EXAMINATION PAPER CONTAINS STUDENT'S ANSW

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The Handbook of Mathematics, Physics and Astronomy Data is provided

KEELE UNIVERSITY

EXAMINATIONS, 2011/12

Level I

Monday 21st May 2011, 09:30 - 11:30

PHYSICS/ASTROPHYSICS

PHY-10021

ELECTRICITY AND MAGNETISM

Candidates should attempt ALL of PARTS A and B, and ONE question from each of PARTS C and D. PARTS A and B should be answered on the exam paper; PARTS C and D should be answered in the examination booklet which should be attached to the exam paper at the end of the exam with a treasury tag. PART A yields 16% of the marks, PART B yields 24%, PART C yields 30%, PART D yields 30%.

Please do not write in the box below

A		C1		Total
B		C2		
		D1		
		D2		

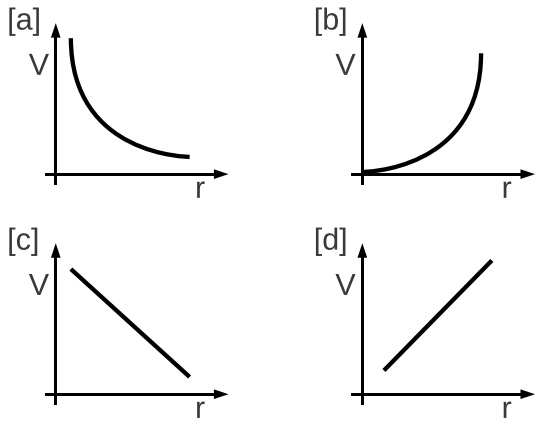
NOT TO BE REMOVED FROM THE EXAMINATION HALL

PART A Tick one box by the answer you judge to be cor
(marks are not deducted for incorrect answers)

A1 The electrostatic force between two point charges is 20 N. If the distance between the charges is doubled, then the force will be:

☐ 5 N ☐ 10 N ☐ 40 N ☐ 80 N [1]

A2 Which of the following graphs illustrates the variation of the electrostatic potential, V, with distance from a point charge.



☐ a ☐ b

☐ c ☐ d [1]

A3 The potential energy of a dipole in an electric field is *maximum* when the dipole is:

☐ parallel to the electric field

☐ perpendicular to the electric field

☐ anti-parallel to the electric field (180° between the two vectors)

☐ at an angle of 135° to the electric field [1]

/Cont'd

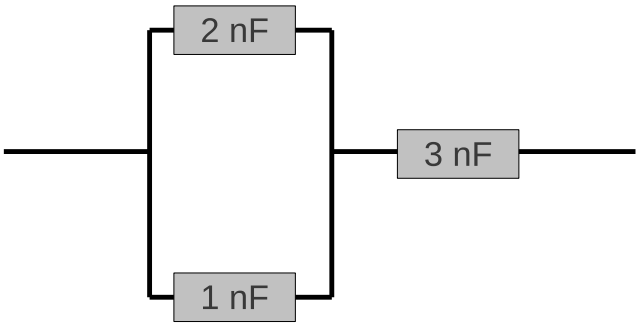
A4 The electric potential inside a conductor is always:

- ☐ dependent on the shape of the conductor
- ☐ constant
- ☐ dependent on the size of the conductor
- ☐ zero [1]

A5 What is the electric potential across a distance of 10 m in a uniform electric field, $E = 200\,\mathrm{V/m}$.

☐ 20 V ☐ 200 V ☐ 400 V ☐ 2000 V [1]

A6 What is the equivalent capacitance of the following circuit:



☐ 1 nF ☐ 1.5 nF ☐ 3 nF ☐ $\frac{11}{3}$ nF [1]

A7 The cyclotron frequency of a particle in a magnetic field is *independent* of:

- ☐ the particle velocity
- ☐ the particle mass
- ☐ the particle charge
- ☐ the magnitude of the magnetic field [1]

/Cont'd

A8 An electron is moving horizontally (parallel to the ground) from west to east at constant velocity. Given that the earth's magnetic field is horizontal and points to the north, in which direction does the magnetic force on the electron point?

- ☐ South
- ☐ Vertically upwards (towards the sky)
- ☐ East
- ☐ Vertically downwards (towards the ground) [1]

A9 A straight electrical wire is placed in a magnetic field, $\vec{B}$. The wire carries a current, I, along its length, $\vec{l}$. The magnetic force, $\vec{F}$, on the wire is given by:

☐ $\vec{l} \cdot \vec{B}/I$ ☐ $I\vec{l} \cdot \vec{B}$ ☐ $I\vec{l} \times \vec{B}$ ☐ IlB [1]

A10 Inside an infinitely long solenoid, the magnetic field is:

- ☐ proportional to the radial distance from the centre of the solenoid.
- ☐ inversely proportional to the radial distance from the solenoid.
- ☐ zero.
- ☐ uniform. [1]

A11 A loop of conducting wire exposed to an external magnetic field will experience an induced current if:

- ☐ The area of the loop changes
- ☐ The direction of the magnetic field changes
- ☐ The magnitude of the magnetic field changes
- ☐ All of the above [1]

/Cont'd

A12 A horizontal, uniform magnetic field of strength B threads thr vertical, rectangular loop of a conducting wire of area, A. The pla of the loop is initially perpendicular to the magnetic field. If the loop is then rotated by 180° about its vertical axis over time t, the induced voltage is:

☐ $\frac{BA}{2t}$ ☐ $2BAt$ ☐ $\frac{2BA}{t}$ ☐ BAt [1]

A13 The energy stored in an inductor (of inductance L) when the current has risen from 0 to I is given by:

☐ $\frac{LQ^2}{2}$ ☐ $\frac{LI^2}{2}$ ☐ LI^2 ☐ LQ^2 [1]

A14 The impedance of an RLC series circuit is given by:

☐ $\sqrt{R^2-(X_L-X_C)^2}$ ☐ $\sqrt{R^2+(X_L+X_C)^2}$
☐ $\sqrt{R^2+(X_L-X_C)^2}$ ☐ $\sqrt{R^2+X_L^2+X_C^2}$ [1]

A15 In an AC circuit, the reactance of a capacitor is 10 Ω. If the frequency is halved, the reactance of the capacitor becomes:

☐ 5 Ω ☐ 10 Ω ☐ 20 Ω ☐ 40 Ω [1]

A16 In an AC circuit, the phase difference between the voltage and the current is ϕ. The power factor is:

☐ $\sin(\phi)$ ☐ $\sin^2(\phi)$ ☐ $\cos(\phi)$ ☐ $\tan(\phi)$ [1]

/Cont'd

PART B Answer all EIGHT questions

B1 Calculate the ratio of the electric force to the gravitational force between two protons. [3]

B2 State Gauss's law and which physical quantity is usually determined using this law. [3]

/Cont'd

B3 Sketch the electric potential due to a pair of charges −q and −q separated by a distance d. [3]

B4 How does the velocity selected by a velocity selector apparatus depend on the magnetic and electric fields used (justify your answer)? [3]

/Cont'd

B5 A long cylindrical conductor of 0.04-m radius carries a 10-A current. At what distance from the conductor in the direction perpendicular to its length, will the magnetic field outside the conductor be equal to half of the magnetic field at the surface of the conductor? [3]

B6 What is the induced voltage as a function of time produced on a loop of conducting wire (area of $2\,\mathrm{m}^2$) due to a perpendicular magnetic field B if the magnetic field is given by $B = 5t^2 + 30$ Tesla (where t is the time)? [3]

/Cont'd

B7 A 40-mH inductor is connected to a source with a peak potential difference of 20 V and a frequency of 200 Hz. Calculate the peak current. [3]

B8 Sketch two different circuit diagrams for a low-pass filter. [3]

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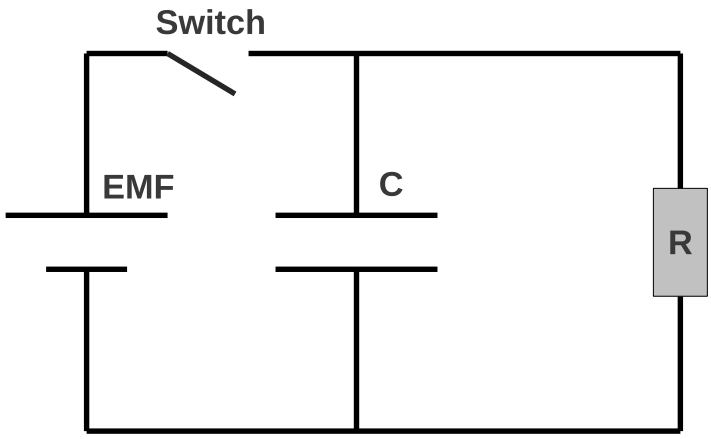
PART C Answer ONE out of TWO questions

C1 The switch in the circuit diagram below is initially closed.



(a) What is the initial charge on the capacitor if its capacitance is $100\,\mu$F and the *emf* is 50 V? [3]

(b) The switch is opened at $t = 0$ s. The capacitor discharges and the charge on the capacitor at time t is given by $Q(t) = Q_0\, e^{-t/(RC)}$ with $R = 10\,\Omega$.

i. How long does it take for the charge on the capacitor to reach 10% of the initial value? [8]

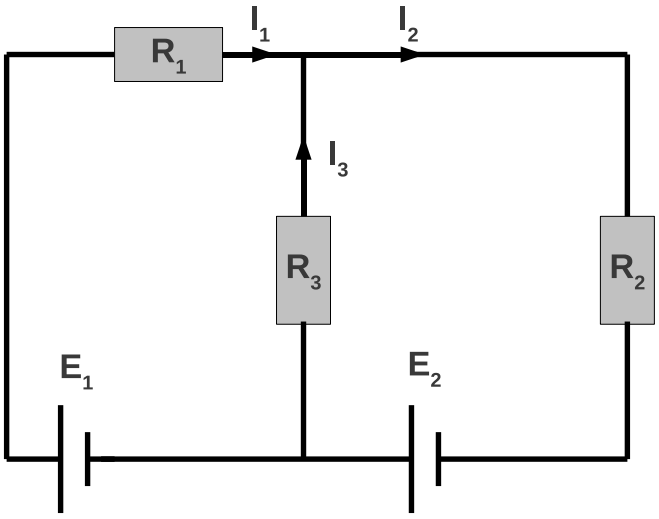
ii. Derive an expression for the time evolution of the current in the circuit. [7]

iii. What is the magnitude of the current at the time determined in part (i)? [8]

iv. Which quantities influence the rate of discharge of the capacitor? [4]

/Cont'd

C2 In the circuit diagram below, $I_1 = 4\,\text{A}$, $I_2 = 6\,\text{A}$, $R_1 =$ [illegible] $R_2 = 10\,\Omega$, and $R_3 = 5\,\Omega$.



(a) Using Kirchhof's laws, calculate the potential difference across each of E_1 and E_2. [14]

(b) State the rules to calculate the equivalent resistance for series and parallel combinations of resistors. [6]

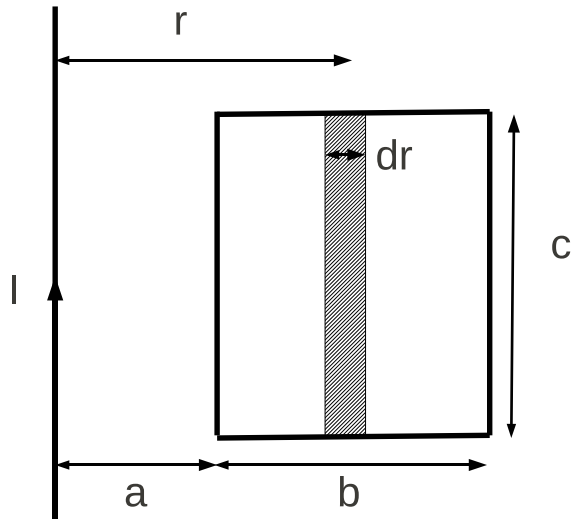
(c) Calculate the new current I_2 if the *emf* E_1 is replaced by a fourth resistor $R_4 = 5\,\Omega$. [10]

/Cont'd

PART D Answer ONE out of TWO questions

D1 (a) State and explain the laws of electromagnetic induction. [8]

(b) The current I in the infinite wire on the left in the figure below is upward and is increasing slowly at a rate $\frac{dI}{dt} > 0$.



i. What are the magnitude and direction of the field $\vec{B}$ at a distance r from the wire? (Express your answer in terms of the variables given in the figure.) [4]

ii. What is the flux $d\phi$ through the narrow hatched strip of width dr and height c? [4]

iii. What is the total flux through the loop? [8]

iv. What are the magnitude and direction of the induced emf in the loop? [6]

/Cont'd

D2 (a) State the formulae to calculate the power delivered to an AC circuit and a DC circuit and explain why the two formulae are different. [6]

(b) A series LCR circuit has the following properties: $L = 20\,\text{mH}$, $C = 0.2\,\mu\text{F}$ and $R = 400\,\Omega$. The input voltage is 240 V (rms) and the angular frequency is $\omega = 10^4\,\text{rad}\,\text{s}^{-1}$.

i. Calculate the total impedance. [6]

ii. Calculate the peak current in the circuit. [4]

iii. Determine the phase angle and whether the voltage is leading or lagging the current. [6]

iv. Calculate the average power delivered to the circuit and the average power dissipated in R and comment on your answers. [8]