UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2007/2008

TITLE OF PAPER	:	ELECTRICITY & MAGNETISM
COURSE NUMBER	:	P221
TIME ALLOWED	:	THREE HOURS
INSTRUCTIONS	:	ANSWER ANY FOUR OUT OF SIX QUESTIONS
		EACH QUESTION CARRIES 25 MARKS
		MARKS FOR DIFFERENT SECTIONS OF EACH QUESTION ARE SHOWN IN THE RIGHT-HAND MARGIN

THIS PAPER HAS 8 PAGES, INCLUDING THIS PAGE

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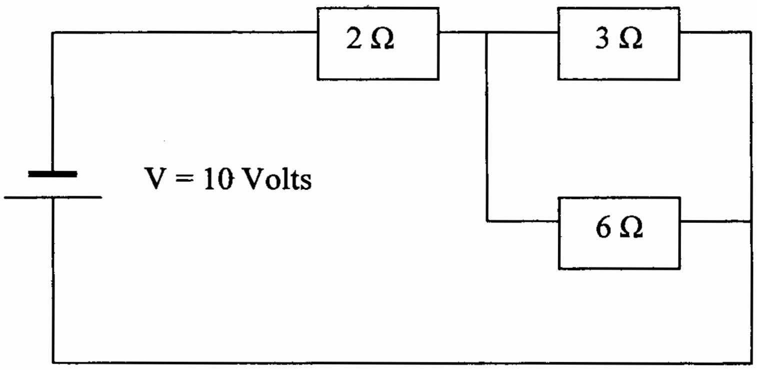
Question 1

Describe the physical content of Kirchhoff's current law and Kirchoffoff's voltage law. [8]



In the circuit drawn above, the battery provides a steady voltage of 10 volts. The values of the resistances are given in the figure in Ohms.

What is the current that flows through each resistance? [9]

What is the potential drop across each resistance? [8]

Question 2

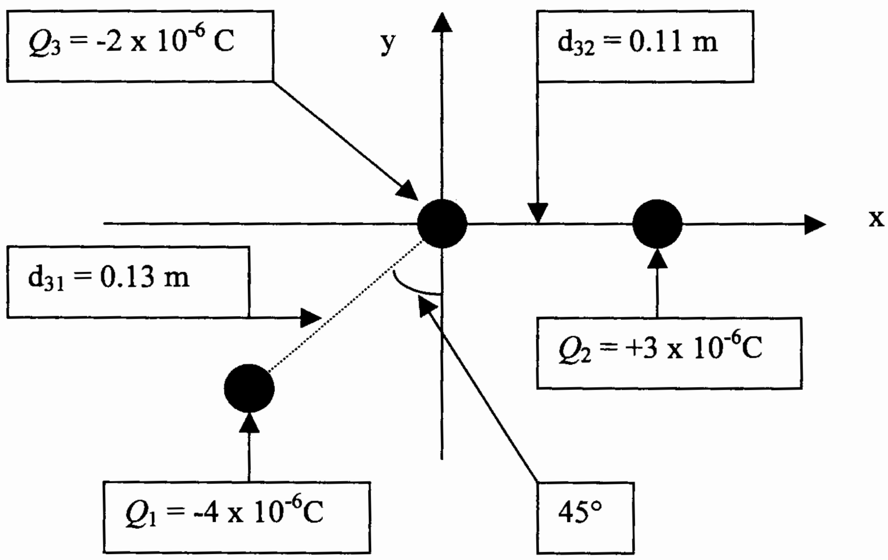
Consider a positive point charge of magnitude Q_1. What is the magnitude and direction of the electric field produced by this charge at a distance r from the charge expressed in S.I. units? [2]

What is the force that acts between two point charges of magnitudes Q_1 and Q_2? [2]

What is the principle of superposition? [3]

From the figure, determine the magnitude of the resultant force acting on Q_3 produced by charges Q_1 and Q_2. The three point charges are represented by black circles. d_{32} is the distance between point charges Q_3 and Q_2, and d_{31} is the distance between charges Q_3 and Q_1. The line connecting Q_1 and Q_3 is inclined at 45° to the horizontal and vertical axes. [12]

What angle does the resultant force make with the horizontal axis? [6]



3 Write down an expression for the Lorentz force acting on a point charge Q which is moving in a region of space where both the electric field $\boldsymbol{E}$ and magnetic flux density $\boldsymbol{B}$ are non-zero. 3

Describe how a charged particle with a well-defined velocity can be selected from a beam of similar particles which have a range of velocities. 12

A proton is in a uniform magnetic field of 0.1 *tesla*, which is perpendicular to the velocity of the proton.The proton moves in a circular orbit of radius 0.25 *m*. Calculate the orbital speed of the proton. 5

If the proton were to be replaced by an electron moving with the same velocity as the proton, what would the radius of the orbit of the electron be? 5

Question 4

Write down an expression for Ampère's circuital law, and hence determine the magnitude of the magnetic field H at a distance a from a very long, straight wire carrying current I. The wire is parallel to the z-direction.

[6]

The conducting wire carries a conventional current that flows in the positive z-direction. Draw a diagram showing the long, straight wire and the direction and orientation, with respect to the wire, of lines of H. [6]

2 long, straight wires, both parallel to the z-direction, carry a conventional current in the positive z-direction. Is there a force between them, and, if it exists, is it attractive or repulsive? [6]

The direction of the conventional current is reversed in one of the wires, but its magnitude is kept the same. Explain all the differences that this change in direction of current causes. [7]

Question 5

A circuit contains a resistor, an inductor and a capacitor connected in series to an alternating voltage supply. What is the impedance of this circuit? Explain carefully the meaning of each of the symbols you have used in your expression for the impedance. [7]

For a certain angular frequency, the current is in phase with the alternating voltage. What is this frequency called: what is its magnitude, and why are the voltage and current n phase ? [12]

The quality factor, $Q = \sqrt{\frac{L}{C}}\frac{1}{R}$. What feature of the response of the circuit is determined by this factor? [6]

Question 6

A parallel-plate capacitor was constructed from two rectangular plates of aluminium, each of area A, separated by a distance d. A battery that provided $80V$ was used to charge the capacitor. After the capacitor was fully charged, the battery was disconnected from the capacitor, and a dielectric was inserted between the two aluminium plates, which completely filled the space between the aluminium plates. What changes were caused by the insertion of the dielectric? [5]

The dimensions of the capacitor and dielectric were as follows:

$A = 0.05\ \text{m}^2$
$d = 0.06$ m
relative permittivity of the dielectric = 6

Calculate the following quantities

(a) the capacitance before the dielectric slab was inserted [5]
(b) the charge on the plates of the capacitor [5]
(c) the magnitude of the electric field in the dielectric, and in the space between the aluminium rectangular plates and the dielectric [5]
(d) the potential difference between the plates, and the capacitance, when the dielectric was between the plates. [5]

PHYSICAL CONSTANTS AND UNITS

Acceleration due to gravity	g	9.81 m s^{-2}
Gravitational constant	G	6.673 × 10^{-11} N m^2 kg^{-2}
Avogadro constant	N_A	6.022 × 10^{23} mol^{-1}
	(Note: 1 mole = 1 *gram* molecular-weight)	
Ice point	T_{ice}	273.15 K
Gas constant	R	8.314 J K^{-1} mol^{-1}
Boltzmann constant	k, k_B	1.381 × 10^{-23} J K^{-1} = 0.862 × 10^{-4} eV K^{-1}
Stefan constant	σ	5.670 × 10^{-8} W m^{-2} K^{-4}
Rydberg constant	R_∞	1.097 × 10^7 m^{-1}
	$R_\infty hc$	13.606 eV
Planck constant	h	6.626 × 10^{-34} J s = 4.136 × 10^{-15} eV s
$h/2\pi$	$\hbar$	1.055 × 10^{-34} J s = 6.582 × 10^{-16} eV s
Speed of light *in vacuo*	c	2.998 × 10^8 m s^{-1}
	$\hbar c$	197.3 MeV fm
Charge of proton	e	1.602 × 10^{-19} C
Mass of electron	m_e	9.109 × 10^{-31} kg
Rest energy of electron		0.511 MeV
Mass of proton	m_p	1.673 × 10^{-27} kg
Rest energy of proton		938.3 MeV
One atomic mass unit	u	1.66 × 10^{-27} kg
Atomic mass unit energy equivalent		931.5 MeV
Electric constant	ϵ_0	8.854 × 10^{-12} F m^{-1}
Magnetic constant	μ_0	4π × 10^{-7} H m^{-1}
Bohr magneton	μ_B	9.274 × 10^{-24} A m^2 (J T^{-1})
Nuclear magneton	μ_N	5.051 × 10^{-27} A m^2 (J T^{-1})
Fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	7.297 × 10^{-3} = 1/137.0
Compton wavelength of electron	$\lambda_c = h/mc$	2.426 × 10^{-12} m
Bohr radius	a_0	5.2918 × 10^{-11} m
angstrom	Å	10^{-10} m
torr (mm Hg, 0°C)	torr	133.32 Pa (N m^{-2})
barn	b	10^{-28} m^2