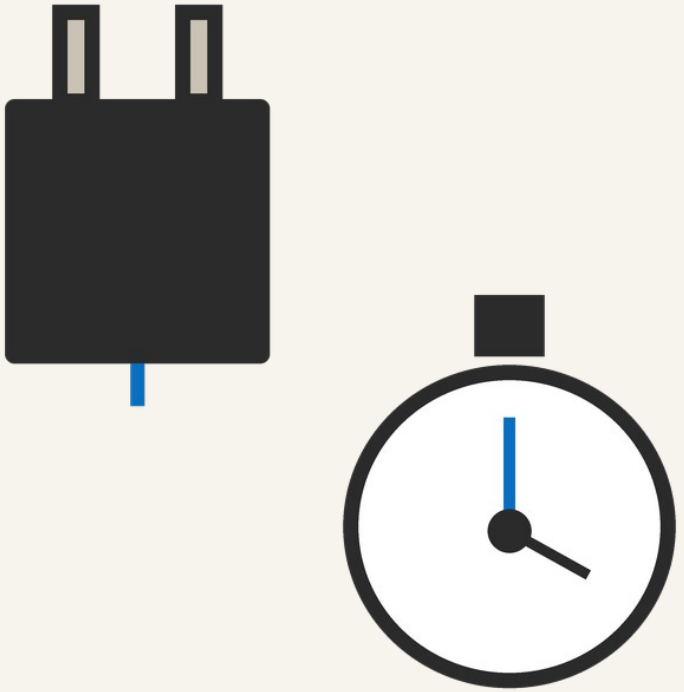
ELECTRICITY 1 · MONITORING & MEASURING AC

# Monitoring & Measuring AC



A supply that never stops changing.

Higher Physics

# Starter

## 2009 Higher Physics

Scan the code and answer these:

**Q9** **Q24**

Section A · resistors, internal r

Show your working, not just the letter.

**Scan for the paper**

Marking scheme

PART 1

# What alternating current is

Direct current goes one way and stays there. Alternating current will not sit still — and that changes how you measure it.

# By the end of this part…

1. I can state what is meant by alternating current.
2. I can describe the difference between a.c. and d.c.
3. I can give an everyday example of each.

# Direct and alternating current

## DIRECT CURRENT (d.c.)

- Charge flows one way only.
- The value stays constant.
- A battery or a cell.

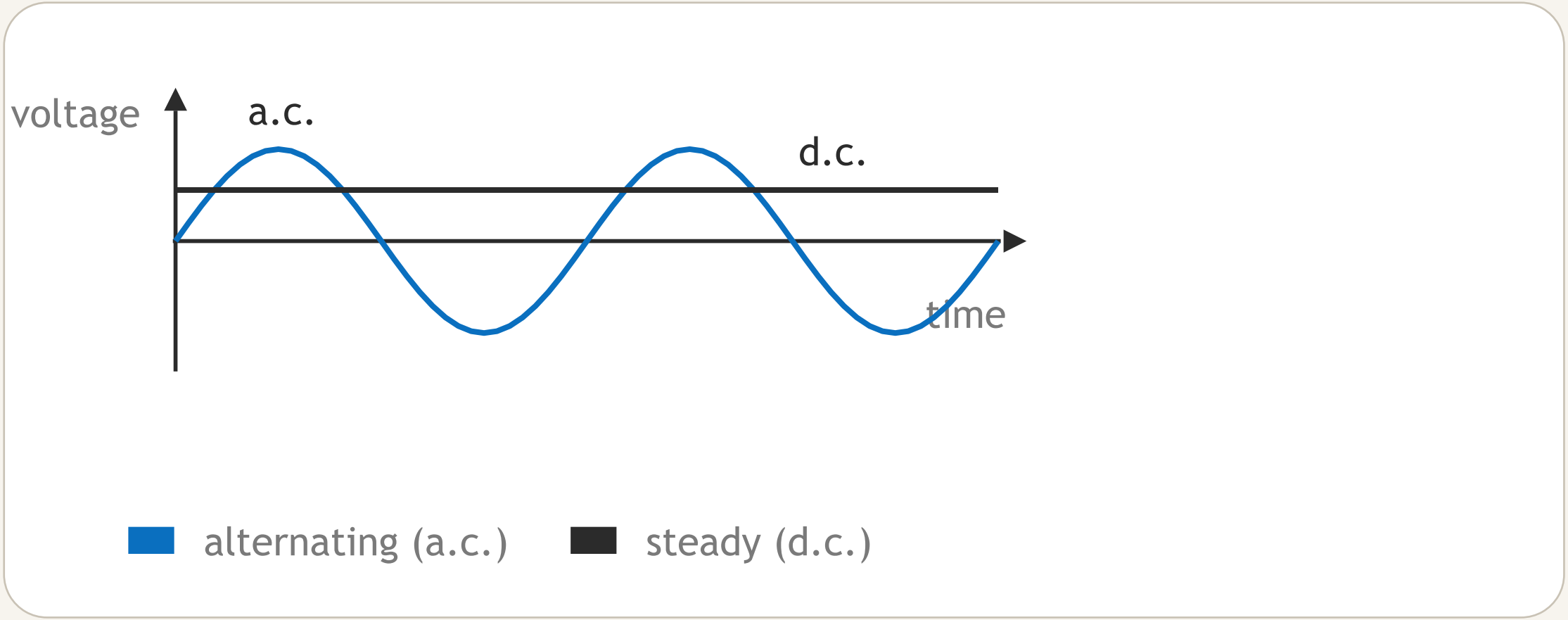
## ALTERNATING CURRENT (a.c.)

- Charge flows back and forth.
- The value changes all the time.
- The mains supply.

# What the two look like

JOTTER NOTES

Same axes, same time. One holds still; the other never does.



JOTTER NOTES

# What alternating current is

An alternating current is one which changes direction and changes its instantaneous value with time.

Both halves of that sentence are needed — direction on its own is not the definition.

A direct current flows one way only, and its value stays steady.

JOTTER NOTES

# Where you meet each one

The mains supply in every socket in the building is alternating.

A battery or a cell gives direct current.

This is why a plug-in charger has to convert the mains before it can charge a phone.

# Watch Out — the definition of a.c.

**THE MISTAKE**

- Saying only that the current changes direction
- Describing the shape of the graph instead

**THE CORRECT ANSWER**

- Both halves: direction AND instantaneous value.
- The definition is words, not a sketch.

# Show Me: a.c. and d.c.

SHOW ME BOARDS

1. State what is meant by an alternating current.
2. State one everyday example of an a.c. supply.
3. State one everyday example of a d.c. supply.
4. State the two things about an alternating current that change with time.
5. A pupil writes "a.c. changes direction". State what is missing and why the mark is lost.

# Task

Learn the definition of alternating current word for word.
Write it out from memory, then check it against your notes.

**Past papers: 2024 Q13(a)**

Past Paper Finder

# Starter

## 2011 Higher Physics

Scan the code and answer these:

**Q24**

Section A · internal resistance

Show your working, not just the letter.

**Scan for the paper**

No marking scheme

PART 2

# Reading an oscilloscope

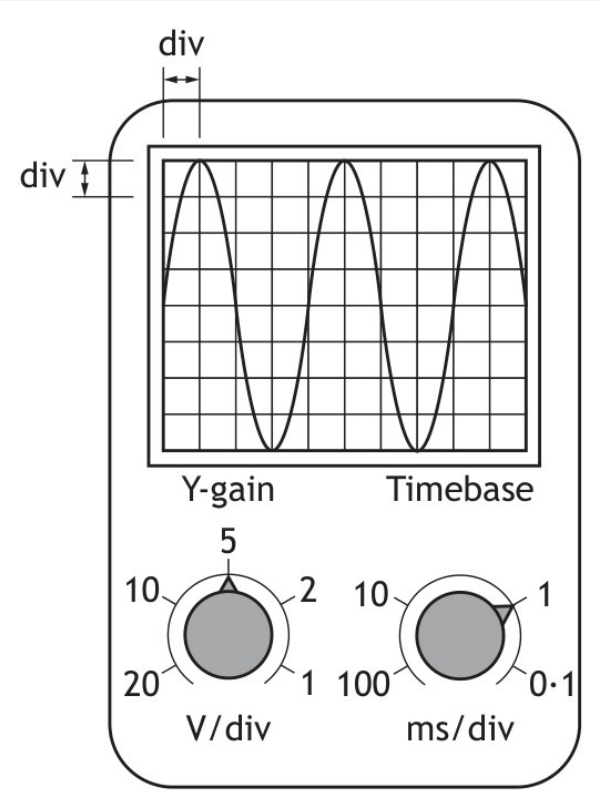
Two dials and a grid. Get what each dial means and the trace tells you everything.

# By the end of this part…

1. I can state what the Y-gain and the timebase settings control.
2. I can measure a height and a length on the screen in divisions.
3. I can set up an oscilloscope to display an a.c. signal.

# A real oscilloscope

The screen, the Y-gain dial and the timebase dial.



JOTTER NOTES

# The two dials

The Y-gain dial is marked in volts per division. It tells you how many volts each square up the screen is worth.

The timebase dial is marked in seconds per division. It tells you how much time each square across the screen is worth.

A division is one square on the grid.

JOTTER NOTES

# How to read the screen

Count the squares from the centre line up to the top of the trace. That height is the peak value, in divisions.

Count the squares across one complete cycle. That length is the period, in divisions.

Multiply each count by its own dial setting to turn divisions into volts and into seconds.

# Setting one up

The practical: get a trace on the screen before you measure anything.

- Connect the lab pack, set to $2\ \mathrm{V}$ a.c., to the oscilloscope input.
- Adjust the timebase until you can see one or two complete cycles.
- Adjust the volts per division until the trace fills a useful part of the screen without going off the top.

JOTTER NOTES

# Setting up the oscilloscope

Connect the a.c. supply to the input terminals of the oscilloscope.

Turn the timebase until one or two complete cycles fill the screen.

Turn the volts per division until the trace is tall, but still fits on the screen.

A trace that runs off the top cannot be measured, and neither can one squashed flat.

# Show Me: the oscilloscope

SHOW ME BOARDS

1. State what the Y-gain setting on an oscilloscope controls.
2. State what the timebase setting controls.
3. A trace is 3 divisions from the centre to the crest, with the Y-gain at 2.0 V/div. Calculate the peak voltage.
4. One complete cycle spans 4 divisions, with the timebase at 5.0 ms/div. Calculate the period.
5. A trace runs off the top of the screen. State which dial you would change, and which way.

# Task

Set up the oscilloscope and get a steady trace on the screen.
Record your Y-gain and timebase settings before you measure anything.

**Experiment and Examples P1/2**

# Starter

## 2008 Higher Physics

Scan the code and answer these:

**Q9**

Section A · e.m.f. definition

Show your working, not just the letter.

**Scan for the paper**

Marking scheme

PART 3

# Peak and r.m.s. values

The mains is quoted as 230 V, but it is only at 230 V for an instant. So what does the number mean?

# By the end of this part…

1. I can explain what an r.m.s. value is and why it is used.
2. I can use the relationship between peak and r.m.s. voltage.
3. I can use the relationship between peak and r.m.s. current.

# Why an average is not enough

- An alternating voltage spends half its time positive and half negative, so its plain average over a cycle is zero.
- Squaring every value first makes them all positive. Now the average means something.
- Take the square root of that average and you have the root mean square — the r.m.s. value.

JOTTER NOTES

# Why we use r.m.s. values

An alternating voltage is positive for half a cycle and negative for the other half, so its ordinary average is zero.

Squaring every value makes them all positive, so the average of the squares is a useful number.

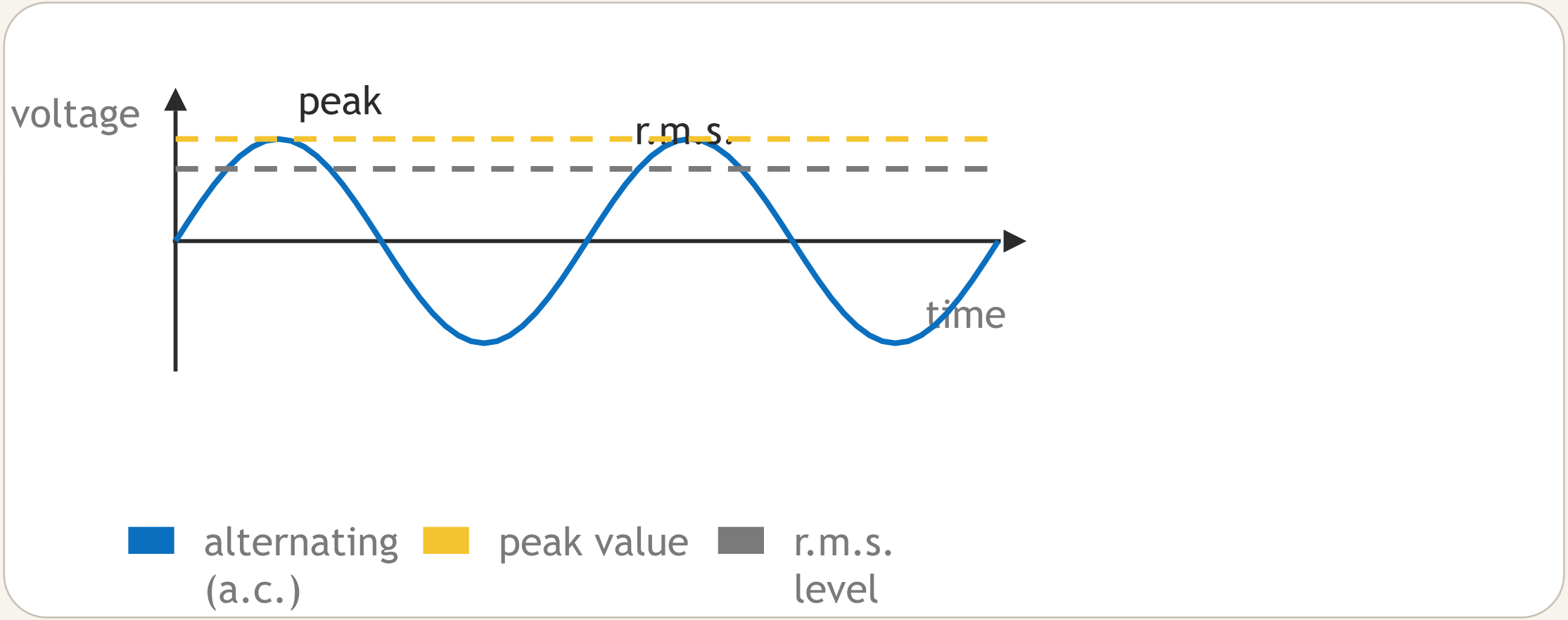
Taking the square root of that average gives the root mean square value, written r.m.s.

The r.m.s. value is the steady direct value that would heat a resistor at exactly the same rate.

# Peak and r.m.s. on the same trace

JOTTER NOTES

The peak is the crest. The r.m.s. level always sits below it.



# The two relationships

JOTTER NOTES

$$V_{rms} = V_{peak}/\sqrt{(2)}$$

| $V_{rms}$ | $V_{peak}$ |
| --- | --- |
| r.m.s. voltage (V) | peak voltage (V) |

The current relationship has exactly the same shape.

# The current version

JOTTER NOTES

$$I_{rms} = I_{peak}/\sqrt{(2)}$$

| | |
|---|---|
| $I_{rms}$ | r.m.s. current (A) |
| $I_{peak}$ | peak current (A) |

JOTTER NOTES

# Using the relationships

The r.m.s. value is always smaller than the peak value, because you divide by the square root of two.

Going the other way, from r.m.s. up to peak, you multiply by the square root of two instead.

A meter reading an alternating supply gives you the r.m.s. value, not the peak.

# Worked example — peak to r.m.s.

The peak voltage of an a.c. supply is 8.0 V.

Calculate the r.m.s. voltage.

$V_{peak} = 8.0\ V$

$V_{rms} = ?$

$V_{rms} = V_{peak}/\sqrt{(2)}$

$V_{rms} = 8.0/\sqrt{(2)}$

$\underline{V_{rms} = 5.7\ V}$

# Watch Out — which value is which

**THE MISTAKE**

- Multiplying by √2 when going peak to r.m.s.
- Assuming a meter reads the peak value

**THE CORRECT ANSWER**

- r.m.s. is the SMALLER one, so divide.
- An a.c. meter reads r.m.s.

# Show Me: peak and r.m.s.

SHOW ME BOARDS

1. The peak voltage of a supply is $12\ \text{V}$. Calculate the r.m.s. voltage.
2. The r.m.s. voltage of a supply is $9.0\ \text{V}$. Calculate the peak voltage.
3. The peak current in a lamp is $2.0\ \text{A}$. Calculate the r.m.s. current.
4. State what is meant by the r.m.s. value of an alternating voltage.
5. State and justify whether the peak or the r.m.s. value of a supply is the larger.

# Task

Work through the peak and r.m.s. questions.
Write the relationship down before you substitute, every time.

**Past papers: 2018 Q12(b), 2015 Q18**

Past Paper Finder

# Starter

## 2012 Revised Higher Physics

Scan the code and answer these:

**Q17** **Q18**

Section A · resistors, internal r

Show your working, not just the letter.

**Scan for the paper**

Marking scheme

PART 4

# Frequency and period

How many cycles a second, and how long each one takes — two ways of saying the same thing.

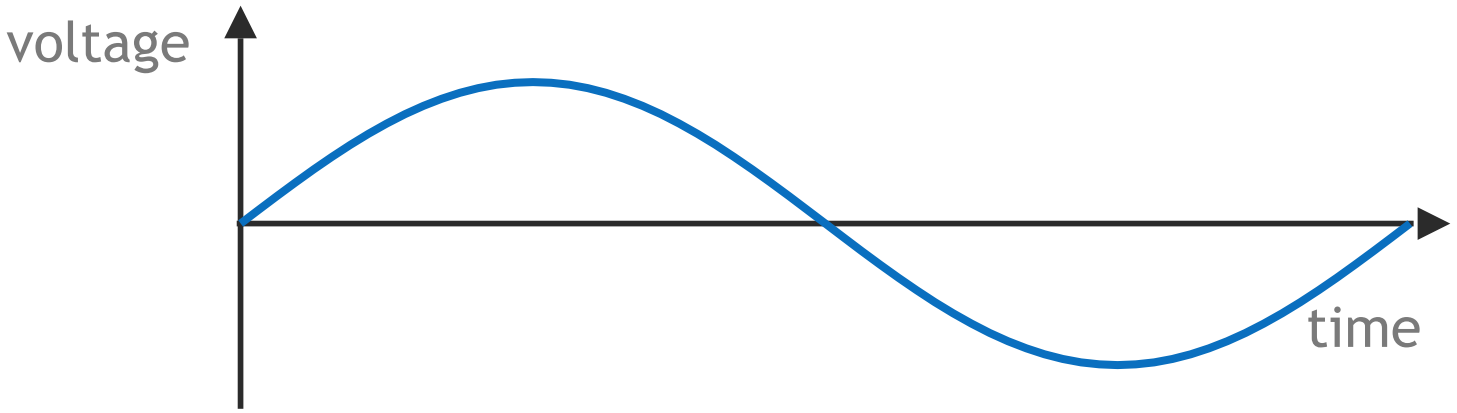
# By the end of this part…

1. I can state what the period of an alternating signal is.
2. I can state what its frequency is.
3. I can find the frequency from a trace on an oscilloscope.

# One complete cycle

JOTTER NOTES

The pattern repeats. One repeat is one cycle.




one complete cycle — the time it takes is the period, T

JOTTER NOTES

# Period and frequency

The period is the time taken for one complete cycle. It is measured in seconds.

The frequency is the number of complete cycles in one second. It is measured in hertz.

They are two ways of describing the same thing, so one is always the reciprocal of the other.

# The relationship

JOTTER NOTES

$$f = 1/T$$

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

# Worked example — frequency from a trace

One complete cycle of a trace spans 4.0 divisions.

The timebase is set to 5.0 ms/div. Calculate the frequency.

4.0 divisions

5.0 ms/div

T = ?

f = ?

$T = 4.0 \times 5.0 \times 10^{-3}$

$T = 0.020\ s$

$f = 1/T$

$f = 1 / 0.020$

$\underline{f = 50\ Hz}$

# Watch Out — show where T came from

**THE MISTAKE**

- Giving a frequency with no period shown
- Counting only half a cycle as one cycle

**THE CORRECT ANSWER**

- Show T, and where it came from.
- One cycle is crest to crest, not crest to trough.

# Show Me: frequency and period

SHOW ME BOARDS

1. State what is meant by the period of an alternating signal.

2. The period of a signal is $0.020\ \text{s}$. Calculate its frequency.

3. A signal has a frequency of $250\ \text{Hz}$. Calculate its period.

4. One cycle spans $8.0\ \text{divisions}$ at $2.0\ \text{ms/div}$. Calculate the frequency.

5. A signal has a frequency of $200\ \text{Hz}$. State how many complete cycles there are in one second.

# Task

Work through the frequency and period questions.
On every trace question, show the period before you find the frequency.

**Frequency P1**
**Past papers: 2016 Q17, 2017 Q16**

Past Paper Finder

# Starter

## 2015 Revised Higher Physics

Scan the code and answer these:

**Q13** **Q30**

Section A · uncertainty, internal r

Show your working, not just the letter.

**Scan for the paper**

Marking scheme

PART 5

# Putting it together

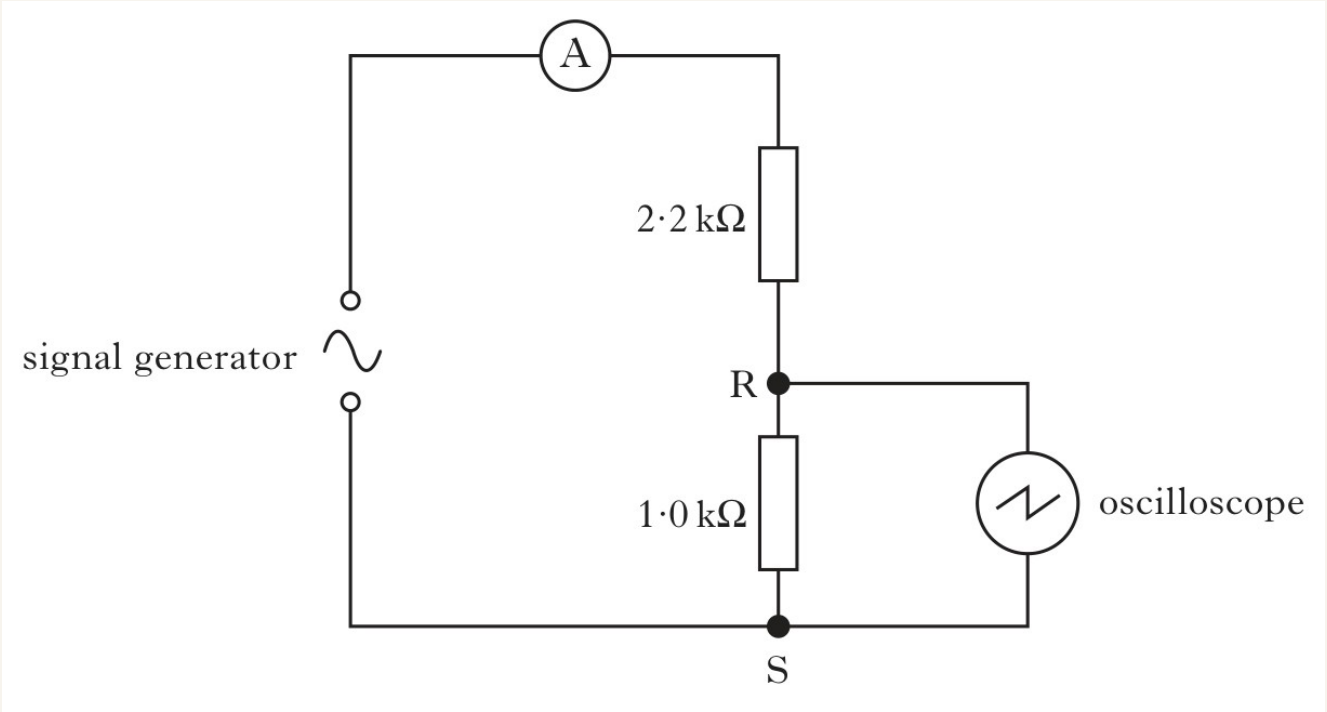
One trace, four numbers: peak voltage, r.m.s. voltage, period and frequency — all off the same screen.

# By the end of this part…

1. I can find the peak and r.m.s. voltage from an oscilloscope trace.
2. I can find the period and frequency from the same trace.
3. I can explain what the 230 V of the UK mains actually means.

# An oscilloscope in a circuit

The oscilloscope is connected across one resistor, not across the supply.



JOTTER NOTES

# Where the oscilloscope goes

An oscilloscope is connected across the component whose voltage you want to see, just like a voltmeter.

Here it is across one of the two resistors, so it shows that resistor's share of the supply voltage.

The ammeter is in series, so it reads the current through the whole circuit.

# Worked example — reading a trace

A trace reaches 3.0 divisions above the centre line at 2.0 V/div, and one cycle spans 4.0 divisions at 5.0 ms/div. Find $V_{rms}$ and f.

3.0 div at 2.0 V/div

4.0 div at 5.0 ms/div

$V_{rms}$ = ?

f = ?

$V_{peak} = 3.0 \times 2.0 = 6.0$ V

$V_{rms} = 6.0/\sqrt{(2)}$

$V_{rms} = 4.2$ V

$T = 4.0 \times 5.0 \times 10^{-3} = 0.020$ s

$f = 1 / 0.020 = 50$ Hz

# What 230 V really means

- The UK mains is quoted as $230\ \mathrm{V}$ — and that is the $\mathrm{r.m.s.}$ value.
- Its peak is higher: $230 \times \sqrt{2}$, which is about $325\ \mathrm{V}$.
- Its frequency is $50\ \mathrm{Hz}$, so one complete cycle takes $0.020\ \mathrm{s}$.

JOTTER NOTES

# The UK mains supply

The mains is quoted as 230 volts, and that figure is the r.m.s. value, not the peak.

Its peak voltage is about 325 volts, which is why mains insulation has to cope with far more than 230 volts.

Its frequency is 50 hertz, so one complete cycle takes one fiftieth of a second.

# Watch Out — 230 V is not the peak

**THE MISTAKE**

- Treating the quoted mains voltage as the peak
- Designing for 230 V when the peak is higher

**THE CORRECT ANSWER**

- 230 V is the r.m.s. value.
- The peak is about 325 V.

# Show Me: reading a trace

SHOW ME BOARDS

1. A trace reaches $2.5$ divisions at $4.0\ \mathrm{V/div}$. Calculate the peak voltage.
2. For that same trace, calculate the r.m.s. voltage.
3. State what the quoted mains voltage of $230\ \mathrm{V}$ represents.
4. Calculate the peak voltage of the UK mains supply.
5. The mains frequency is $50\ \mathrm{Hz}$. Calculate the period of one cycle.

# Task

Work through the mixed oscilloscope questions.
Each one wants the peak, the r.m.s., the period and the frequency.

**Experiment and Examples P1/2**
**Past papers: 2025 Q11, 2022 Q18**

Past Paper Finder

# Checkpoint

1. State the definition of alternating current, in full.

2. State what the Y-gain and the timebase settings each control.

3. Explain why an r.m.s. value is used rather than a plain average.

4. The peak voltage is $12\ \mathrm{V}$. Calculate the r.m.s. voltage.

5. One cycle spans $4.0\ \mathrm{divisions}$ at $5.0\ \mathrm{ms/div}$. Calculate the frequency, showing the period.

# Exam Practice

2025 Q11 — frequency from a trace, with the period shown.
2024 Q13 — the definition of a.c., then r.m.s. and timebase.
2022 Q18 — peak and r.m.s. from a trace.

**Past papers, Section A**

LOOKING AHEAD

# Next: Capacitors

Two plates and an insulator — and a store of charge that can empty in a flash.

# Plenary

SHOW ME BOARDS

1. State what is meant by alternating current.
2. State what the timebase setting on an oscilloscope controls.
3. Explain, in terms of heating, what an r.m.s. value means.
4. The r.m.s. voltage is $9.0\ \mathrm{V}$. Calculate the peak voltage.
5. The UK mains is $230\ \mathrm{V}$ at $50\ \mathrm{Hz}$. State the peak voltage and the period.

# Extension

SHOW ME BOARDS

1. Show that a lamp running at $12\ \mathrm{V}$ r.m.s. dissipates the same mean power as one running at $12\ \mathrm{V}$ d.c.
2. A diode is put in series with an a.c. supply. Sketch the trace you would now expect, and explain its shape.
3. Explain why the peak voltage matters to an engineer choosing insulation, even though meters read r.m.s.