may only read the paper and plan your approach. Answer every question you can. Write your working in the space provided for long-answer questions. Marking guidance and full explanations are provided in the separate answer key.

Section A — multiple choice

25 minutes • Calculator allowed

INSTRUCTIONS

- Answer all questions.
- Choose the response that is correct or that best answers the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will not be deducted for incorrect answers.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1

A book rests on a horizontal table. According to Newton’s third law, the force that pairs with the gravitational force of Earth on the book is

A. the normal force of the table on the book
B. the gravitational force of the book on Earth
C. the normal force of the book on the table
D. the weight of the table

Question 2

A ball is kicked from level ground with a speed of 20.0 m s^{-1} at 30.0° above the horizontal. Ignoring air resistance, the ball is in the air for

A. 1.02 s
B. 1.77 s
C. 2.04 s
D. 3.53 s

Question 3

A curve on a racetrack has a radius of 80.0 m and is banked at 12.0° to the horizontal. The speed at which a car can take the curve with no sideways friction is closest to

A. 4.12 m s^{-1}
B. 12.9 m s^{-1}
C. 28.0 m s^{-1}
D. 60.8 m s^{-1}

Question 4

A 2.0 kg trolley moving at 3.0 m s^{-1} collides with a stationary 1.0 kg trolley. The trolleys stick together. The kinetic energy lost in the collision is

A. 0 J
B. 3.0 J
C. 6.0 J
D. 9.0 J

Question 5

A spring with spring constant 200 N m^{-1} is compressed by 0.10 m and used to launch a 0.050 kg ball along a smooth horizontal surface. The speed of the ball as it leaves the spring is

A. 4.47 m s^{-1}
B. 6.32 m s^{-1}
C. 8.94 m s^{-1}
D. 20.0 m s^{-1}

Question 6

A satellite orbits at an altitude of 6.37×10^6 m above Earth's surface. The strength of Earth's gravitational field at the satellite is closest to

A. 2.45 N kg^{-1}
B. 4.91 N kg^{-1}
C. 9.81 N kg^{-1}
D. 19.6 N kg^{-1}

Question 7

A charge $+Q$ and a charge $+4Q$ are fixed 3.0 m apart. At a point P on the line between them, the electric field is zero. The distance of P from the $+4Q$ charge is

A. 0.75 m
B. 1.0 m
C. 1.5 m
D. 2.0 m

Question 8

An electron moves to the right across the page through a uniform magnetic field directed into the page. As it enters the field, the magnetic force on the electron is directed

A. into the page
B. out of the page
C. towards the top of the page
D. towards the bottom of the page

Question 9

Which one of the following statements about gravitational, electric and magnetic fields is correct?

A. Electric field lines begin on positive charges and end on negative charges.
B. Gravitational forces can be attractive or repulsive.
C. An isolated magnetic pole produces a radial magnetic field.
D. A stationary charged particle in a uniform magnetic field experiences a force perpendicular to the field.

Question 10

An ideal transformer has 1200 turns on its primary coil and 60 turns on its secondary coil. The primary is connected to a 240 V RMS supply. The peak voltage across the secondary is closest to

A. 8.49 V
B. 12.0 V
C. 17.0 V
D. 339 V

Question 11

The rate at which the coil of an AC generator rotates is doubled. The magnetic field and the coil are unchanged. Which one of the following gives the effect on the output?

	Peak EMF	**Frequency of the output**
A.	unchanged	doubled
B.	doubled	unchanged
C.	halved	doubled
D.	doubled	doubled

Question 12

A power station transmits 50 kW at 5000 V through transmission lines with a total resistance of 4.0 Ω. The power lost in the lines is

A. 40 W
B. 400 W
C. 4.0 kW
D. 6.25 MW

Question 13

In a DC motor, the split-ring commutator

A. reverses the direction of the current in the coil every half-turn, so the coil keeps turning in the same direction
B. keeps the current in the coil flowing in the same direction at all times
C. increases the magnetic field whenever the coil is parallel to it
D. stops the coil at the position where the net force on it is zero

Question 14

Light of wavelength 600 nm passes through two slits 0.40 mm apart and falls on a screen 2.0 m away. The distance between adjacent bright bands on the screen is

A. 0.30 mm
B. 1.5 mm
C. 3.0 mm
D. 6.0 mm

Question 15

In a photoelectric experiment, the intensity of the light is increased while its frequency is kept constant (and above the threshold frequency). Which one of the following gives the effect?

	Maximum kinetic energy of photoelectrons	**Photocurrent**
A.	unchanged	increases
B.	increases	increases
C.	increases	unchanged
D.	unchanged	unchanged

Question 16

An electron is accelerated from rest through a potential difference of 150 V. Its de Broglie wavelength is closest to

A. 4.01×10^{-20} m

B. 7.09×10^{-11} m

C. 1.00×10^{-10} m

D. 8.28×10^{-9} m

Question 17

The energy levels of hydrogen are $E_n = -\frac{13.6}{n^2}$ eV. The wavelength of the photon emitted when an electron moves from the $n = 3$ level to the $n = 1$ level is closest to

A. 91.3 nm

B. 97.4 nm

C. 103 nm

D. 122 nm

Question 18

Muons have a lifetime of 2.2 μs in their own frame of reference. For muons travelling at $0.98c$, the lifetime measured by an observer on Earth is closest to

A. 0.44 μs

B. 2.2 μs

C. 5.0 μs

D. 11 μs

Question 19

Which one of the following is one of Einstein's two postulates of special relativity?

A. The laws of physics are different in frames of reference moving at different constant velocities.

B. Time passes at the same rate for all observers.

C. The speed of light depends on the speed of its source.

D. The speed of light in a vacuum is the same for all observers in inertial frames of reference.

Question 20

A student measures the period of a swinging pendulum by timing 10 complete oscillations and dividing by 10, rather than timing a single oscillation. The main reason for this is to

A. reduce the effect of the uncertainty in starting and stopping the stopwatch on the period

B. remove any systematic error from the stopwatch

C. increase the precision of the length measurement

D. allow for the period changing during the first few swings

Section B — short answer

125 minutes • Calculator allowed

INSTRUCTIONS

- Answer all questions in the spaces provided.
- Write your responses in English.
- Where an answer box is provided, write your final answer in the box.
- If an answer box has a unit printed in it, give your answer in that unit.
- In questions where more than one mark is available, appropriate working must be shown.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1

(5 marks)

A 3.0 kg block on a horizontal table is connected by a light string passing over a pulley to a 1.0 kg block that hangs freely, as shown in Figure 1. The system is released from rest. Ignore friction and the mass of the pulley.

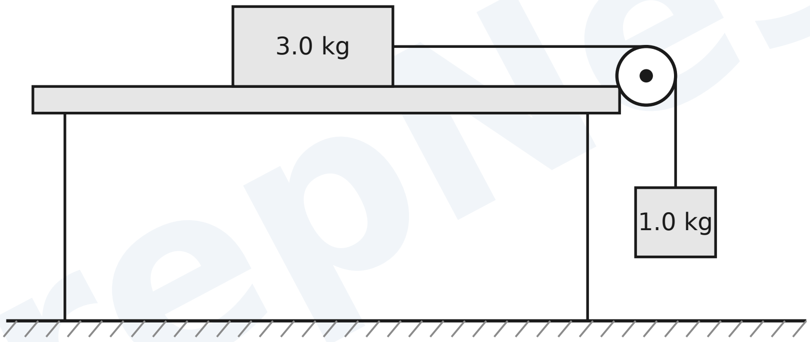


Figure 1

a. Show that the magnitude of the acceleration of the blocks is 2.45 m s^{-2}. 2 marks

b. Calculate the tension in the string. 2 marks

N

c. Explain why the tension in the string is less than the weight of the hanging block. 1 mark

Question 2

(7 marks)

A soccer ball is kicked from ground level with a speed of 18.0 m s^{-1} at 35.0° above the horizontal, towards a wall 2.40 m high that is 25.0 m away, as shown in Figure 2. Ignore air resistance and the size of the ball.

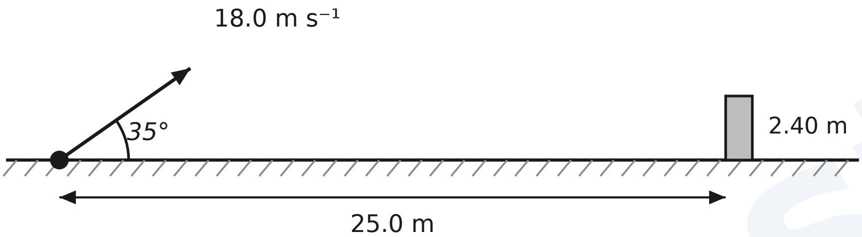


Figure 2

a. Calculate the horizontal and vertical components of the ball's initial velocity. 1 mark

b. Determine whether the ball passes over the wall. Show your working. 3 marks

c. Calculate the maximum height reached by the ball. 2 marks

m

d. State the ball's speed at its highest point. 1 mark

m s^{-1}

Question 3

(6 marks)

A roller-coaster car of mass 400 kg travels around a vertical circular loop of radius 8.0 m, as shown in Figure 3. At the top of the loop the car is upside down and moving at 12 m s^{-1}.

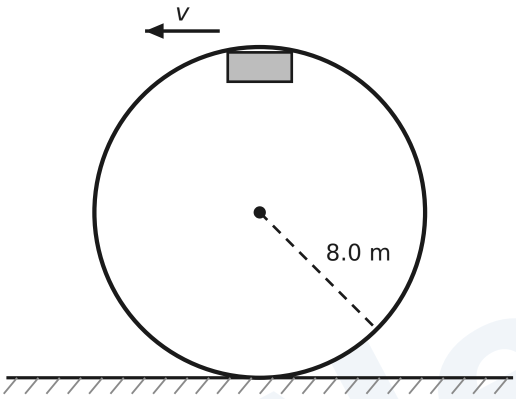


Figure 3

a. Calculate the magnitude and direction of the net force on the car at the top of the loop. 2 marks

b. Calculate the magnitude of the normal force exerted on the car by the track at the top of the loop. 2 marks

N

c. Calculate the minimum speed at which the car can travel over the top of the loop without losing contact with the track. 2 marks

m s^{-1}

Question 4

(5 marks)

In a crash test, a 1200 kg car travelling at 15 m s^{-1} hits a rigid barrier and comes to rest in 0.080 s.

a. Calculate the magnitude of the impulse on the car. 2 marks

N s

b. Calculate the magnitude of the average force exerted on the car by the barrier. 1 mark

N

c. Car designers build crumple zones into the front of cars. Using physics principles, explain how a crumple zone reduces the average force on the occupants in a collision. 2 marks

Question 5

(7 marks)

A navigation satellite moves in a circular orbit around Earth with a period of 12.0 hours.

a. Show that the radius of the satellite's orbit is approximately 2.66×10^7 m. 3 marks

b. Calculate the orbital speed of the satellite. 2 marks

m s^{-1}

c. An astronaut on a space station in orbit feels weightless. Explain why, even though Earth's gravitational field at the station is not zero. 2 marks

Question 6

(5 marks)

Two parallel metal plates 2.0 cm apart are connected to a 500 V supply, as shown in Figure 4. An electron is released from rest close to the negative plate.

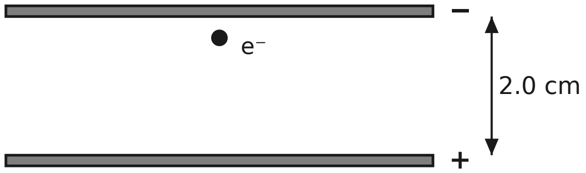


Figure 4

a. Calculate the magnitude of the electric field between the plates. 1 mark

V m^{-1}

b. Calculate the magnitude of the electric force on the electron. 1 mark

N

c. Calculate the speed of the electron when it reaches the positive plate. 3 marks

m s⁻¹

Question 7

(6 marks)

In a mass spectrometer, singly charged positive ions (charge $+1.60 \times 10^{-19}$ C) enter a uniform magnetic field of strength 0.50 T at a speed of 2.0×10^{5} m s⁻¹. They travel in a semicircle and strike a detector, as shown in Figure 5.

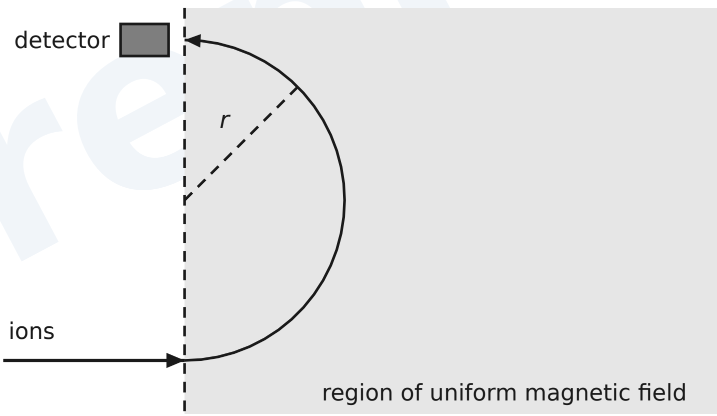


Figure 5

a. State the direction of the magnetic field in the region shown in Figure 5. 1 mark

b. The radius of the ions' path is 8.3 cm. Calculate the mass of one ion. 2 marks

kg

c. Explain why the magnetic field does not change the speed of the ions. 2 marks

d. Ions of a heavier isotope, with the same charge and speed, are also in the beam. Describe how their path differs. 1 mark

Question 8

(8 marks)

Figure 6 shows the coil of a simple DC motor between the poles of a magnet. The square coil JKLM has 50 turns and sides of length 4.0 cm, and lies in the plane of the page in a uniform magnetic field of 0.20 T directed from N to S. The coil can rotate about the axis shown. A current of 1.5 A flows through the coil in the direction J → K → L → M.

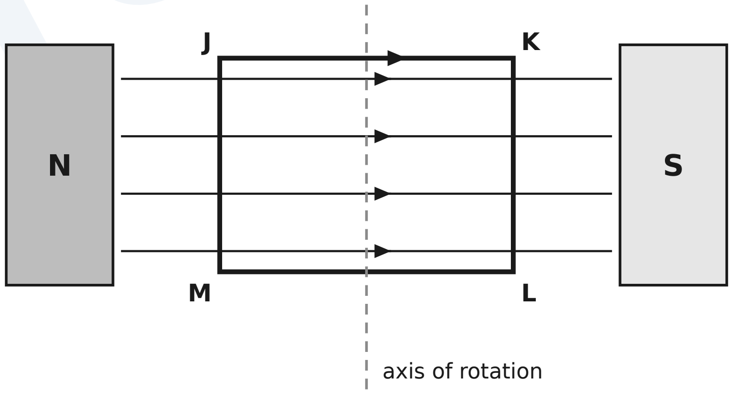


Figure 6

a. Calculate the magnitude of the magnetic force on side KL. 2 marks

N

b. State the magnitude of the magnetic force on side JK, and explain your answer. 2 marks

c. State whether side KL begins to move into or out of the page, and explain how this makes the coil rotate. 2 marks

d. Explain the role of the split-ring commutator in keeping the coil rotating in one direction. 2 marks

Question 9

(8 marks)

A simple AC generator has a coil of 100 turns and area 0.010 m². It rotates at 50 revolutions per second in a uniform magnetic field of 0.30 T. At time $t = 0$ the plane of the coil is perpendicular to the magnetic field.

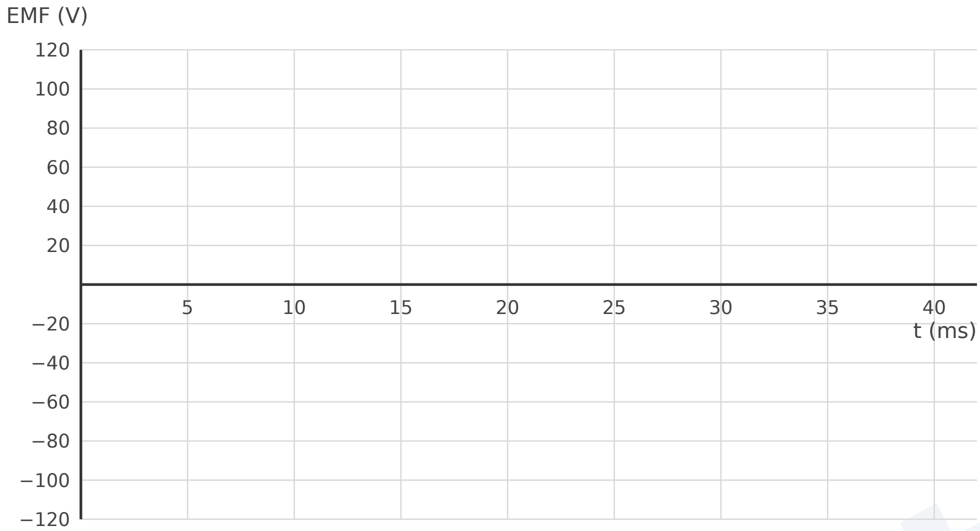
a. Calculate the maximum magnetic flux through the coil. 1 mark

Wb

b. Calculate the average EMF induced in the coil during the first quarter-turn. 2 marks

V

c. The peak EMF is 94 V. On the axes below, sketch the EMF produced by the generator for the first two revolutions, starting at $t = 0$. Label the peak values. 3 marks



d. The slip rings of the generator are replaced by a split-ring commutator. Describe how the output changes. 2 marks

Question 10

(8 marks)

A wind farm generator produces 400 kW of power at 690 V RMS. A step-up transformer T_1 with a turns ratio of 1 : 20 raises the voltage for transmission along lines with a total resistance of 5.0 Ω to a step-down transformer T_2 in a nearby town, as shown in Figure 7. Treat the transformers as ideal.

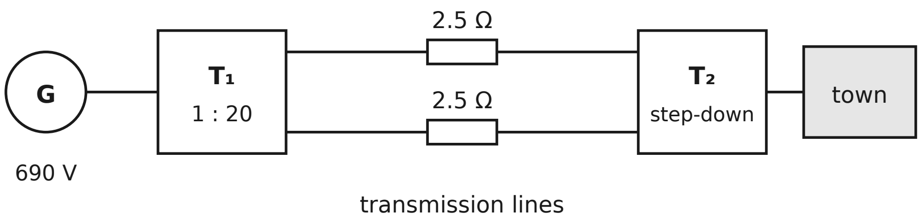


Figure 7

a. Calculate the RMS current in the transmission lines. 2 marks

A

b. Calculate the power lost in the transmission lines. 2 marks

W

c. Calculate the voltage at the input of T_2. 1 mark

V

d. Without the transformers, the 400 kW would be sent at 690 V along the same lines. Use a calculation to explain why this would not work. 3 marks

Question 11

(7 marks)

Green laser light of wavelength 532 nm passes through two narrow slits 0.25 mm apart. An interference pattern of bright and dark bands forms on a screen 2.0 m away, as shown in Figure 8.

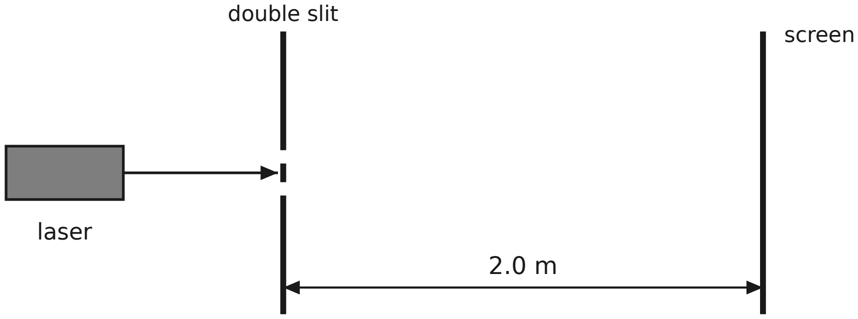


Figure 8

a. Calculate the distance between adjacent bright bands on the screen. 2 marks

m

b. Calculate the path difference between the light from the two slits at the third dark band from the centre of the pattern. 2 marks

m

c. Explain how this pattern provides evidence for the wave model of light. 2 marks

d. The green laser is replaced by a red laser. State the effect on the pattern. 1 mark

Question 12

(7 marks)

In a photoelectric experiment, light of different frequencies falls on a metal surface and the maximum kinetic energy of the emitted photoelectrons is measured. The results are shown in Figure 9.

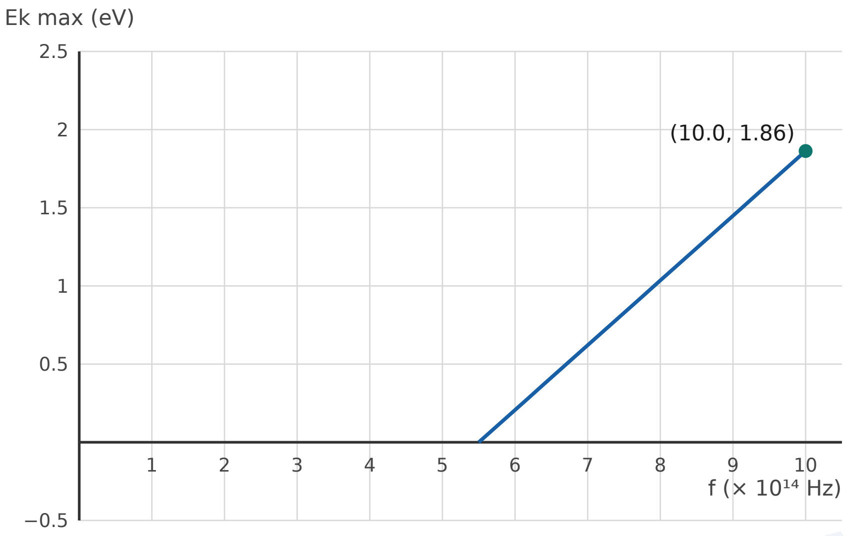


Figure 9

a. State the threshold frequency of the metal. 1 mark

Hz

b. Calculate the work function of the metal, in electronvolts. 2 marks

eV

c. State what the gradient of the graph represents. 1 mark

d. Calculate the maximum speed of the photoelectrons when the light has a frequency of 7.5×10^{14} Hz. 2 marks

m s⁻¹

e. Very bright light of frequency 4.0×10^{14} Hz shines on the metal. Explain why no photoelectrons are emitted. 1 mark

Question 13

(5 marks)

In the Davisson–Germer experiment, electrons accelerated from rest through 54 V were diffracted by a nickel crystal.

a. Show that the de Broglie wavelength of the electrons is 1.67×10^{-10} m. 2 marks

b. X-rays produce the same diffraction pattern with the same crystal. Calculate the energy of one X-ray photon, in keV. 2 marks

keV

c. Explain why an electron and a photon with the same wavelength produce the same diffraction pattern. 1 mark

Question 14

(6 marks)

A spacecraft travels at a constant speed of $0.90c$ from Earth to a star that is 12 light-years from Earth, as measured by observers on Earth.

a. Calculate the time taken for the journey according to observers on Earth. 1 mark

years

b. Calculate the time taken for the journey according to the crew. 2 marks

years

c. Calculate the distance between Earth and the star as measured by the crew. 2 marks

light-years

d. Explain which observers measure the proper time for the journey. 1 mark

Question 15

(10 marks)

Students investigate the force on a current-carrying wire. A straight horizontal wire of length 5.0 cm runs between the poles of a magnet that sits on an electronic balance. When a current flows, the balance reading changes, and the students convert the change in mass Δm to a force $F = \Delta m \times g$. Their results are shown in Table 1.

Table 1

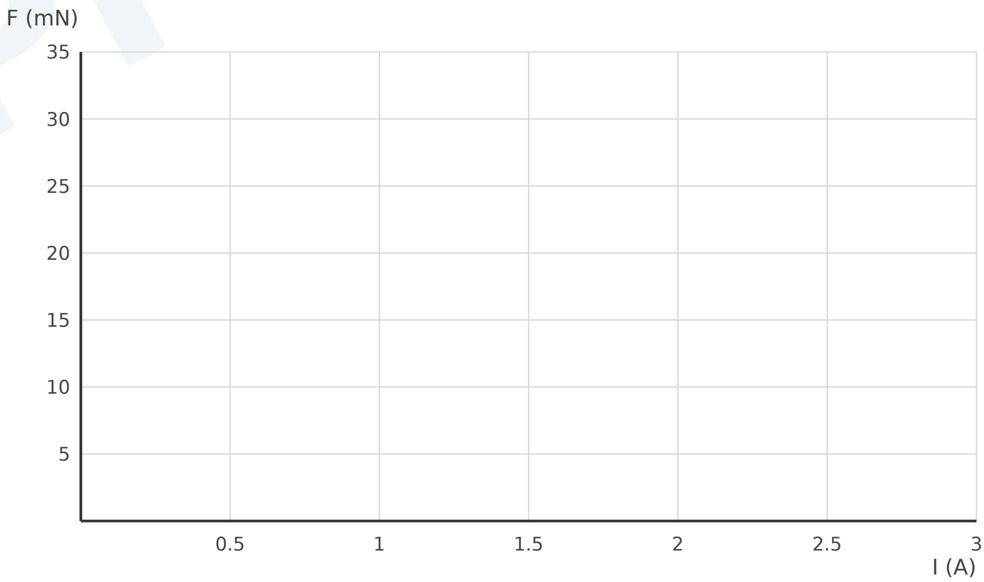
I (A)	**Δm (g)**	**F (mN)**
0.50	0.62	6.08
1.00	1.20	
1.50	1.85	18.15
2.00	2.43	23.84
2.50	3.05	29.92

a. Identify the independent variable, the dependent variable and one variable that must be controlled. 2 marks

b. Calculate the missing value of F, in mN. 1 mark

mN

c. On the axes below, plot F against I and draw a line of best fit. 3 marks



d. Use the gradient of your line to calculate the strength of the magnetic field. 2 marks

e. The students suspect the magnet's poles do not cover the full 5.0 cm of wire. State the type of error this would introduce and its effect on their value of B. 2 marks

Physics formulas

Motion and related energy transformations

velocity; acceleration	$v = \frac{\Delta s}{\Delta t}; \quad a = \frac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at \qquad s = ut + \frac{1}{2}at^2 \qquad s = vt - \frac{1}{2}at^2$
	$v^2 = u^2 + 2as \qquad s = \frac{1}{2}(u+v)t$
Newton's second law	$\Sigma F = ma$
uniform circular motion	$F_{\text{net}} = \frac{mv^2}{r}; \quad v = \frac{2\pi r}{T}$
Hooke's law	$F = -kx$
elastic potential energy	$E_s = \frac{1}{2}kx^2$
gravitational potential energy	$E_g = mg\Delta h$
kinetic energy	$E_k = \frac{1}{2}mv^2$
Newton's law of universal gravitation	$F_g = G\frac{m_1 m_2}{r^2}$
gravitational field	$g = G\frac{M}{r^2}$
impulse	$F\Delta t = m\Delta v$
momentum	$p = mv$

Einstein's special theory of relativity

Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
time dilation	$t = t_0\gamma$
length contraction	$L = \frac{L_0}{\gamma}$
relativistic rest energy	$E_0 = mc^2$
relativistic total energy	$E_{\text{total}} = E_k + E_0 = \gamma mc^2$
relativistic kinetic energy	$E_k = (\gamma - 1)mc^2$

Fields and application of field concepts	
electric field between charged plates	$E = \dfrac{V}{d}$
energy transformations of charges in an electric field	$\frac{1}{2}mv^2 = qV$
field of a point charge	$E = \dfrac{kQ}{r^2}$
electric force on a charged particle	$F = qE$
Coulomb's law	$F = \dfrac{kq_1q_2}{r^2}$
magnetic force on a moving charge	$F = qvB$
magnetic force on a current-carrying conductor	$F = nIlB$
radius of a charged particle in a uniform magnetic field	$r = \dfrac{mv}{qB}$

Generation and transmission of electricity	
current; power	$I = \dfrac{V}{R}; \quad P = VI$
resistors in series	$R_T = R_1 + R_2 + \cdots$
resistors in parallel	$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots$
ideal transformer action	$\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$
AC voltage and current	$V_{\text{RMS}} = \dfrac{1}{\sqrt{2}}V_{\text{peak}} \qquad I_{\text{RMS}} = \dfrac{1}{\sqrt{2}}I_{\text{peak}}$
electromagnetic induction	$\varepsilon = -N\dfrac{\Delta\Phi_B}{\Delta t} \qquad \Phi_B = B_{\perp}A$
transmission losses	$V_{\text{drop}} = I_{\text{line}}R_{\text{line}} \qquad P_{\text{loss}} = I_{\text{line}}^2R_{\text{line}}$

Waves	
wave equation	$v = f\lambda$
constructive interference	path difference $= n\lambda$
destructive interference	path difference $= \left(n + \frac{1}{2}\right)\lambda$
interference pattern spacing	$\Delta x = \dfrac{\lambda L}{d}$ when $L \gg d$

The nature of light and matter	
photoelectric effect	$E_{k\,\max} = hf - \phi$
photon energy	$E = hf = \dfrac{hc}{\lambda}$
photon momentum	$p = \dfrac{h}{\lambda}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

Data		
acceleration due to gravity at Earth's surface	$g = 9.81\ \mathrm{m\,s^{-2}}$	
mass of the electron	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$	
magnitude of the charge of the electron	$q_e = 1.60 \times 10^{-19}\ \mathrm{C}$	
Planck's constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$	$h = 4.14 \times 10^{-15}\ \mathrm{eV\,s}$
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$	
universal gravitation constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$	
mass of Earth	$M_E = 5.97 \times 10^{24}\ \mathrm{kg}$	
radius of Earth	$R_E = 6.37 \times 10^{6}\ \mathrm{m}$	
Coulomb constant	$k = 8.99 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$	

Metric (SI) multipliers			
p = pico = 10^{-12}	n = nano = 10^{-9}	µ = micro = 10^{-6}	m = milli = 10^{-3}
k = kilo = 10^{3}	M = mega = 10^{6}	G = giga = 10^{9}	T = tera = 10^{12}

Unit conversions	
1 tonne (t) $= 10^3$ kg	1 kilowatt hour (kW h) $= 3.6 \times 10^6$ J

Nomenclature	
force due to gravity	F_g
terminology for force	$F_{\mathrm{on\ A\ by\ B}}$
normal force	F_N

END OF FORMULA SHEET