

Physics 3.6 : Demonstrate understanding of electrical systems

Level 3 Credits 6

This achievement standard involves knowledge and understanding of phenomena, concepts, principles and/or relationships related to direct current (DC) circuits, capacitance, electromagnetic induction, alternating current (AC) circuits, and the use of appropriate methods to solve related problems.

DC Circuits and Capacitance

Internal resistance; simple application of Kirchhoff's Laws; parallel plate capacitor; capacitance; dielectrics; series and parallel capacitors; charge/discharge characteristics of capacitors in DC RC circuits; voltage/time and current/time graphs for a capacitor; time constant; energy stored in a capacitor.

Electromagnetic Induction and AC Circuits

Magnetic flux; magnetic flux density; Faraday's Law; Lenz's Law; voltage/time and current/time graphs for an inductor; time constant; self inductance; the inductor; energy stored in an inductor; mutual inductance; the transformer; the comparison of the energy dissipation in a resistor carrying direct current and alternating current; peak and rms voltage and current; phase; phasors in AC; reactance and impedance and their frequency dependence in a series circuit; voltage and current and their phase relationship in LR and CR series circuits; resonance in LCR circuits.

Relationships:

$$\begin{array}{lllll}
 E = \frac{1}{2} QV & Q = CV & C = \frac{\epsilon_0 \epsilon_r A}{d} & C_T = C_1 + C_2 + \dots & \tau = RC \\
 \\
 \frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \dots & \phi = BA & \epsilon = -L \frac{\Delta I}{\Delta t} & \epsilon = - \frac{\Delta \phi}{\Delta t} & \\
 \\
 \epsilon = -M \frac{\Delta I}{\Delta t} & \frac{N_p}{N_s} = \frac{V_p}{V_s} & E = \frac{1}{2} LI^2 & & \\
 \\
 & \tau = \frac{L}{R} & & & \\
 \\
 I = I_{MAX} \sin \omega t & V = V_{MAX} \sin \omega t & I_{MAX} = \sqrt{2} I_{rms} & & \\
 \\
 V_{MAX} = \sqrt{2} V_{rms} & X_C = \frac{1}{\omega C} & & & \\
 \\
 X_L = \omega L & V = IZ & \omega = 2\pi f & &
 \end{array}$$

ELECTRICITY AND ELECTROMAGNETISM: Direct Current Electricity

By the end of this unit students should be able to:

- Use the formula $R = V/I$ to calculate the resistance of a conductor
- Investigate the E.M.F and internal resistance of various voltage loops
- Calculation of voltages and currents in one- and two-loop circuits, which may include DC voltage sources and resistors
- Understand the terms capacitance, the parallel plate capacitor, dielectric.
- Describe the function of a capacitor in a DC circuit
- Investigate the relationship between variables affecting a parallel plate capacitor
- Calculate the total capacitance for series and parallel capacitor combinations
- Calculate the energy stored in a capacitor in terms of the area under the Q-V graph
- Explain capacitor charge/discharge curves (Voltage/time and current/time) in terms of accumulation of charge and comment on the meaning of the time constant.

ELECTRICITY AND ELECTROMAGNETISM: Electromagnetism

By the end of this unit students should be able to:

- Understand the terms magnetic flux and magnetic field strength
- Investigate the factors affecting the magnetic field strength inside a solenoid
- Describe the function of an inductor in a DC circuit
- Explain inductor charge/discharge curves (Voltage/time and current/time) and comment on the meaning of the time constant.
- Investigate energy stored in an inductor
- Understand the relationship between rate of change of flux and the voltage induced across a conductor
- Use Faraday's Law to calculate the magnitude of the Induced voltage in a coil rotating with a constant angular velocity in a uniform magnetic field
- Apply Lenz's law to predict the direction of an induced current
- Identify factors which affect the size and direction of the induced voltage of an inductor
- Understand the terms mutual and self- inductance
- Understand the factors which affect the size and direction of the induced voltage of an inductor
- Investigate the relationship between primary(input) voltage/current and secondary(output) voltage/current in a transformer.

ELECTRICITY AND ELECTROMAGNETISM: Alternating Current

By the end of this unit students should be able to:

- Investigate and compare the energy dissipation of a resistor carrying DC and AC
- Recognise the difference between the RMS and peak values of current and voltage in an AC circuit
- Realise that the current and voltage for a resistor in an AC circuit are in phase
- Describe full and half wave rectification and smoothing in DC power supplies
- Demonstrate experimentally that for AC: current leads p.d by 90° in a capacitor in an RC circuit
- current lags p.d by 90° in an inductor in an LR circuit
- Understand the terms Reactance and impedance and their frequency dependence in a series circuit
- Use equations and graphs to depict the phase and amplitude relationship of the current and voltages in an LCR series circuit
- Describe energy changes, phase relationships and the resonant condition for an inductor-capacitor-resistor series circuit
- Use phasor diagrams to illustrate the relationship between V_{total} , V_R , V_L and V_C in an AC LCR circuit
- Use the resistance, capacitor reactance and inductor reactance to calculate the impedance of an LCR circuit
- Deduce from phasors that the alternating current in an LCR series circuit will be at a maximum when $V_L = V_C$ and use this observation to derive the resonant frequency equation $f = \frac{1}{2\pi\sqrt{LC}}$