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:

$E = \frac{1}{2}QV$ $\quad Q = CV$ $\quad C = \frac{\varepsilon_o \varepsilon_r A}{d}$ $\quad C_T = C_1 + C_2 + \ldots$ $\quad \tau = RC$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$ $\quad \phi = BA$ $\quad \varepsilon = -L\frac{\Delta I}{\Delta t}$ $\quad \varepsilon = -\frac{\Delta \phi}{\Delta t}$

$\varepsilon = -M\frac{\Delta I}{\Delta t}$ $\quad \frac{N_p}{N_s} = \frac{V_p}{V_s}$ $\quad E = \frac{1}{2}LI^2$ $\quad \tau = \frac{L}{R}$

$I = I_{MAX} \sin \omega t$ $\quad V = V_{MAX} \sin \omega t$ $\quad I_{MAX} = \sqrt{2} I_{rms}$

$V_{MAX} = \sqrt{2} V_{rms}$ $\quad X_C = \frac{1}{\omega C}$

$X_L = \omega L$ $\quad V = IZ$ $\quad \omega = 2\pi f$

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 = 2Π☆LC