TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
1.0 ELECTROSTATICS	At the end of this topic, students will be able to:		**10**
1.1 Coulomb's law	a) Explain the concepts of electrons, protons, charged objects, charged up, gaining charge, losing charge, charging by contact, charging by induction, grounding, charge quantization, charge conservation, conductors and insulators. . b) Describe the motion of point charges when placed near another charged object. c) Relate the motion of charges to a force and state Coulomb's Law. d) Explain, qualitatively, how the direction and the strength of this force changes with magnitude of the charges and the distance between the charges. e) Draw a force diagram to a system of point charges and obtain the direction and magnitude of the resultant force acting on a point charge due to the presence of other point charges.	➢ Relate the motion to Newton's 2nd law of motion and to the concept of motion. ➢ $\vec{F} = k\dfrac{q_1 q_2}{r^2}$ where the electric constant $k = \dfrac{1}{4\pi\varepsilon_0} = 9.0\times10^9\ \dfrac{\text{N}}{\text{C}^2\ \text{m}^2}$ ➢ 2 point charges along the x-axes, along the y-axes and 3 charges that forms a right-angled triangle.	2

http://drjj.uitm.edu.my; HP:+60-19-355-1621
Prepared by Assoc. Prof. Dr. Jaafar Jantan aka Dr. JJ
Email: jjnita@salam.uitm.edu.my; drjjlanita@hotmail.com

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
1.2 Electric field	a) State qualitative meaning of an electric field b) Write the electric field strength produced by a point charge and explain qualitatively how the field strength and direction changes when measured at different places. c) Sketch the electric field lines produced by an isolated point charge, by two positive or two negative point charges, by a pair of positive-negative charge and for a point charge placed between a uniformly-charged parallel plates. d) Obtain numerically and show pictorially the electric field strength and direction for a point charge, for a system of two charges and for a system of three charges. e) Explain the effect of the electric field on a positive test charge placed at midpoint between a pair of positive or negative charges and a pair of positive-negative charge.	➢ $\vec{E} = k\frac{q}{r^2}$. Note also the direction. ➢ Indicate the change of strength (field intensity) by varying the length of the field lines. ➢ Draw the field lines for a system of 2 positive charges, 2 negative charges and a pair of positive- negative charge. ➢ Numerically determine the field intensity on the right, on the left and at midpoints along the line of a pair of positive charges and a pair of positive-negative charge. ➢ $\vec{F} = q_0\vec{E} = k\frac{q_0 q}{r^2}$.	2
2.0 ELECTRIC POTENTIAL	At the end of this topic, the student will be able to:		**2**

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
2.1 Electric Potential & Equipotential Surfaces	a) Define electric potential and an equipotential surface. b) Sketch equipotential lines for an isolated positive charge, for an isolated negative charge, for a pair of positive-positive charge, for a pair of positive-negative charge and for a parallel-plate capacitor c) Write the strength and numerically obtain the potential for an isolated charge. d) Write the strength and numerically obtain the potential to the right, to the left and at midpoints for a pair of positive-positive charge and for a pair of positive-negative charge. e) Write, explain and numerically obtain the field strength in the area between a uniformly-charged parallel-plate capacitors. f) Explain, qualitatively, the electric potential energy gain or lost when a positive point charge is moved in an electric field.	➢ Electric potential as the amount of work done in moving a point charge from far away (infinity) to some point A in an electric field (compare to moving a mass in a gravitational field). $V_\infty - V_A = -V_A = \frac{W_{BA}}{q_0}$. ➢ Equipotential surface as a surface where V is a constant. ➢ For a point charge, $V = \frac{q_0 E}{q_0} r = k\frac{q}{r^2} r = k\frac{q}{r}$ ➢ $E = \frac{V}{d}$ ➢ Explain the work energy relation $W_{AB} = U_B - U_A = -q_0 V$	2

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
3.0 CAPACITOR AND DIELECTRICS	**At the end of this topic, the student will be able to:**		**3**
3.1 Capacitance and energy of capacitors	a) Define capacitance and state the purpose of a capacitor. b) Explain, qualitatively and algebraically, the factors affecting the capacitance of a parallel plate capacitor and the changes in the capacitance when the geometrical dimensions are changed. c) Numerically determine the capacitance of parallel plate capacitors and the changes in the capacitance when the geometrical dimensions are changed. d) Qualitatively, algebraically and numerically explain and obtain the changes in energy stored by a parallel-plate capacitor when the charging source and/or the geometrical dimensions are changed.	➢ Capacitance as a measure the charge on the capacitor per unit voltage, $C = \frac{Q}{V}$ ➢ Air-filled capacitor ➢ $C_0 = \frac{\varepsilon_0 A}{d}$, $C = \varepsilon_r C_o$ ➢ Table of dielectric constant ➢ Other types of capacitors are not discussed. ➢ $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$	1
3.2 Capacitors in series and parallel combination	a) Draw a schematic diagram for capacitors connected in series and capacitors connected in parallel. b) Obtain the mathematical formulation for effective capacitances for capacitors connected in series and connected in parallel. c) Calculate the effective capacitances of capacitors in series, capacitors in parallel and capacitors in series-parallel combination. d) Determine the voltage, the charge stored and the energy stored on each capacitor in a series, in parallel and in connected in series-parallel combination.	➢ Limit to five capacitors. ➢ Use the constant potential difference for a parallel circuit and constant current in series circuit to obtain effective capacitance. ➢ Parallel: $C = C_1 + C_2 + .. + C_5$ ➢ Series: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_5}$	2
4.0 ELECTRIC CURRENT AND DIRECT-CURRENT CIRCUITS	**At the end of this topic, the student will be able to:**		**10**

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
4.1 Ohm's law and Resistivity	a) Define electric current. b) Explain the relationship between current flow, electric field and potential difference between two points in a circuit. c) Define electromotive force (emf) of a battery and explain its role to current flow in a circuit. d) Draw an equivalent circuit to represent a battery with emf ε and internal resistance *r* and explain its effect to the current flowing in circuit. e) State and mathematically write Ohm's law. f) State and explain the relationship between the resistance of a wire to its physical dimensions and to its resistivity. g) Explain the concept of potential drop across a resistor in a simple circuit.	➢ $I = \frac{\Delta Q}{\Delta t}$, $I = \frac{\mathrm{d}Q}{\mathrm{d}t}$ ➢ $V=IR$ ➢ $R = \frac{\rho l}{A}$ ➢ Introduce conductivity as the inverse of resistivity ➢ $\sigma = \frac{1}{\rho}$ ➢ Simple circuit is limited to only one load (bulb or resistor) ➢ $V = \xi - Ir$	3
4.2 Electrical energy and power	a) Define electrical power and explain joule heating in a resistor. b) Determine the dissipative power and energy loss in a simple circuit.	➢ Include $P = I^2 R$ and $P = \frac{V^2}{R}$ for power. ➢ Emphasize on V as potential difference across resistors. ➢ $P = VI$ and $Energy \equiv VIt$	1

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
4.3 Resistors in series and parallel	a) Draw a circuit diagram for resistors in series and resistors in parallel. b) Obtain the mathematical formulation for effective resistances for resistors connected in series and resistors connected in parallel. c) Calculate the effective resistance of resistors in series, resistors in parallel and resistors in series-parallel combination. d) Determine the voltage and the current on each resistor connected in series, connected in parallel and connected in a series-parallel combination.	➢ Limit to four resistors. ➢ Use Ohm's Law. ➢ Use the constant potential difference for a parallel circuit and constant current in series circuit to obtain the effective resistance. ➢ Limit to a maximum of only 3 resistors in series and 3 resistors in parallel for the combination circuit.	3
4.4 Kirchhoff's Laws	a) State Kirchoff's current and voltage laws and write the mathematical representation for both laws. b) Label the high and low potential points across resistors and batteries for a given current direction in a loop. c) Write Kirchhoff's laws applied to a two-loop circuit.	➢ $\Sigma V_{drop} = \Sigma V_{rise}$, $\Sigma I_{in} = \Sigma I_{out}$ ➢ Limit to a maximum of only 3 resistors and 2 batteries in each loop. ➢ Specify the current before labelling the high and low potential ends. ➢ Maximum of two closed circuit loops.	3
5.0 MAGNETIC FIELD	**At the end of this topic, the student will be able to:**		**9**

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
5.1 Permanent magnets and magnetic force	a) Sketch the magnetic field lines produced by permanent magnets. b) Describe the relationship between a magnet's poles and the field lines produced. c) Describe the effect of magnetic field on static and moving electric charges. d) Write the strength and determine the direction of magnetic force acting on moving charges by using the First Right Hand Rule. e) Use the First Right Hand Rule to obtain direction of motion, direction of magnetic field or the magnetic force whenever any two of the quantities are known.	➢ Bar magnet and horse-shoe magnets ➢ Use tiny compasses to represent B field lines and to show direction of the field. Briefly describe the Earth as a giant magnet. Briefly mention the common units used for field strength and some typical values of B. ➢ Only moving charges with velocity perpendicular to or having the velocity component which is perpendicular to the field will experience a magnetic force. $F = qvB\sin\theta_{vB}$. NO NEED to introduce cross product. Use either the first right hand rule (thumb along velocity, other fingers along B then the palm will show force acting on a +ve charge) or any other easy-to remember rules to determine direction of the force.	2

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
5.2 Magnetic field produced by current-carrying conductor	a) Determine the direction of magnetic field produced by current-carrying conductor. b) Sketch the field lines produced by a long current-carrying conductor and by a circular wire. c) Write and numerically determine the strength (intensity) of the field produced by a long wire as a function of the current carried by the wire and distance from the wire. d) Write and numerically determine the strength (intensity) of the field produced at the centre of a circular wire. e) Draw the magnetic field lines and label the North-South poles for a solenoid. f) Write and numerically determine the strength (intensity) of the field produced along the centre of a solenoid.	Use the 2nd Right Hand Rule (corkscrew) to determine direction of $\vec{B}$ for both the long wire and circular wire. ➢ $B = \frac{\mu_0 I}{2\pi r}$ for a long straight wire ➢ $B = \frac{\mu_0 I}{2r}$ at the centre of a circular wire of radius R. ➢ $B = \mu_0 nI$ for a solenoid with N turns per meter of the wire.	3

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
5.3 Magnetic Force on a moving charged particle and on a current-carrying conductor.	a) Determine the magnitude and direction of force acting on a charged particle moving near a current-carrying conductor. b) Determine the magnitude and direction of the force acting between two parallel current-carrying conductors and between two wires carrying current in opposite directions. c) Determine the direction of the force acting between two parallel circular wires carrying current in the same directions and two parallel circular wires carrying current in the opposite directions. d) Compute the force per unit length on two adjacent parallel current-carrying conductors	➢ Use the 1st Right Hand Rule. $F = qvB\sin\theta_{vB}$ ➢ Force between two parallel wires: $F = qvB\sin\theta_{vB} = ILB\sin\theta_{IB}$. You need to first determine the B field produced by each wire (using the corkscrew rule) before applying the 1st Right Hand Rule. ➢ Determine the poles for the circular wires before determining the direction of forces between two parallel coils. ➢ Assume wires of same lengths L, then $\frac{F}{L} = I_1 B = I_1 \frac{\mu_0 I_2}{2\pi d}$	3
5.4 Torque on a coil	a) Determine the force directions on the sides of a rectangular coil with surface area A and carrying current I placed in a magnetic field B. b) Describe the effect of the magnetic force on the coil, qualitatively and pictorially. c) List and explain the factors affecting speed of rotation for a rectangular coil of surface area A, carrying current I placed in a magnetic field B.	➢ Use results from section 13.3 ➢ Show the force directions and the direction of rotation for both sides and how that changes when current direction or field direction is reversed. ➢ Area, field strength, number of turns and the current	2
6.0 ELECTROMAGNETIC INDUCTION	At the end of this topic, the student will be able to:		4

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
6.1 Magnetic Flux and Faraday's Law	a) Define magnetic flux and explain the factors that will change magnetic flux, b) Qualitatively and diagrammatically describe what happens in a conducting wire coil when a bar magnet is moved towards or away from the coil. c) State Faraday's law and mathematically write the law. d) Use Faraday's law to qualitatively explain the maximum induced current and hence the *emf* in a conducting wire coil connected in series with a resistor. e) Qualitatively explain the relationship between induced voltage (*emf*) and the induced current. f) Calculate the induced *emf* in a single coil and in coils with N turns for changes in B field strength and for changes in the area of the coil. g) Determine the imaginary poles for the induced magnetic field for magnets moving into and away from a conducting wire coil.	➢ Flux governed by product of the magnetic field (its perpendicular component) strength passing through the surface of a coil and the area of the coil.. $\Phi = BA\cos\Theta$. Limit to field lines that are perpendicular to surface. ➢ Emphasize on the magnet's polarity and its direction of motion as the determining factor in describing the direction of induced current. ➢ $emf = -N\frac{\Delta\Phi}{\Delta t}$ (induced voltage) ➢ Example of changes in *B* only and changes in *A* only. ➢ Use the imaginary poles for the induced B field to decide direction of induced I and the high and low potential ends of the resistor.	3

TOPIC	LEARNING OUTCOMES	REMARKS	HOUR
6.2 Lenz's Law	a) State Lenz's law and describe how the law is used to explain part (g)of section 6.1, the direction of the induced current and hence the induced *emf*. b) Apply Lenz's Law to determine the direction of the induced current and the induced *emf* in a coil being rotated between poles of a permanent magnet and to explain the sinusoidal behaviour of the induced *emf* and induced current. c) Apply Faraday's Law to obtain the magnitude of the induced *emf* for a coil rotating between the poles of a permanent magnet and use Ohm's Law to determine the induced current in the coil.	➢ $emf = -N\frac{\Delta\Phi}{\Delta t} = NAB\frac{\Delta(\cos\Theta)}{\Delta t}$	2
6.3 Electric Generators, Inductors & Transformers	a) Qualitatively compare and contrast the induction mechanism in an electric generator and an electric motor. b) Quantitatively compare and contrast self inductance and mutual inductance on coils carrying current which is time-dependent c) Determine the induced emf in inductors from a current-time graph and obtain the energy stored by the inductor. d) Qualitatively and quantitatively explain the mechanism of a step-up and a step-down AC transformer.	➢ Show that for mutual inductance: $emf = -N\frac{\Delta\Phi}{\Delta t} = M\frac{\Delta I_p}{\Delta t}$ ➢ Show that for self inductance: $emf = -N\frac{\Delta\Phi}{\Delta t} = L\frac{\Delta I}{\Delta t}$ ➢ Energy stored is $Energy = \frac{1}{2}LI^2$ ➢ Discuss the flux change between the primary & secondary coil being the same since it shares the same core: $emf_s = -N_s\frac{\Delta\Phi}{\Delta t}$, $emf_p = -N_p\frac{\Delta\Phi}{\Delta t}$; $emf_s = emf_p$ $\frac{emf_p}{emf_s} = \frac{N_p}{N_s}$ or $\frac{V_p}{V_s} = \frac{N_p}{N_s}$	1

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Prepared by Assoc. Prof. Dr. Jaafar Jantan aka Dr. JJ
Email: jjnita@salam.uitm.edu.my; drjjlanita@hotmail.com