MA99 EDUCATION

Electricity and magnetism: Summary

03

NSW PHYSICS 11-12 SYLLABUS 2025 FOR HSC 2028 AND LATER

1. Key ideas

- **Charging is electrons moving.** Gain electrons: negative. Lose them: positive. Charge is conserved and comes in whole electron charges, $q = ne$.
- **Three ways to charge.** Friction (two insulators; opposite charges), conduction (contact; same sign as the charging object), induction (near, earth, remove earth, remove rod; opposite sign).
- **A point charge's field is radial**, away from + and towards −, and follows an inverse square law: $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$. Double r, quarter E.
- **Lightning is static electricity at storm scale.** Graupel and ice crystal collisions separate charge (top +, base −); the ground is charged by induction; a strong field ionises air; leader and streamer meet; the return stroke is the flash.
- **Field line rules.** Start on +, end on −; never cross; crowded means strong. Between parallel plates: parallel, evenly spaced, uniform.
- **Force on a charge:** $\vec{F} = q\vec{E}$; an electron is pushed against the field.
- **Between plates** $E = \frac{V}{d}$: $E \propto V$, $E \propto \frac{1}{d}$ (not inverse square).
- **Energy in a uniform field.** $W = qV = qEd$; with only the electric force, $W = -\Delta U = \Delta KE$. Potential energy falls when a charge moves the way the field pushes it. $V = \frac{\Delta U}{q}$: a volt is a joule per coulomb.
- **Current** $I = \frac{q}{t}$. Conventional current flows + to − outside the supply; electrons drift the other way, slowly (about 10^{-4} m s^{-1}), pushed by the field the voltage sets up in the wire.
- **DC** flows one way; **AC** reverses (Australian mains 230 V, 50 Hz): electrons oscillate with no net drift, yet energy is transferred.
- **Resistance** rises with length, falls with cross-sectional area, depends on material, and rises with temperature in metals: all through collisions.
- **Ohmic** conductors have constant R (straight I-V line through the origin); **non-ohmic** ones (filament lamp, diode, thermistor) do not. $R = \frac{V}{I}$ at a point, never the gradient of a curve.
- **Power** is the rate of energy transformation: $P = \frac{\Delta E}{\Delta t} = VI$; losses in wires $P = I^2R$; energy is conserved across the whole circuit.
- **Series:** one current; voltages and resistances add. **Parallel:** one voltage; currents and reciprocal resistances add. Ammeters in series (low R); voltmeters in parallel (high R).
- **Magnetic field lines are closed loops** (S to N inside a magnet). A wire's field circles it (right hand grip rule), $B = \frac{\mu_0 I}{2\pi r} \propto \frac{1}{r}$. A solenoid's field is uniform inside, bar magnet shaped outside, $B = \frac{\mu_0 NI}{L}$.
- **Electromagnets** are strengthened by more current, more turns per metre and a high permeability, low retentivity core: soft iron for DC, laminated silicon steel or ferrite for AC.

> Before any calculation, write which field you are in: point charge, plates, wire or solenoid. Each has its own formula.

2. Formulae, with when to use them

Every formula here is on NESA's sample 2028 formulae sheet.

FORMULA	USE IT FOR	WATCH OUT
$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$	Field of a point charge	Inverse square; $\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9$

FORMULA	USE IT FOR	WATCH OUT
$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$	Force between two point charges	Square r, not q; like repel
$\vec{F} = q\vec{E}$	Force on a charge in any field	Sign of q sets direction
$E = \frac{V}{d}$	Uniform field between plates	d in metres
$W = qV = qEd; W = \Delta KE$	Work and kinetic energy in a uniform field	d along the field only
$V = \frac{\Delta U}{q}$	Potential difference from energy	One volt = one joule per coulomb
$I = \frac{q}{t}$	Current	t in seconds
$V = IR$	Any component	Same component for all three
$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t}; P = VI; P = I^2R$	Power, energy, losses	$\Delta E = P\Delta t$
$V_{series} = V_1 + V_2 + \cdots; R_{series} = R_1 + R_2 + \cdots$	Series	Current the same throughout
$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots; I_{parallel} = I_1 + I_2 + \cdots$	Parallel	Flip $\frac{1}{R}$ at the end
$B = \frac{\mu_0 I}{2\pi r}$	Near a long straight wire	$\frac{1}{r}$, not $\frac{1}{r^2}$
$B = \frac{\mu_0 N I}{L}$	Inside a solenoid (air core)	N total turns; L in metres

Data: $q_e = -1.602 \times 10^{-19}$ C; $m_e = 9.109 \times 10^{-31}$ kg; $m_p = 1.673 \times 10^{-27}$ kg; $\varepsilon_0 = 8.854 \times 10^{-12}$ A² s⁴ kg⁻¹ m⁻³; $\mu_0 = 4\pi \times 10^{-7}$ N A⁻².

3. How to answer the question

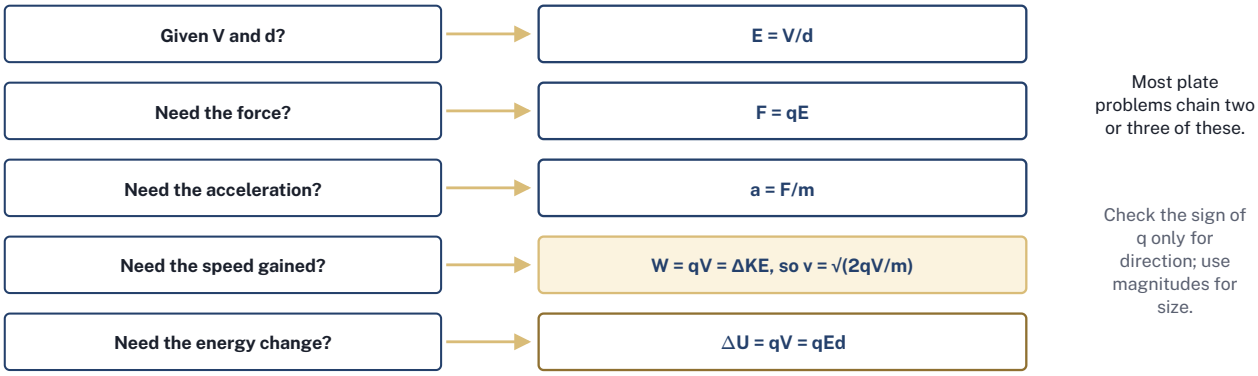


Figure 1 · The chain for a charged particle between plates.

A charged particle between plates. (1) $E = \frac{V}{d}$. (2) $F = qE$, direction from the sign of q. (3) $a = \frac{F}{m}$. (4) Speed from energy: $qV = \frac{1}{2}mv^2$, so $v = \sqrt{\frac{2qV}{m}}$. (5) Check with $v^2 = 2ad$. Example: an electron across 150 V reaches 7.3×10^6 m s⁻¹.

Will it get there? A charge fired against the field: compare its KE with qV. If $KE > qV$ it crosses with $KE - qV$ left; if not, it stops and returns.

A combination circuit. (1) Reduce parallel groups, add series parts. (2) $I = \frac{V}{R_{\text{total}}}$. (3) Series voltages from IR; the leftover voltage is across the parallel group. (4) Branch currents $\frac{V_p}{R}$. (5) Check: voltages add to the supply, branch currents add to the total, powers add to VI.

Charging by induction. Near (charge separates), earth (electrons flow to or from earth), break the earth **first**, then remove the rod. Final charge opposite to the rod's.

Field directions. Point charge: away from +. Plates: + to −. Wire: thumb with current, fingers give B. Solenoid: fingers with current, thumb to N; seen anticlockwise is N.

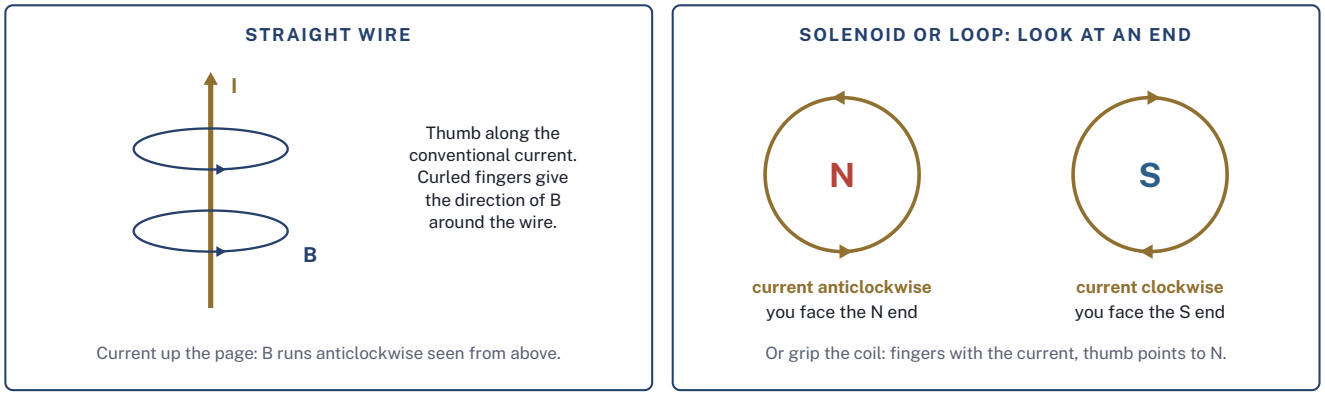


Figure 2 · The two right hand grip rules.

4. The four investigations

CONTENT POINT	WHAT YOU DO	KEY RESULT	WHAT LIMITS IT
Ohmic and non-ohmic conductors (laboratory experiment)	Vary V across a resistor and a lamp, measure I; plot I-V	Resistor: straight line through origin, $R = \frac{1}{\text{gradient}}$. Lamp: curve, R rises (6.3 Ω to 20 Ω in the notes' data)	Meter resolution at small currents; heating, so switch off between readings
Combination circuit (laboratory experiment)	Measure currents and voltages; compare with calculated values	Conservation laws hold; measured values slightly low	Supply internal resistance, ammeter and lead resistance, resistor tolerance, meter resolution
Core materials (secondary-source investigation)	Assess materials on permeability, retained magnetism, saturation, cost, AC losses	Soft iron for DC electromagnets; silicon steel or ferrite for AC; hard steel for permanent magnets	Source reliability: check values against a second, independent source
Electromagnet strength (practical investigation)	Vary current, turns or core; measure B with a sensor	$B \propto I$, $B \propto N$; iron core about 10 times air in the notes' data	Paperclip counts are discrete; saturation; heating; single trials

Percentage error, as NESA defines it: the absolute error as a percentage of the recorded measurement, $\frac{|\text{accepted} - \text{recorded}|}{\text{recorded}} \times 100$. Also be ready to find a mean, range and standard deviation of repeated values.

5. Common errors

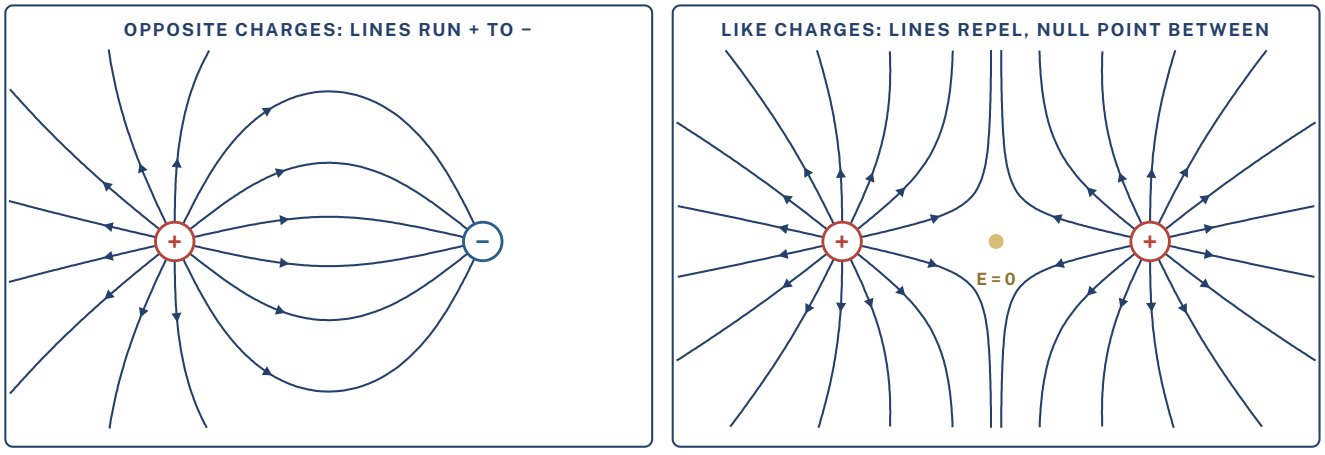
COMMON ERROR	INSTEAD
"Protons moved" or "positive charge flowed"	Only electrons move in solids
Using $E = \frac{V}{d}$ for a point charge	Plates only; point charge uses $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
Squaring r in $B = \frac{\mu_0 I}{2\pi r}$	Wire field is $\frac{1}{r}$; point charge field is $\frac{1}{r^2}$
Force on an electron along the field	Opposite to the field
Full gap d in $W = qEd$ for a partial move	Distance moved along the field
R from the gradient of a curved I-V graph	$R = \frac{V}{I}$ at the point
"Current is used up" in a lamp	Energy is used; current is the same all round a series loop

COMMON ERROR	INSTEAD
Forgetting to flip $\frac{1}{R_{parallel}}$	Total must be below the smallest branch
Supply voltage across a parallel group with a series resistor	Subtract the series voltage first
“Thicker wire, more resistance”	More area, more paths, less resistance
Electric field lines as closed loops, or magnetic lines that end	Electric lines end on charges; magnetic lines always close

6. Checklist

- ☐ A sphere has $+6.4$ nC. How many electrons has it lost? (4.0×10^{10})
- ☐ The field at 0.50 m from a charge is 360 N C^{-1}. What is it at 1.5 m? (40 N C^{-1})
- ☐ Two charges 0.10 m apart attract with 2.0 N. What is the force at 0.20 m? (0.50 N)
- ☐ Plates 2.5 cm apart, 500 V. Field? (2.0×10^{4} V m^{-1}) Work to move 4.0 μC across? (2.0×10^{-3} J)
- ☐ A proton crosses 1000 V from rest. Its speed? (4.4×10^{5} m s^{-1})
- ☐ A 1.5 kW heater on 230 V: current? (6.5 A) Energy in 20 minutes? (1.8×10^{6} J)
- ☐ 2.0 Ω in series with (3.0 Ω parallel 6.0 Ω) across 8.0 V: current from the supply? (2.0 A)
- ☐ B 3.0 cm from a wire carrying 15 A? (1.0×10^{-4} T)
- ☐ B inside a 0.20 m solenoid of 400 turns carrying 0.80 A? (2.0×10^{-3} T)
- ☐ Explain why soft iron, not hard steel, is used in a lifting electromagnet.

7. Diagrams you must be able to draw



Where lines are crowded the field is strong. A test charge feels a force along the tangent to the line through its position.

Figure 3 · Electric field lines for unlike and like pairs of equal charges.

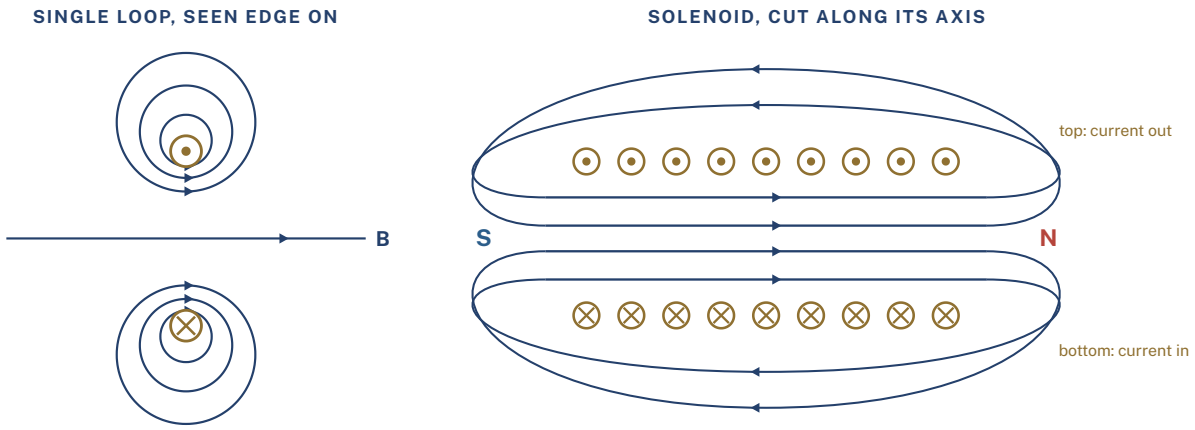


Figure 4 · A current loop seen edge on, and a solenoid cut along its axis.

About this resource

MA99 EDUCATION

Scope

NSW Physics, Year 11. Written to the NSW Physics 11-12 Syllabus 2025, Electricity and magnetism, for students sitting the HSC in 2028 and later years. Written to the new syllabus, taught in Year 11 from 2027. Every value in a worked example was recomputed from its inputs before printing; contexts are invented unless a source is named.

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MA99 EDUCATION

Electricity and magnetism: Practice Questions

03

NSW PHYSICS 11-12 SYLLABUS 2025

FOR HSC 2028 AND LATER

1. Instructions

Fifty five marks: ten multiple choice and forty five marks of short answer, including an eight mark item on an electromagnet investigation. Every question is written to the 2025 syllabus content for Electricity and magnetism, in the style of HSC Physics questions. Do it under time, on paper, before you look at anything at the back.

How to run this

Give yourself about 100 minutes, with a calculator and NESA's formulae and data sheet, but no notes. Mark it against the guidance at the back. For every lost mark, write the one line that would have earned it. Then redo only the questions where you lost two or more marks, a week later.



Figure 1 · How the 55 marks are split across the sections. Your time should follow the same split.

Data you will need

Charge on electron -1.602×10^{-19} C; mass of electron 9.109×10^{-31} kg; mass of proton 1.673×10^{-27} kg; $\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}$ N m^2 C^{-2}; $\mu_0 = 4\pi \times 10^{-7}$ N A^{-2}. All data in investigation stimulus is hypothetical unless a source is named.

FOUNDATION Section I tests one idea per item. Every wrong option is a real error students make.

STANDARD Section II asks you to show working. A number without a formula and a unit rarely earns full marks.

2. Section I · Multiple choice

Ten marks. One mark each. About 15 minutes.

Question 1

1 MARK

A polythene rod is rubbed with a woollen cloth and becomes negatively charged. Which statement best explains this?

A Protons moved from the rod to the cloth.

B Electrons moved from the cloth to the rod.

C Friction created electrons on the surface of the rod.

D Positive charge moved from the rod to the cloth.

Question 2

1 MARK

The electric field strength 0.20 m from a point charge is 8.0×10^{4} N C^{-1}. What is the field strength 0.40 m from the charge?

A 1.6 × 10^5 N C^{-1}

B 4.0 × 10^4 N C^{-1}

C 2.0 × 10^4 N C^{-1}

D 1.0 × 10^4 N C^{-1}

Question 3

1 MARK

Two point charges exert a force F on each other. Both charges are doubled and the distance between them is doubled. What is the new force?

A F
B 2F
C F/2
D 4F

Question 4

1 MARK

An electron is between two horizontal parallel plates. The upper plate is positive. Which statement describes the force on the electron?

A Downward, because the field points from the upper plate to the lower plate.
B Zero, because the field between parallel plates is uniform.
C Downward, towards the negative plate.
D Upward, opposite to the direction of the field.

Question 5

1 MARK

An electron starts from rest and is accelerated through a potential difference of 200 V. What kinetic energy does it gain?

A 3.2×10^{-17} J
B 1.6×10^{-17} J
C 1.2×10^{21} J
D 8.0×10^{-22} J

Question 6

1 MARK

Two parallel plates stay connected to the same supply while their separation is tripled. The field strength between them becomes

A three times as large.
B one ninth as large.
C one third as large.
D unchanged.

Question 7

1 MARK

Which statement correctly compares the alternating current in a mains heater with the direct current in a torch?

A In AC the electrons travel from the power station to the heater; in DC they stay in the torch.
B AC transfers no energy on average, because the current reverses.
C In AC the current is constant in size; in DC it rises and falls.
D In AC the electrons oscillate back and forth with no net drift; in DC they drift one way.

Question 8

1 MARK

Three 6.0 Ω resistors are connected so that two are in parallel and that pair is in series with the third. What is the total resistance?

A 18 Ω
B 9.0 Ω
C 4.0 Ω
D 2.0 Ω

Question 9

1 MARK

Why is an ammeter connected in series and designed to have a very low resistance?

A All the current to be measured must pass through it, and it must not reduce that current.
B It must have the same voltage across it as the component it measures.
C A low resistance makes the ammeter more sensitive to voltage.
D Current is used up as it passes through components, so it must be measured before them.

Question 10

1 MARK

A long straight wire carries a current of 3.0 A. What is the magnetic field strength 2.0 cm from the wire?

A 1.5×10^{-3} T

B 3.0×10^{-7} T

C 1.9×10^{-4} T

D 3.0×10^{-5} T

3. Section II · Short answer

Forty five marks. About 85 minutes. Show working, with a formula, a substitution and a unit.

Question 11

3 MARKS

Explain how a neutral metal sphere on an insulating stand can be given a positive charge using a negatively charged rod, without the rod touching the sphere. You may use diagrams.

Question 12

3 MARKS

Explain the role of static electricity in producing a lightning strike from a thundercloud to the ground.

Question 13

4 MARKS

A small sphere carries a charge of $+5.0$ nC.

(a) Calculate the electric field strength 0.15 m from the sphere. (2 marks)

(b) Use $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ to show that the field strength 0.45 m from the sphere is one ninth of your answer to (a), and explain what this demonstrates. (2 marks)

Question 14

5 MARKS

A proton is released from rest at the positive plate of a pair of parallel plates 5.0 mm apart, with 400 V between them.

(a) Calculate the electric field strength between the plates. (1 mark)

(b) Calculate the acceleration of the proton. (2 marks)

(c) Use energy to calculate the speed of the proton when it reaches the negative plate. (2 marks)

Question 15

3 MARKS

An electron is fired through a small hole in the positive plate of a pair of parallel plates, directly towards the negative plate. It slows down, stops before reaching the negative plate and returns. Account for the energy transformations during this motion.

Question 16

4 MARKS

A student measured the current through a component at different voltages.

VOLTAGE (V)	1.0	2.0	3.0	4.0
Current (A)	0.050	0.080	0.100	0.115

Hypothetical data.

Determine whether the component is ohmic or non-ohmic, using calculations, and suggest what the component could be. Justify your answer.

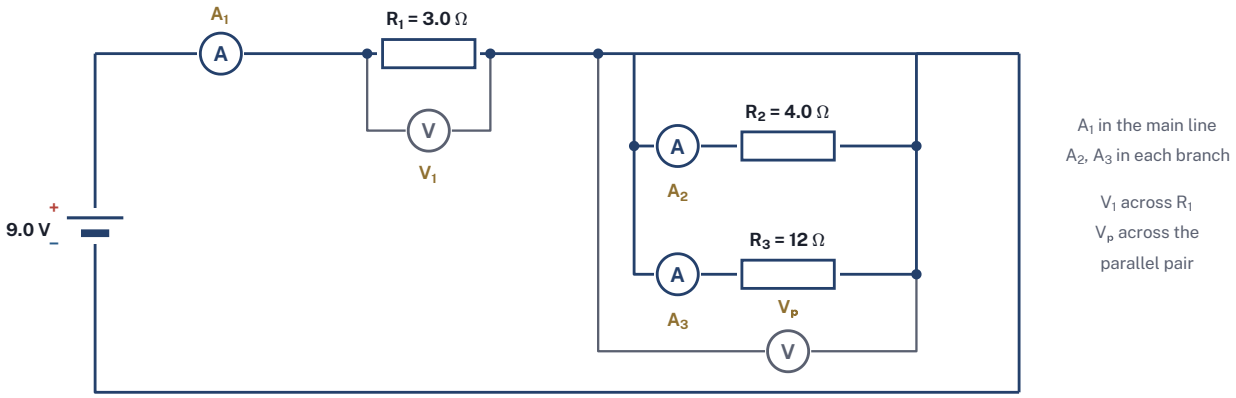


Figure 2 · The circuit for question 17.

Question 17

5 MARKS

Refer to Figure 2. The supply is 9.0 V. Assume the meters are ideal.

(a) Calculate the total resistance of the circuit. (1 mark)

(b) Calculate the reading on ammeter A_2, in series with the 4.0 Ω resistor. (2 marks)

(c) Calculate the power dissipated in the 12 Ω resistor. (2 marks)

Question 18

3 MARKS

A heater draws 12 A through an extension lead whose conductors have a total resistance of 0.15 Ω. Calculate the rate of energy loss in the lead, and use the law of conservation of energy to explain why the heater receives less than the full supply voltage.

Question 19

4 MARKS

(a) Calculate the magnetic field strength 5.0 cm from a long straight wire carrying 8.0 A. (2 marks)

(b) A solenoid 15 cm long has 300 turns and carries 1.5 A. Calculate the magnetic field strength inside it, and state ONE way to increase it without changing the current. (2 marks)

Question 20

3 MARKS

Draw the magnetic field around a long straight wire carrying current out of the page, and explain how your diagram shows both the direction and the variation in strength of the field.

STIMULUS FOR QUESTION 21

A student investigated how the number of turns on an electromagnet affects its strength. The coil was wound on a steel nail. For each number of turns the student kept the current at 1.5 A by adjusting the supply, then counted the paperclips the nail could hold. Each measurement was made once.

NUMBER OF TURNS	20	40	60	80	100
Paperclips held	3	7	10	12	13

Hypothetical data.

Question 21

8 MARKS

Analyse the student's results and evaluate the validity and reliability of the investigation. In your answer, propose improvements.

4. Marking guidance

Mark accurately. A generous mark hides what needs fixing. Equivalent physics, correctly expressed, earns the same marks.

Section I

Q	ANSWER	WHY THE ANSWER IS RIGHT, AND WHERE THE WRONG OPTIONS COME FROM
1	B	Only electrons move in charging. A and D move positive charge; C creates charge, which friction cannot do.
2	C	Doubling r quarters E (inverse square): $\frac{8.0\times10^{4}}{4}$. B halves it (inverse, not inverse square); A and D are other wrong powers.
3	A	q_1q_2 is four times larger and r^2 is four times larger, so the force is unchanged. D forgets the distance; B and C mishandle the square.
4	D	A negative charge feels a force opposite to the field, so upward, towards the positive plate. A and C give the force on a positive charge; B confuses uniform with zero.
5	A	$W = qV = 1.602 \times 10^{-19} \times 200 = 3.2 \times 10^{-17}$ J. B halves it; C is $\frac{V}{q}$; D is $\frac{q}{V}$.
6	C	$E = \frac{V}{d}$ with V constant, so tripling d gives one third. B treats it as an inverse square.
7	D	AC electrons oscillate about fixed positions. A is a common misconception; B is false, since heating happens in both directions; C reverses the graphs.
8	B	The parallel pair is 3.0 Ω; plus 6.0 Ω gives 9.0 Ω. A adds all three; D puts all three in parallel; C puts the single resistor in parallel with the other two in series.
9	A	The ammeter must carry the current and not change it. B describes a voltmeter; D is the “current is used up” error.
10	D	$B = \frac{4\pi\times10^{-7}\times3.0}{2\pi\times0.020} = 3.0 \times 10^{-5}$ T. A squares r; B uses r in centimetres; C leaves out the 2π.

Section II

Q	MARKS	WHAT A FULL MARK ANSWER CONTAINS
11	3	The negative rod is brought near; free electrons in the sphere are repelled to the far side, leaving the near side positive (1). With the rod still near, the sphere is earthed and electrons flow from the sphere to earth (1). The earth connection is broken before the rod is removed; the sphere is left with fewer electrons than protons, a net positive charge that spreads over it (1).
12	3	Collisions between ice crystals and graupel transfer charge, and updrafts carry the lighter positive particles up, leaving the cloud base negative (1). The negative base induces a positive charge on the ground below (1). The field becomes strong enough to ionise the air, a conducting path forms (stepped leader and streamer) and charge flows, discharging the separation in the strike (1).
13	4	(a) $E = 8.99 \times 10^{9} \times \frac{5.0\times10^{-9}}{0.15^2}$ (1) $= 2.0 \times 10^{3}$ N C^{-1} (1). (b) $E = 8.99 \times 10^{9} \times \frac{5.0\times10^{-9}}{0.45^2} = 2.2 \times 10^{2}$ N C^{-1}, which is $\frac{2.0\times10^{3}}{9}$ (1). Tripling the distance divided E by 3^2: the field follows the inverse square law (1).
14	5	(a) $E = \frac{400}{5.0\times10^{-3}} = 8.0 \times 10^{4}$ V m^{-1} (1). (b) $F = qE = 1.28 \times 10^{-14}$ N (1); $a = \frac{F}{m} = 7.7 \times 10^{12}$ m s^{-2} (1). (c) $W = qV = 6.41 \times 10^{-17}$ J $= \Delta KE$ (1); $v = \sqrt{\frac{2W}{m}} = 2.8 \times 10^{5}$ m s^{-1} (1).
15	3	Entering, the electron has kinetic energy. Moving towards the negative plate it moves against the force on it, so its kinetic energy is transformed into electric potential energy (1). It stops where all its kinetic energy has become potential energy, because its initial KE was less than qV for the gap (1). The force still acts towards the positive plate, so it accelerates back, transforming the potential energy back into kinetic energy; total energy is conserved throughout (1).
16	4	$R = \frac{V}{I}$ at each point: 20, 25, 30 and 35 Ω (2 for all four; 1 for two). The resistance increases as the current increases, so the component is non-ohmic (1). It could be a filament lamp: the larger current heats the filament, its ions vibrate more and electrons collide more often, raising R (1).

Q	MARKS	WHAT A FULL MARK ANSWER CONTAINS
17	5	(a) Parallel pair: $\frac{1}{R_p} = \frac{1}{4.0} + \frac{1}{12}$, so $R_p = 3.0\ \Omega$; total $3.0 + 3.0 = 6.0\ \Omega$ (1). (b) $I = \frac{9.0}{6.0} = 1.5$ A; $V_p = 9.0 - 1.5 \times 3.0 = 4.5$ V (1); $I_2 = \frac{4.5}{4.0} = 1.1$ A (1.125 A) (1). (c) $I_3 = \frac{4.5}{12} = 0.375$ A (1); $P = VI = 4.5 \times 0.375 = 1.7$ W (1).
18	3	$P = I^2R = 12^2 \times 0.15 = 22$ W (21.6 W) (1). The lead has a potential difference $V = IR = 1.8$ V across it (1). Each coulomb's energy from the supply is shared: some is transformed to thermal energy in the lead, so less is left for the heater; the heater's voltage is the supply voltage less 1.8 V (1).
19	4	(a) $B = \frac{4\pi \times 10^{-7} \times 8.0}{2\pi \times 0.050}$ (1) $= 3.2 \times 10^{-5}$ T (1). (b) $B = \frac{4\pi \times 10^{-7} \times 300 \times 1.5}{0.15} = 3.8 \times 10^{-3}$ T (1); more turns in the same length, a shorter coil with the same turns, or a soft iron core (1).
20	3	Concentric circles centred on the wire, anticlockwise for current out of the page (right hand grip rule) (1). Arrows on the circles show the direction (1). The circles are drawn further apart with distance, showing the field weakening as $\frac{1}{r}$ (1).

Question 21

What separates 7 and 8 from 5 and 6

A top answer **analyses** the numbers (a relationship, with the point where it breaks down, and a physical reason) and **evaluates** with named terms used correctly: validity (does it measure strength fairly?), reliability (single trials) and accuracy (paperclips are a coarse scale). Each weakness is matched to a specific improvement.

MARKS	CRITERIA
7 to 8	Identifies the trend with evidence from the data, including where it departs from proportionality, and explains it. Evaluates validity and reliability with correct terminology and specific reasons. Proposes improvements linked to each weakness.
5 to 6	Identifies the trend with some data. Makes relevant judgements about validity and reliability. Proposes some improvements.
3 to 4	Describes the trend. Identifies some limitations or improvements.
1 to 2	Makes a relevant statement about the results or the method.

Model answer. Up to 60 turns the number of paperclips rises roughly in proportion to the number of turns: tripling the turns from 20 to 60 raised the count from 3 to 10, consistent with $B = \frac{\mu_0 NI}{L}$, which predicts $B \propto N$ at constant current. Beyond 60 turns the increase slows: 80 and 100 turns added only 2 and 1 paperclips. One explanation is that the steel core approaches saturation, so extra turns add little field; another is the method itself, since a chain of paperclips does not hang from a single point.

The investigation is partly valid. The current was correctly controlled at 1.5 A, which matters because adding turns adds resistance. However, paperclip count is an indirect, discrete measure of strength: it depends on how the clips are hung and cannot record a change smaller than one clip, so it may not measure field strength fairly at the high end. The coil may also warm with more turns and longer use. The results are not reliable, because each measurement was made once, so the levelling off cannot be distinguished from random variation.

To improve, measure B at a fixed distance from the end of the core with a magnetic field sensor, which gives continuous, precise readings; repeat each measurement three times and use the mean; switch off between readings to control temperature; and extend the range of turns to test whether the levelling off is real. Using a soft iron core instead of steel would also show whether the core is limiting the field.

DATE	MARK, OUT OF 55	THE ONE CHANGE I MADE NEXT TIME

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About this resource

Scope

NSW Physics, Year 11. Written to the NSW Physics 11-12 Syllabus 2025, Electricity and magnetism, for students sitting the HSC in 2028 and later years. Written to the new syllabus, taught in Year 11 from 2027. Every value in a worked example was recomputed from its inputs before printing; contexts are invented unless a source is named.

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