



SKJ Education

LC HL PHYSICS
FOUNDATION PHYSICS
PROGRAM: WEEK 5

ELECTRICITY

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LC HL PHYSICS – FOUNDATION PROGRAM

Week 5: Electricity

Learning Objectives

- **5.1:** To define current, potential difference, and resistance, and apply Ohm's Law.
- **5.2:** To use the formula for resistivity to solve problems.
- **5.3:** To analyse series and parallel circuits to calculate current, voltage, and resistance.
- **5.4:** To define capacitance and describe how capacitors store charge.

Key Terms - Week 5

- **Current (I):** The flow of electric charge, measured in amperes (A).
- **Potential Difference (V):** The energy required to move a unit charge between two points, measured in volts (V).
- **Resistance (R):** The opposition to the flow of electric current, measured in ohms (Ω).
- **Ohm's Law:** $V = IR$, relating the potential difference across a conductor to the current flowing through it and its resistance.
- **Resistivity (ρ):** A measure of a material's ability to resist the flow of electric current, related to resistance by $R = \frac{\rho L}{A}$.
- **Series Circuit:** A circuit where components are connected end-to-end, so that the current flows through each component in sequence.
- **Parallel Circuit:** A circuit where components are connected between the same two points, so that the voltage across each component is the same.
- **Capacitance (C):** The ability of a capacitor to store electric charge, measured in farads (F).
- **Capacitor:** A device that stores electric charge, consisting of two conductors separated by a dielectric material.
- **Charge Storage:** The ability of a capacitor to store electric charge, given by $Q = CV$, where Q is the charge stored and V is the potential difference across the capacitor.

Weekly Challenge: Design and build a simple electric circuit using everyday materials, such as a battery, wires, and a light bulb. Analyse the circuit and explain how it works, using concepts such as current, voltage, and resistance. Share your findings on Google Classroom.



A1. Proficiency Drills

Learning Focus: Foundational concepts of **Current, Voltage, Resistance**, analysing **Series and Parallel Circuits**, and understanding **Resistivity and Capacitance**.

Part 1: The Holy Trinity - V, I, and R

Key Concepts Formulae

Current (I): The rate of **flow of electric charge**. It is measured in Amperes (A).

- **Formula:** $I = \frac{Q}{t}$ (Charge Q in Coulombs, time t in seconds).

Potential Difference (V): The **work done (or energy converted) per unit charge** moving between two points. It is measured in Volts (V). It's the "push" that drives the current.

- **Formula:** $V = \frac{W}{Q}$ (Work W in Joules, Charge Q in Coulombs).

Resistance (R): A measure of the **opposition to the flow of current**. It is measured in Ohms (Ω).

- **Ohm's Law:** $V = IR$ (For Ohmic conductors, R is constant).

Task #1: Identify the missing quantity, formula, or unit.

Scenario	Key Quantity	Governing Formula	Unit
Electrons flowing through a wire		$I = Q/t$	A
A battery providing energy to a circuit	Potential Difference		V
A component that heats up and restricts current	Resistance	$R = V/I$	
Charge stored on a capacitor		$Q = CV$	C

Part 2: Circuit Rules - Series vs. Parallel

Essential Principles

Series Circuits: Components are connected end-to-end, providing **only one path** for the current.

- **Current** is the **same** through all components.
- **Voltage** is **shared** between components.
- **Total Resistance:** $R_T = R_1 + R_2 + \dots$

Parallel Circuits: Components are connected on separate branches, providing **multiple paths** for the current.

- **Voltage** is the **same** across all branches.
- **Current** is **split** between the branches.
- **Total Resistance:** $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

Task #2: Perform these basic calculations.

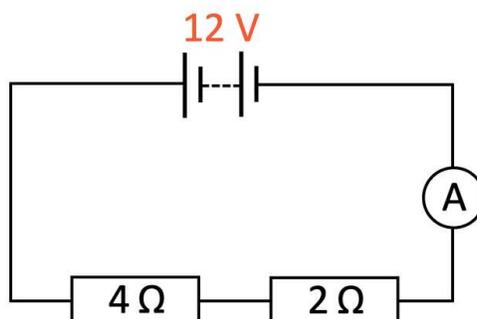
1. A 5Ω and a 10Ω resistor are in series. Their total resistance is _____ Ω .
2. A 6Ω and a 3Ω resistor are in parallel. Their total resistance is _____ Ω .
3. A 12V battery is connected to a 4Ω resistor. The current flowing is _____ A.
4. A wire of resistance 2Ω , length 5 m and area $1 \times 10^{-6} \text{ m}^2$ has a resistivity of _____ Ωm .
5. A $200 \mu\text{F}$ capacitor is connected to a 6V supply. The charge stored is _____ C.
6. The current in a circuit is 2 A. The charge that passes a point in 30 seconds is _____ C.

Part 3: Circuit Analysis

Physics Vocabulary

- **Resistivity (ρ):** An intrinsic property of a material that quantifies how strongly it resists electric current. A low resistivity indicates a material that readily allows the flow of current (a good conductor).
- **Capacitance (C):** The ability of a component (a capacitor) to store electric charge. It is the ratio of the charge stored to the potential difference across it. Unit: Farad (F).

Task #3: Consider the circuit shown, containing a 12V battery, a 2Ω resistor and a 4Ω resistor in series.





Electricity Resistance Experiments

This week's experiments shift our focus to electricity. We will explore Joule's law of heating, determine the resistivity of a wire, and graphically analyse the I-V characteristics of various circuit components. These practicals are fundamental to understanding everything from simple circuits to complex electronics.

Mastery of these experiments requires careful circuit construction and data logging. For each one, ask: **What is the correct circuit diagram? What is the independent and dependent variable?** and **What does the shape of the graph tell us about the component?**

Experiment	What is being Measured?	Why This Matters (The 'Why')
Verification of Joule's Law ($P \propto I^2$)	Temperature rise ($\Delta\theta$) in a liquid caused by varying current (I) through a fixed resistor	Quantifies the heating effect of current. This principle is the basis for fuses, electric heaters, and incandescent bulbs.
Measurement of Resistivity (ρ)	Resistance (R), length (L), and diameter (d) of a wire	Determines an intrinsic property of a material, allowing us to select the right materials for wires (low ρ) or resistors (high ρ).
Resistance vs. Temperature for a conductor and a thermistor	Resistance (R) at different temperatures (T)	Demonstrates how temperature affects charge flow, explaining the operation of digital thermometers (thermistors) and the limitations of conductors.
I-V Characteristics of various components	Current (I) flowing through a component for a range of potential differences (V) across it	Distinguishes between Ohmic and non-Ohmic components. The resulting graphs are the "fingerprints" of their electrical behaviour.

Connecting the Dots: Common Exam Pitfalls

Exam Preparation Tips

Joule's Law:

- The key relationship to verify is $P \propto I^2$. Since temperature rise $\Delta\theta$ is proportional to the energy supplied ($P \times t$), we plot $\Delta\theta$ vs I^2 .
- To ensure a fair test, the **mass of the liquid** and the **time of heating** must be kept constant for each run.
- A primary source of error is **heat loss** to the surroundings. Insulate the calorimeter to minimise this.

Resistivity (ρ):

- Know the formula $\rho = \frac{RA}{L}$. The cross-sectional area A is πr^2 or $\pi(d/2)^2$.
- Key precaution for measuring diameter (d): use a **micrometer**, measure it at several points along the wire and in different orientations, and find the average. This accounts for non-uniformity.
- Key precaution for measuring length (L): ensure the wire is taut and free of kinks when measuring it against a metre stick.

Resistance vs. Temperature:

- For both the metallic conductor and thermistor, the component must be in a water bath with a thermometer to accurately control and measure the temperature.
- **Wait for thermal equilibrium** before taking readings (i.e., allow the component's temperature to stabilise with the water's temperature).
- Know the shapes of the graphs: For a metallic conductor, Resistance vs. Temperature is a **straight line with a positive slope** (not through the origin). For a thermistor, it is a **downward-sloping curve**.

I-V Characteristics:

- Be able to draw the standard circuit containing a variable power supply, ammeter in series, and voltmeter in parallel with the component under test.
- Know the graphs:
 - **Metallic Conductor:** Straight line through the origin (Ohmic).
 - **Filament Bulb:** S-shaped curve through the origin (non-Ohmic as filament heats up).
 - **Semiconductor Diode:** No current in reverse bias, then a sharp increase in current after 0.7V in forward bias.
 - **Copper Sulfate with Copper Electrodes:** Straight line that does *not* go through the origin (due to back-emf).

Video Review & Active Recall Quiz

Experiment Video Demonstrations

Watch these videos to see the circuit setups and data collection for these experiments.

- **Joule's Law:** [\[VIDEO LINK\]](#)
- **Resistivity of a Wire:** [\[VIDEO LINK\]](#)
- **R vs. Temperature (Thermistor):** [\[VIDEO LINK\]](#)
- **I-V Characteristics:** [\[VIDEO LINK\]](#)

Active Recall Exam Questions

Answer the following questions **from memory**.

1. State Joule's Law.
2. To verify Joule's Law, what quantities are plotted on a graph to yield a straight line through the origin?
3. Define resistivity.
4. What instrument is used to measure the diameter of a wire in the resistivity experiment? Why is an average of several readings taken?
5. Draw a circuit diagram that could be used to investigate the I-V characteristics of a semiconductor diode. Don't forget the protective resistor!
6. Sketch the I-V graph for a filament bulb.
7. Why is a filament bulb described as a "non-Ohmic" conductor?
8. Sketch the graph showing the variation of resistance with temperature for a thermistor.
9. An ammeter must be connected in _____ with a component, while a voltmeter must be connected in _____ with it.
10. What are the charge carriers in (a) metallic conductors and (b) semiconductors?
11. In an experiment to measure the resistivity of nichrome, a wire of length 1.5 m and radius 0.11 mm was found to have a resistance of 38.5Ω . Calculate the resistivity of nichrome.

D. Weekend Assessment – Past Exam Questions

Learning Focus: Applying learning to exam questions under timed conditions.
Think deeply about these questions.

Assessment Instructions

Answer as many questions as you can in 60 minutes - try to solve them alone first before checking your notes!

Past Exam Questions

Question 1 (2013, Q12(c))

- Define the unit of charge, the coulomb.
- State Coulomb's law.
- Calculate the force of repulsion between two small spheres when they are held 8 cm apart in a vacuum (each sphere has a positive charge of +3 C).
- Copy the diagram and show on it the electric field generated by the charges.
- Mark on your diagram a place where the electric field strength is zero.

Question 2 (2005, Q10)

- Define electric field strength.
- State Coulomb's law of force between electric charges.
- Why is Coulomb's law an example of an inverse square law?
- Give two differences between the gravitational force and the electrostatic force between two electrons.
- Describe an experiment to show an electric field pattern.
- Calculate the electric field strength at the point B, which is 10 mm from an electron.
- What is the direction of the electric field strength at B?
- A charge of 5 C is placed at B. Calculate the electrostatic force exerted on this charge.

Question 3 (2007, Q8)

- Define electric field strength and give its unit of measurement.
- Describe how an electric field pattern may be demonstrated in the laboratory.
- The dome of a Van de Graff generator is charged. The dome has a diameter of 30 cm and its charge is 4 C. A 5 C point charge is placed 7 cm from the surface of the dome. Calculate the electric field strength at a point 7 cm from the dome.
- Calculate the electrostatic force exerted on the 5 C point charge.
- All the charge resides on the surface of a Van de Graff generator's dome. Explain why.
- Describe an experiment to demonstrate that total charge resides on the outside of a conductor.
- Give an application of this effect.



Self-Assessment

After completing the assessment:

- Grade your work honestly
- Identify areas needing improvement
- Scan and submit via Google Classroom
- Reflect on your performance in your weekly reflection

Another excellent week of work completed - ***well done!*** You are another step closer to *smashing your exams*, and another week closer to your summer holidays!

Weekly Reflection Zone

What worked well this week?

What challenges did I face?

What surprised me the most this week?

Key physics concepts I want to review:

Goals for next week: