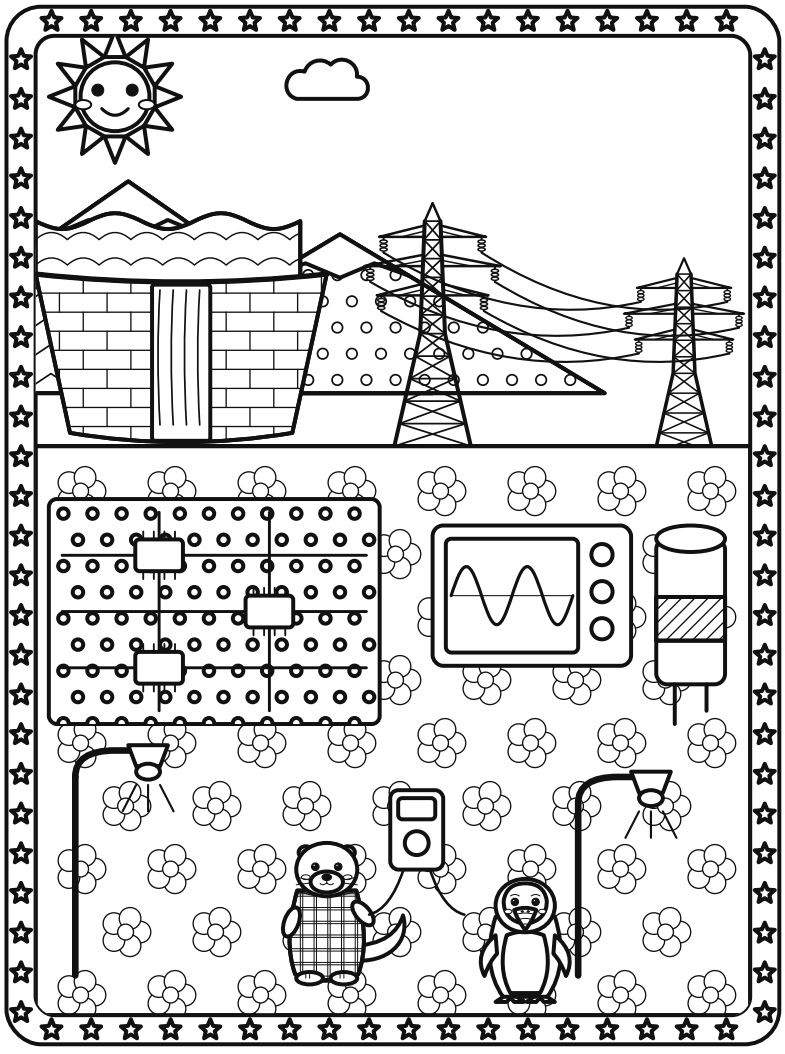
REAL-LIFE PHYSICS

Electricity

Workbook for Higher Physics

Unit: Electricity



C. Blewis

Blewis LEARNING

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How to use this book

This book covers Electricity for Higher Physics: monitoring and measuring a.c., current, potential difference, power and resistance, electrical sources and internal resistance, capacitors, and semiconductors and p-n junctions. 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.

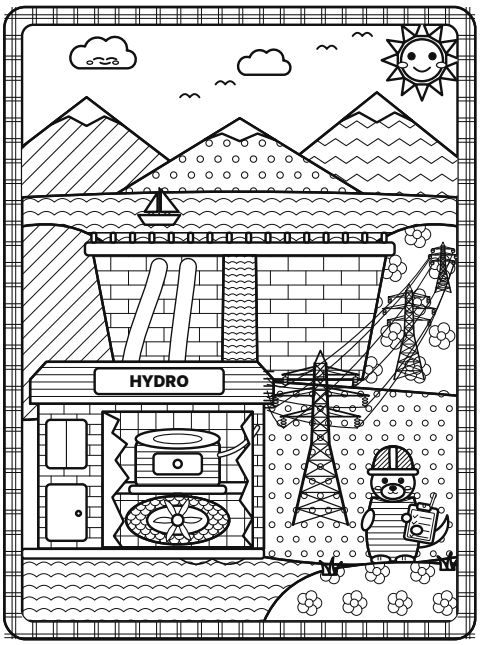
NO LAB TODAY?

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.

Monitoring and measuring a.c.



The Loch Arrin hydro dam sends alternating current to the grid. Why does a 230 V supply actually reach 325 V?

Theme: the Loch Arrin hydro dam. Ewan is an apprentice at the Loch Arrin hydro station. Before he can work on the control room equipment, he has to read a.c. signals on an oscilloscope and know exactly what every meter reading means.

IN THIS TOPIC YOU WILL LEARN TO

Skill 1	use peak and r.m.s. values for a.c.
Skill 2	measure peak p.d. and frequency on an oscilloscope
Skill 3	show by experiment how peak and r.m.s. values compare

KEY WORDS

Alternating current	current that keeps reversing direction
Peak value	the largest value, measured from zero
r.m.s. value	the d.c. value that gives the same power
Timebase	time for one horizontal division
Y-gain	volts for one vertical division

❶ Peak and r.m.s. values

In an **alternating current** the size and direction of the current keep changing. The p.d. rises to a **peak**, falls through zero, reverses and repeats. The **root mean square (r.m.s.)** value is the steady d.c. value that would give the same power in a resistor. Mains values (230 V) are r.m.s.; the peak is √2 (about 1.41) times bigger. Peak-to-peak is twice the peak.

RELATIONSHIPS

$$V_{peak} = \sqrt{2}\, V_{rms} \qquad I_{peak} = \sqrt{2}\, I_{rms}$$

V	p.d. in volts (V)
I	current in amperes (A)

WORKED EXAMPLE

A transformer in the dam gives 110 V r.m.s. Find its peak p.d.

Relationship $V_{peak} = \sqrt{2}\, V_{rms}$

Substitute $V_{peak} = \sqrt{2} \times 110$

Answer $\mathbf{V_{peak} = 156\ V}$

1 A lamp in the control room is rated 6.0 V r.m.s. Calculate the peak p.d. across it.

Relationship

Substitute

Answer

2 The peak current in a pump motor is 2.4 A. Calculate the r.m.s. current.

Relationship

Substitute

Answer

3 **Show that** the peak p.d. of the 230 V mains supply is about 325 V.

Relationship

Substitute

Answer

❷ Reading an oscilloscope

An oscilloscope draws p.d. against time on a grid of **divisions**. The **Y-gain** gives the volts per vertical division; the **timebase** gives the time per horizontal division. Count from the centre line to a crest for the peak, and across one whole wave for the period.

RELATIONSHIP

$$f = \frac{1}{T}$$

f	frequency in hertz (Hz)
T	period in seconds (s)

WORKED EXAMPLE

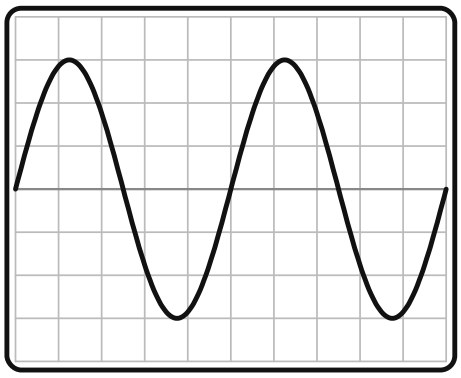
Peak height 2 div on 10 V/div; one wave covers 2 div on 0.2 ms/div. Find the peak, the frequency and the r.m.s. p.d.

Peak 2 div × 10 V/div = **20 V**

Period T = 2 div × 0.2 ms = 0.4 ms = 0.0004 s

Frequency $f = \frac{1}{T} = \frac{1}{0.0004}$ = **2500 Hz**

r.m.s. $V_{rms} = 20 \div \sqrt{2}$ = **14 V**



timebase 1 ms/div · Y-gain 2 V/div

1 For the trace shown, find (a) the peak p.d., (b) the period, (c) the frequency and (d) the r.m.s. p.d.

(a) and (b)

(c)

(d)

2 Another trace has a peak height of 3.5 divisions on 0.2 V/div. One wave covers 4 divisions on 10 ms/div. Calculate the peak p.d. and the frequency.

Peak

Period

Frequency

3 Explain why it is better to measure the time for several waves across the screen and divide, than to measure one wave.

Answer:

PRACTICAL 1

Plan it: peak and r.m.s. values

AIM To find how the **PEAK** p.d. of an a.c. supply compares with its **R.M.S.** p.d., by plotting the peak (from an oscilloscope) against the r.m.s. (from a meter).

1 Variables

I will change the independent variable	
I will measure the dependent variable	
I will keep the same controlled variables (give two)	

2 Prediction

I predict the graph of peak p.d. against r.m.s. p.d. will be .....

with a gradient of about .....

3 Equipment

Tick the equipment you need. Not everything here is useful.



☐ Low-voltage a.c. supply



☐ Oscilloscope



☐ a.c. voltmeter



☐ Leads



☐ Lamp as load



☐ Light gate



☐ Thermo-meter

4 Stay safe

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?
Mains electricity	Electric shock or burns	Use only a low-voltage supply (12 V a.c. or less). Never connect the oscilloscope or meter to the mains.

Method and results

5 Write your method

1. How will you connect the meter and the oscilloscope across the same load, and set the Y-gain and timebase?

2. How many settings and repeats? How will you find the mean peak p.d.?

3. What will you plot, and what does the gradient tell you?

6 Results

Complete the headings, including units.

				Mean peak

NO LAB TODAY? USE THESE RESULTS

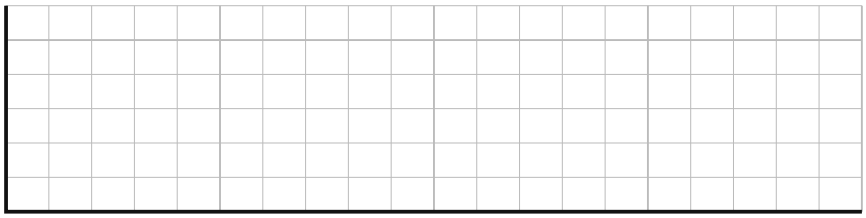
r.m.s. p.d. (V)	Peak 1 (V)	Peak 2 (V)	Peak 3 (V)	Mean peak p.d. (V)
2.0	2.8	2.9	2.8	
4.0	5.6	5.7	5.7	
6.0	8.5	8.4	8.6	
8.0	11.3	11.4	11.2	
10.0	14.1	14.2	14.0	

Meter reads to 0.1 V. The oscilloscope was on 2 V/div for the 2.0 V and 4.0 V settings and 5 V/div for the rest; each division has five small marks, so it can be read to ± 0.2 V (2 V/div) or ± 0.5 V (5 V/div). Work out the means yourself.

Analyse and evaluate

7 Draw a graph

Plot mean peak p.d. against r.m.s. p.d. Choose your scales, label both axes with units, and draw a best-fit straight line. Find the gradient.



Gradient =

Compare with √2 =

UNCERTAINTIES

Random uncertainty = (largest − smallest) ÷ number of readings. Scale-reading uncertainty: ± half the smallest division (analogue) or ± 1 in the last digit (digital). Percentage uncertainty = $\frac{\text{uncertainty}}{\text{value}} \times 100$. The largest percentage uncertainty is the one that matters most in the final answer. Here the oscilloscope reading of ± 0.5 V is 3.5% of 14.1 V, but ± 0.2 V is 7% of 2.8 V, so the small readings are the least precise.

a Work out the random uncertainty in the mean peak p.d. at 10.0 V r.m.s., and its percentage uncertainty.

Answer:

8 Conclusion and evaluation

b Write a conclusion that uses the gradient of your graph.

Answer:

c Suggest one change that would reduce the uncertainty in reading the peak from the oscilloscope.

Answer:

ASSIGNMENT LINK

Find a published statement of the link between peak and r.m.s. values for a sine wave, and reference it fully.

FREE SAMPLE

Electricity (Higher Physics)

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

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