KEELE UNIVERSITY

DEGREE EXAMINATIONS 2009

LEVEL 1 (PRINCIPAL COURSE)

Tuesday 26th May 2009 16:00 – 18:00

PHYSICS

PHY-10013

Electricity and Magnetism

Candidates should attempt ALL of PARTS A and B, and ONE question from PART C and ONE question from PART D. PARTS A and B should be answered on the exam paper, PART C AND PART D should be answered in the examination booklet which should be attached to the exam paper at the end of the exam. PART A yields 16% of the marks, PART B yields 24% PART C yields 30% and PART D yields 30%. You are advised to divide your time in roughly these proportions.

Figures in brackets [ ] denote the marks allocated to the various parts of each question. Tables of physical and mathematical data may be obtained from the invigilator.

Student Number: .....

Please do not write in the box below

Section A	■	
Section B	■	
Section C	C1	
	C2	
Section D	D1	
	D2	
Total %	■	

/Cont'd

PART A TICK THE SQUARE BRACKET BY THE ANSWER YOU JUDGE TO CORRECT. MARKS FOR INCORRECT ANSWERS WILL NOT BE DEDUCTED.

A1. Two charges q_1 and q_2 are separated by a distance r. The electrostatic force between these two charges is given by:

[ ] $\frac{kq_1q_2}{r^2}$

[ ] $\frac{k(q_1+q_2)}{r}$

[ ] $\frac{k{q_1}^2q_2}{r^2}$

[ ] $\frac{k(q_1+q_2)^2}{r^2}$ [1]

A2. The force on an electric charge q due to an electric field is F. The strength of the electric field is given by:

[ ] qF

[ ] $\frac{q}{F}$

[ ] $\frac{F}{q}$

[ ] F [1]

A3. The electrostatic potentials at a point due to charges Q_1, Q_2, Q_3 are -20V, +10V and +30V respectively. The potential at the same point due to all the charges is:

[ ] 60 V

[ ] -20 V

[ ] 40 V

[ ] 20 V [1]

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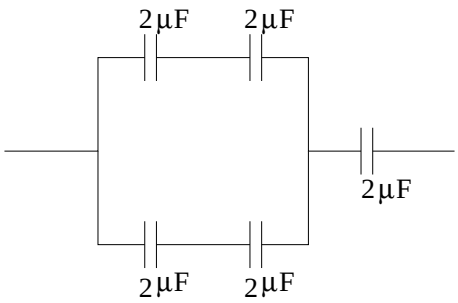
A4. The equivalent capacitance of the following circuit is:



[ ] 10 μF

[ ] 1 μF

[ ] 4 μF

[ ] 3 μF [1]

A5. An electrical conductor carries a charge q coulombs in t seconds, the current is given by:

[ ] q amps

[ ] $\frac{q}{t}$ amps

[ ] $\frac{t}{q}$ amps

[ ] qt amps [1]

A6. The current due to a DC voltage V across a resistance R is I. The electrical power dissipated by the resistor R is:

[ ] VR

[ ] IR

[ ] I^2R

[ ] $\frac{V}{R}$ [1]

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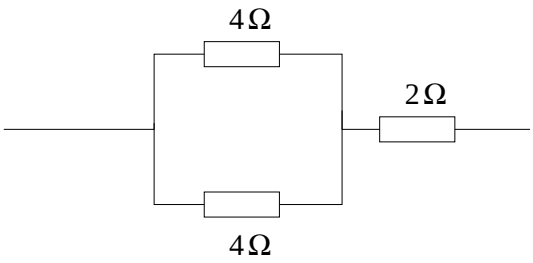
A7. The equivalent resistance of the following circuit is:



[ ] 10 Ω

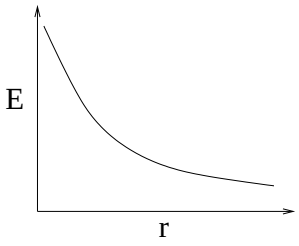
[ ] 4 Ω

[ ] 6 Ω

[ ] 1 Ω [1]

A8. Which of the following graphs illustrate the variation of electric field with distance from a point charge.

[ ]



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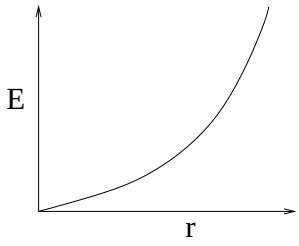

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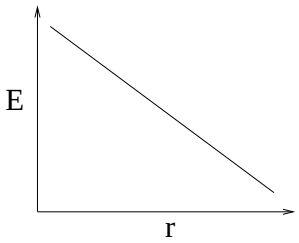

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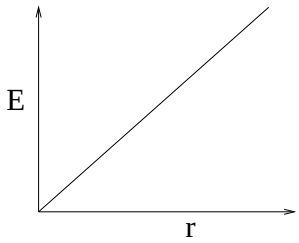

[1]

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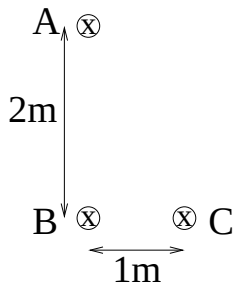
A9. Three infinitely long, electrical conductors, A, B and C, are placed perpendicular to the plane of the paper, as shown below. The currents through all three conductors are identical and the force per unit length between A and B is 10Nm^{-1}. The force



per unit length between B and C is:

[ ] 10Nm^{-1}

[ ] 20Nm^{-1}

[ ] 5Nm^{-1}

[ ] 40Nm^{-1} [1]

A10. The time-constant of an LR circuit is 1 second. If the value of the resistance is halved, the time-constant will be:

[ ] 1 s

[ ] 2 s

[ ] 0.5 s

[ ] 4 s [1]

/Cont'd

A11. A magnetic loop has an area of 0.2 m^2 and carries a 10 A current. The magnitu of the magnetic dipole moment is:

[ ] 0.2 Am^2

[ ] 2.0 Am^2

[ ] 0.02 Am^2

[ ] 50.0 Am^2 [1]

A12. A rectangular loop of cross section 1.0 m $\times$ 0.5 m is in a 2 T magnetic field. Initially, the plane of the rectangular loop is perpendicular to the magnetic field. If the loop is rotated by 180^o about an axis perpendicular to the field lines, the magnitude of the change in magnetic flux through the loop is:

[ ] 2.0 Wb

[ ] 1.0 Wb

[ ] 0.5 Wb

[ ] 1.5 Wb [1]

A13. In an ac-circuit, the phase difference between the voltage and the current is ϕ. The power factor is:

[ ] $\sin \phi$

[ ] $\cos \phi$

[ ] $\tan \phi$

[ ] $\cos^2 \phi$ [1]

A14. In an ac-circuit, the peak value of the current is 1.00 A. The *root mean square (rms)* current is:

[ ] 1.00 A

[ ] 1.41 A

[ ] 2.00 A

[ ] 0.71 A [1]

/Cont'd

A15. In an ac-circuit, the impedance of an inductor is 1000 Ω. If the frequency is halv the impedance of the inductor is:

[ ] 1000 Ω

[ ] 500 Ω

[ ] 2000 Ω

[ ] 250 Ω [1]

A16. A rectangular loop of a conducting wire with area A is in a magnetic field B. The plane of the loop is perpendicular to the magnetic field. If the loop is rotated by 90^{o} in time t, the induced voltage is:

[ ] $\frac{BA}{t}$

[ ] $\frac{BA}{2t}$

[ ] $\frac{2BA}{t}$

[ ] 0 [1]

/Cont'd

PART B Attempt ALL questions

B1. A charged oil drop of mass 3.2×10^{-6} kg falling vertically against a 10^{14} Vm^{-1} uniform electric field reaches a constant velocity. How many electrons are on the oil drop? (For an electron $e = 1.6 \times 10^{-19}$C. Assume that the acceleration due to gravity is 10.0ms^{-2}.) [3]

B2. Calculate the ratio of the electric force to gravitational force between the electron and the proton in a hydrogen atom. ($q_e = -1.6 \times 10^{-19}$ C, $q_p = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg, $m_p = 1.67 \times 10^{-27}$ kg, $\dfrac{1}{4\pi\epsilon_o} = 8.99 \times 10^{9}$ Nm^2C^{-2} and the gravitational constant $G = 6.67 \times 10^{-11}$ $\text{Nm}^2\text{kg}^{-2}$) [3]

/Cont'd

B3. An infinitely long thin wire has a linear charge density 0.5 Cm^{-1}. What is the elect field at 0.1m away from the wire in the direction perpendicular to the length of the wire? [3]

B4. The internal resistance of a galvanometer is 0.5Ω and has a full-scale deflection for a current of 10mA. Sketch a circuit to show how the instrument should be modified to measure up to 500mA. [3]

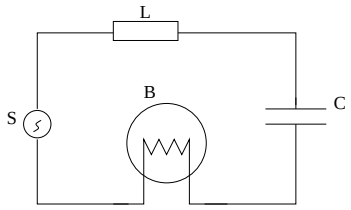
B5. A long electrical conductor of 0.008 m radius carries a 20 A current. At what distance from the conductor in the direction perpendicular to its length, will the magnetic field outside the conductor will be equal to half of the magnetic field at the surface of the conductor ? [3]

/Cont'd

B6. What is the induced voltage produced on a loop of conducting wire (area of A m
due to a perpendicular magnetic field B? Magnetic field is given by $B = 10t^2 + 20$
Tesla, where time is t.

[3]

B7. In the ac-circuit shown below, C is a capacitor, L is an inductor, B is a light bulb and S is a variable frequency voltage supply. Explain, how the brightness of the light changes as the frequency of the voltage supply is varied ? [3]



B8. A motor draws current of 4 A (peak current) from a 250 V (peak voltage) source. The average power consumption is 400W. What is the power factor ? [3]

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PART C Answer ONE question from this section

C1. (a) State and explain Gauss's law describing the flux through a closed surface containing a number of electric charges. [8]

(b) A spherically symmetric distribution of charge has a charge density ρ given as follows:

$$\rho = \rho_o \qquad r \leq R,$$

$$\rho = 0 \qquad r > R,$$

where $\rho_o = \dfrac{3Q}{4\pi R^3}$ is a constant.

i. What is the total charge contained in the charge distribution ? [6]

ii. Obtain an expression for the electric field in the region $r \leq R$. [12]

iii. Show that, for the region defined by $r > R$, the electric field is identical to that produced by a point charge Q. [4]

C2. (a) State and explain Kirchhoff's current and voltage laws for electric circuits. [10]

(b) In the following circuit diagram shown in figure 1, $R_1 = 40\Omega$, $R_2 = 60\Omega$, $R_3 = 20\Omega$, $R_4 = 10\Omega$, $E_1 = 20$ V and $E_2 = 40$ V.

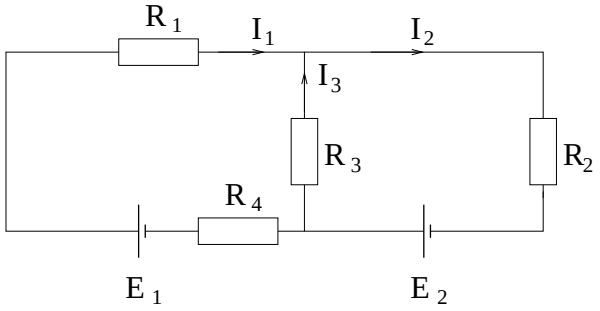

Figure 1:

i. What are values of the currents I_1, I_2, and I_3 ? [16]

ii. What is the power dissipated in R_2? [2]

iii. What is the power delivered by E_2? [2]

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PART D Answer ONE question from this section

D1. (a) What is meant by *resonance* in an ac-circuit ? [9]

(b) A series LCR resonant circuit is excited by a $250V$ variable frequency voltage generator. The amplitude of the current reaches a maximum value of 100.0mA at 0.1MHz. The value of C is 0.02μF.

Sketch a graph to show the following vary as function of the frequency:

i. the total impedance; [3]

ii. the amplitude of the current; [3]

iii. the phase angle between the input voltage and the current in the circuit as a function of the frequency. [3]

(c) Find the values of L and R. [12]

D2. (a) Explain the terms *root mean square* and *power factor* in ac-circuit theory. [8]

(b) The circuit shown in figure 2 acts a crude filter. The values of the components are R = 1000Ω and C = 5μF. The input voltage is 100 V.

i. Show that $\dfrac{V_{out}}{V_{in}} = \dfrac{1}{\sqrt{\left[1 + \dfrac{1}{\omega^2 R^2 C^2}\right]}}$. [12]

ii. What is the value of $\dfrac{V_{out}}{V_{in}}$ at $\omega = 20$ rad sec^{-1} and $\omega = 2000$ rad sec^{-1} ? [6]

iii. Is this a *low-pass* or *high-pass* filter ? [4]

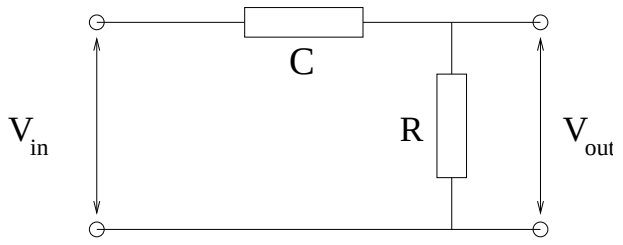

Figure 2: