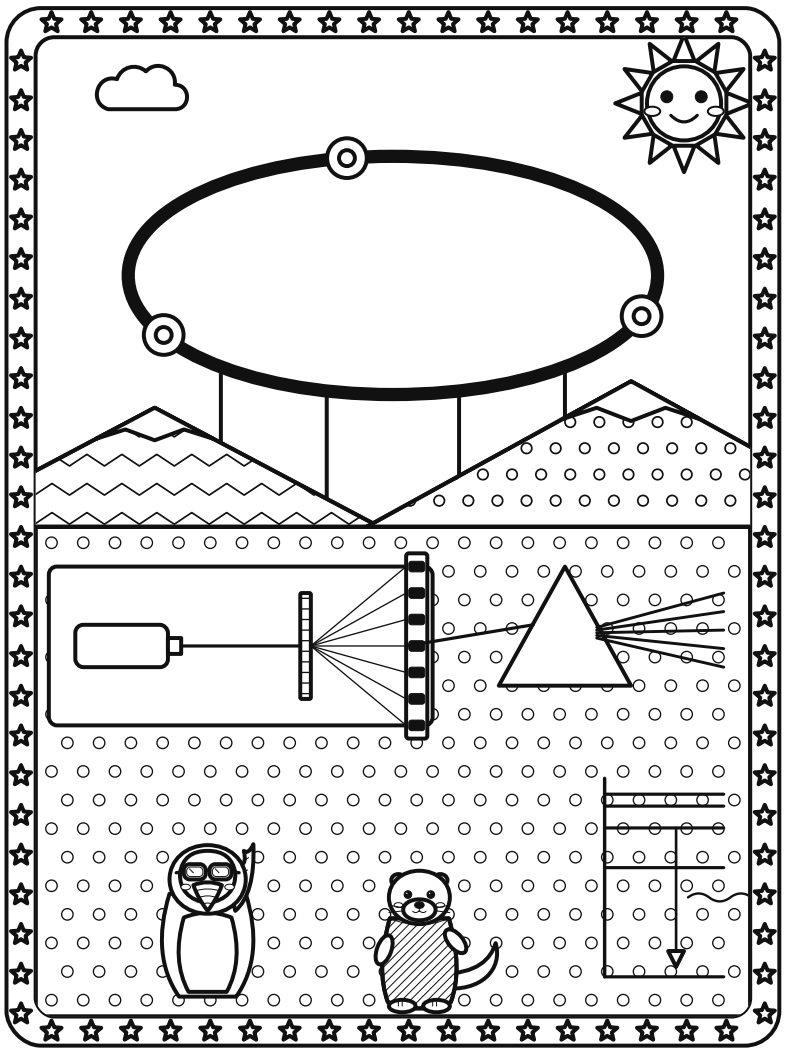
REAL-LIFE PHYSICS

Particles and Waves

Workbook for Higher Physics

Unit: Particles and Waves



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Blewis LEARNING

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How to use this book

This book covers Particles and Waves for Higher Physics: forces on charged particles, the standard model, nuclear reactions, the inverse square law, wave-particle duality, interference, spectra and refraction. Each topic follows the same pattern, so you always know what comes next.

EACH TOPIC HAS

Opener	the story for the topic, what you will learn and the key words
Learn pages	short explanations with diagrams, and questions to try
Practical	You plan the investigation yourself, carry it out safely, take repeat readings, draw a graph and evaluate your method.
Brain break	a calm puzzle or colouring page
Check-up	a few questions to show what you know, and a checklist

PRACTICAL WORK: STAY SAFE

- Only start a practical when an adult says it is OK.
- Read the whole method and the Stay safe table first.
- Tell your teacher about anything that might affect you, like asthma or an allergy.
- Stop and tell an adult if you feel unwell or something goes wrong.

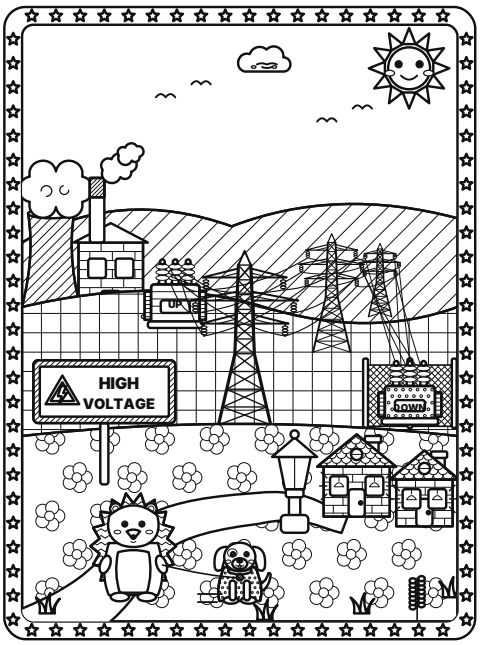
NO LAB TODAY?

Every practical has a set of example results. If you could not do the experiment, use these to finish the results, graph and conclusion.

DOODLE CORNERS

Some pages have a doodle corner. Colour it or doodle in it when you need a short break.

Forces on charged particles



An X-ray tube in a hospital and a ring 27 km round under the Alps both do the same job: they push charged particles with electric fields. How?

Theme: the Port Arrin hospital radiotherapy unit. Mhairi is on work experience with the medical physics team. Their linear accelerator fires fast electrons at a metal target to make X-rays for treating tumours, and she has to explain to visitors how it works.

IN THIS TOPIC YOU WILL LEARN TO

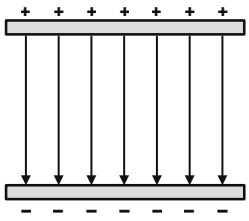
Skill 1	describe electric fields and use $W = Q\,V$ to find the work done on a charge
Skill 2	combine $W = Q\,V$ with $E_k = \frac{1}{2} m v^2$ for charges accelerated by a p.d.
Skill 3	predict the path of a charge in a magnetic field and explain how particle accelerators work

KEY WORDS

Electric field	a region where a charge feels a force
Potential difference	work done per unit charge between two points; 1 V = 1 J/C
Uniform field	same strength and direction everywhere, as between parallel plates
Electron gun	accelerates electrons from rest through a p.d.
Magnetic force	acts at right angles to the field and the motion of a moving charge
Accelerator	uses electric fields to speed particles up and magnetic fields to steer them

❶ Electric fields and work

A charge in an **electric field** feels a force. Field lines show the direction of the force on a small **positive** charge. Between two parallel plates the field is **uniform**: the lines are straight, parallel and evenly spaced. Electrons are pushed the opposite way to the lines.



RELATIONSHIP

$$W = Q\,V$$

W	work done in joules (J)
Q	charge in coulombs (C)
V	potential difference in volts (V)

WORKED EXAMPLE

A charge of 4.0×10^{-6} C moves between two plates with a p.d. of 250 V. How much work is done?

Relationship $W = Q\,V$

Substitute $W = 4.0 \times 10^{-6} \times 250$

Answer $\mathbf{W = 1.0 \times 10^{-3}\ J}$

1 Sketch the field between a positive plate (top) and a negative plate (bottom). Show at least five lines with arrows.

2 Calculate the work done when an electron (charge 1.60×10^{-19} C) moves through a p.d. of 4.5 kV.

Relationship

Substitute

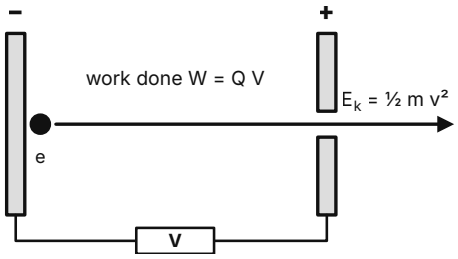
Answer

3 Define the volt in terms of work and charge.

Answer:

2 Accelerating charges

A charge accelerated **from rest** through a p.d. gains kinetic energy equal to the work done by the field: **$Q V = \frac{1}{2} m v^2$**. The heavier the particle, the slower it ends up for the same p.d. (for the same charge). Find the energy first, then rearrange for v and square-root at the end.



WORKED EXAMPLE

The radiotherapy electron gun accelerates electrons from rest through 6.0 kV. Find their speed.

Work done $W = Q V = 1.60 \times 10^{-19} \times 6000 = 9.6 \times 10^{-16}$ J

Energy $E_k = W$, so $\frac{1}{2} m v^2 = W$

Substitute $0.5 \times 9.11 \times 10^{-31} \times v^2 = 9.6 \times 10^{-16}$

Answer **$v = 4.6 \times 10^7$ m/s**

1 An electron is accelerated from rest through 800 V. Calculate its final speed. ($m_e = 9.11 \times 10^{-31}$ kg)

Work done

Substitute

Answer

2 A proton ($m = 1.673 \times 10^{-27}$ kg) leaves a gun at 5.0×10^5 m/s. Calculate the p.d. it was accelerated through.

Energy

Substitute

Answer

3 Show that an electron accelerated through 1.0 kV gains 1.6×10^{-16} J of kinetic energy.

Answer:

PRACTICAL 1

Data practical: the charge to mass ratio of the electron

AIM To use speeds of electrons from an electron gun to find the **CHARGE TO MASS RATIO** e/m of the electron.

High-voltage electron tubes are run by the teacher only, so this is a **data analysis practical**. A teacher measured the speed of the electrons leaving a gun at five different accelerating voltages.

1 Variables

Independent the variable the teacher changed	
Dependent the variable measured	
Controlled one variable kept the same	

2 The physics

Use $Q\,V = \tfrac{1}{2}\,m\,v^2$ to show that $v^2 = (2e/m) \times V$. What graph will give a straight line through the origin, and what does its gradient equal?

Answer:

3 Stay safe (in the real experiment)

The first row is done for you. Add two more hazards.

Hazard What could cause harm?	**Risk** What could happen?	**Control** How will I stay safe?
Several kV supply	Electric shock	Teacher-only set-up; shrouded leads; switch off before touching the tube.

Results and processing

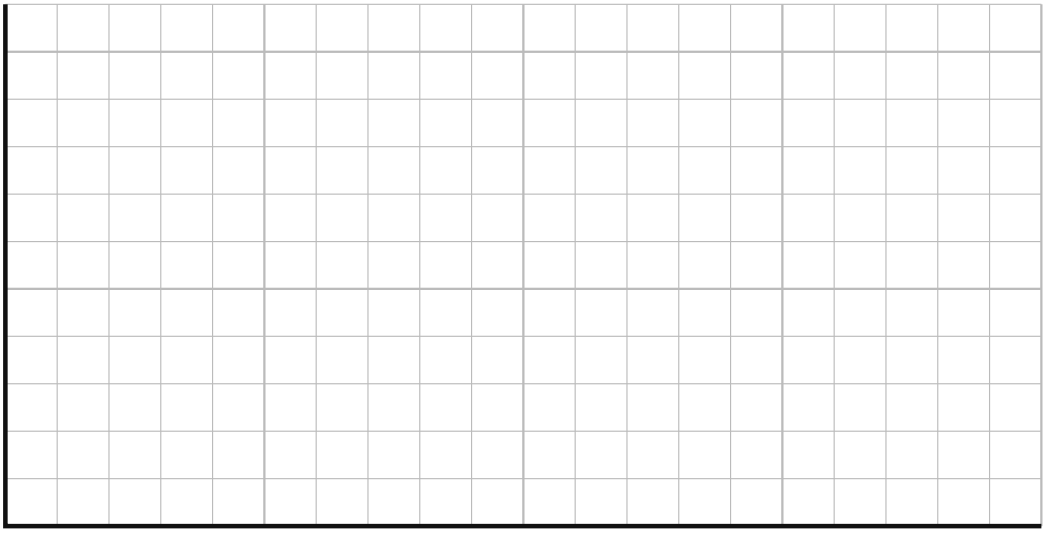
4 Process the data

Complete the table. Give v^2 to 3 significant figures.

Accelerating p.d. V (V)	Speed v (m/s)	v^2 (m^2/s^2)
500	1.33×10^7	
1000	1.86×10^7	
1500	2.30×10^7	
2000	2.66×10^7	
2500	2.95×10^7	

5 Draw the graph

Plot v^2 (y-axis) against V (x-axis). Choose your own scales, label both axes with units and draw a line of best fit.



UNCERTAINTIES

Random uncertainty = (max − min) ÷ number of readings. Scale-reading uncertainty: ± half the smallest division (analogue) or ± 1 in the last digit (digital). Percentage uncertainty = (uncertainty ÷ value) × 100. The largest percentage uncertainty dominates the final answer.

The speed meter reads to ± 0.02×10^7 m/s. Work out the percentage uncertainty in the smallest speed.

Answer:

Analyse and evaluate

6 Find e/m

Gradient =

Charge to mass ratio = gradient ÷ 2 =

a The accepted value is 1.76×10^{11} C/kg. Calculate the percentage difference between your value and this.

Difference

Percentage

Answer

7 Conclusion

The graph shows that

8 Evaluate

a Why is it better to find e/m from the gradient of a graph than from one pair of readings?

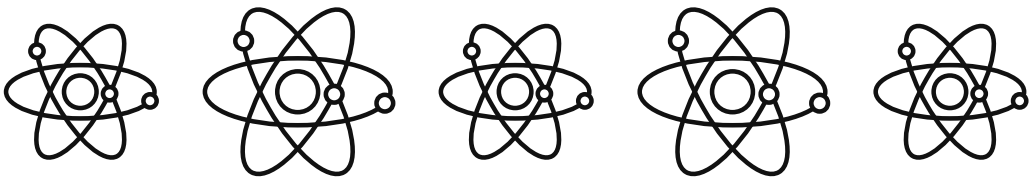
Answer:

b Suggest one source of systematic uncertainty in the real experiment, and its effect.

Answer:

> **ASSIGNMENT LINK**
> For an assignment you would quote the accepted value of e/m with its source and date, then compare your result with it.

DOODLE CORNER



FREE SAMPLE

Particles and Waves (Higher Physics)

This sample shows a few pages. The full printed workbook is available from Amazon.

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