UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2012/13

TITLE O F PAPER: INTRODUCTORY PHYSICS II

COURSE NUMBER: P102

TIME ALLOWED: THREE HOURS

INSTRUCTIONS: ANSWER ANY FOUR OUT OF FIVE QUESTIONS

EACH QUESTION CARRIES 25 MARKS

MARKS FOR EACH SECTION ARE INDICATED IN THE RIGHT HAND MARGIN

GIVE CLEAR EXPLANATIONS AND USE CLEAR DIAGRAMS WHERE NECESSARY IN YOUR SOLUTIONS. MARKS WILL BE LOST WHERE IT IS NOT CLEAR HOW THE EQUATIONS USED WERE OBTAINED

THIS PAPER HAS SEVEN PAGES INCLUDING THE COVER PAGE

THE LAST PAGE CONTAINS INFORMATION THAT MAY BE USEFUL IN SOME QUESTIONS

IF IN DOUBT, RAISE YOUR HAND AND ASK

DO NOT OPEN THE PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE CHIEF INVIGILATOR

QUESTION 1

(a) A wave is described by the following equation:

$y = 9\sin\left(\pi t + \frac{\pi}{5}x - \frac{\pi}{4}\right)$ m.

(i) Write down the general equation for a wave and use it to write down the amplitude, angular velocity, wave number, and phase angle of the given wave, and include appropriate units? **(4 marks)**

(ii) Find the frequency, period, and wavelength for the wave. **(3 marks)**

(b) An isotropic sound source produces 1.50 W of acoustic power. At what distance from the source is the sound level 75 dB? **(5 marks)**

(c) A light ray enters a slab of cubic zirconia of refractive index 2.20 at an angle of 60° with the normal as shown in Figure 1. Below the slab is water and above it is air. Determine whether the light ray is transmitted to air or water on the sides or is trapped in the slab so that it escapes at the other end. **(7 marks)**

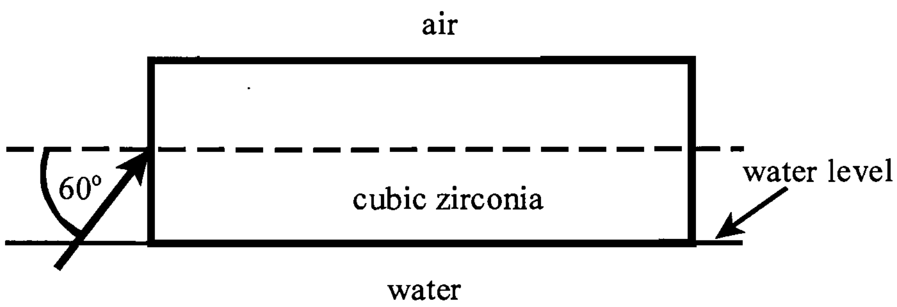

Figure 1.

(d) A lens has a focal length of 8 cm and an object is placed 6 cm in front of the lens.

(i) Find the image distance. **(3 marks)**

(ii) Find the magnification of the image. **(1 mark)**

(iii) State the nature of the image using the result obtained in (i) and independently using the result in (ii). **(2 marks)**

QUESTION 2

Three point charges q_1 = -6.00 μC (negative charge), q_2 = 8.00 μC and q_3 = 4.00 μC are arranged at the vertices of a 45° triangle as shown in Figure 2.

(a) Use a diagram to determine the unit vectors $\hat{r}_{1,3}$ and $\hat{r}_{2,3}$ for the directions from q_1 to q_3, and q_2 to q_3, respectively. **(4 marks)**
(b) Evaluate the scalar value of the force on q_3 due to q_1 ($F_{1,3}$). **(2 marks)**
(c) Evaluate the scalar value of the force on q_3 due to q_2 ($F_{2,3}$). **(2 marks)**
(d) Find the total force vector on q_3 due to the other two charges. **(7 marks)**
(e) Find the electric potential at the origin. **(3 marks)**
(f) How much work would be required to move a charge $q = 9 \times 10^{-6}$ C from ∞ to the origin. **(2 marks)**
(g) What charge q_1' must replace the charge q_1 for electric potential to be zero at the origin? **(5 marks)**

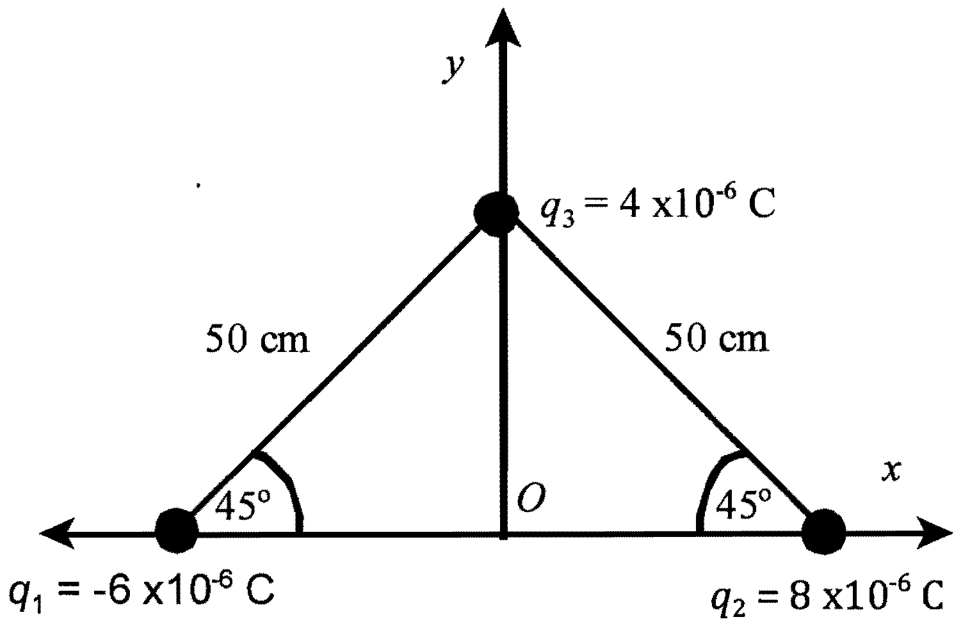

Figure 2.

QUESTION 3

(a) In the circuit shown in Figure 3, use a diagram and Kirchoff's laws to obtain any the three equations that can be used to calculate the currents I_1, I_2 and I_3. ***Do not solve for the currents.*** **(6 marks)**

(b) A galvanometer G requires a current of 0.500 mA for full-scale deflection and has a resistance of 50 Ω. What must be the series resistor R_s connected to the galvanometer to make a voltmeter that has a full-scale deflection of 20.0 V. (See Figure 4). **(3 marks)**

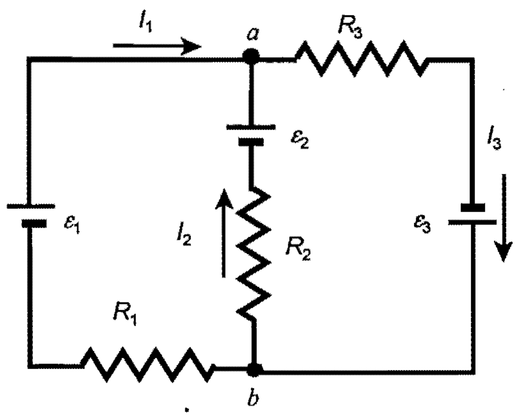

Figure 3.

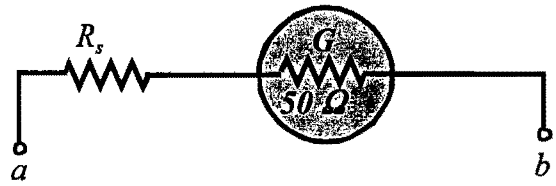

Figure 4.

(c) An initially ucharged 12.0 μF capacitor is charged with a 24.0 V emf source through a 470 Ω resistor for a very long time.

(i) What is the total energy stored in the capacitor? **(2 marks)**

(ii) Determine the power delivered to the capacitor by the battery in one time constant during charging. **(5 marks)**

(iii) After fully charging the emf source is isolated, and the capacitor is discharged through a 0.470 Ω . Determine the power delivered by the capacitor to the 0.470 Ω resistor in one time constant. **(5 marks)**

(iv) Using the results from parts (ii) and (iii) above, explain how a capacitor can deliver more power than the charging source. **(4 marks)**

QUESTION 4

(a) Figure 5 is a diagram of a Bainbridge mass spectrometer. The region with ***B*** and ***E*** is the velocity selector. The doted line is the path of positively charged ions of charge q moving at a velocity υ. The charged particles that go through un-deflected have a velocity υ. In the velocity selector, the magnetic field is $B = 1.20$ T, and the electric field $E = 2500$ V/m. The particles are singly ionized calcium ions, ^{40}Ca, ^{42}Ca, and ^{44}Ca. In the electric field free region, the magnetic field is $B'$and has a magnitude of 0.2 T

(i) Derive an expression for the radius of the particles in the electric field free region of a mass spectrometer in terms of B, B', E, m, q and u.Where all the symbols have their usual meaning in this section. **(4 marks)**

(ii) Find the velocity υ in the velocity selector. **(2 marks)**

(iii)Find the radius of motion of each isotope in the region with B' only. **(6 marks)**

(b) An inductor with $L = 140$-mH and a resistor $R = 4.90\ \Omega$ are connected in series to an *emf* source of 6.00 V through a switch. The switch has three positions where in position a it connects all the three components in series, and position b is the off position, and position c it connects only the inductor and resistor, isolating the battery. See Figure 6.

(i) If the switch is put to position a from b, write down the equation for the current through the inductor as a function of time, and make a diagram that illustrates this current. Also indicate the current at $t = \tau$. **(4 marks)**

(ii) What is the time constant for this system? **(1 mark)**

(iii)What is the maximum current I_{max} that can be reached by this circuit? **(1 mark)**

(iv) When the switch is put in position a from the off position, how much time will elapse before the current reaches 220 mA? **(4 marks)**

(v) If the switch is in position a for a very long time and then quickly turned to position c, isolating the battery leaving the inductor and resistor in series, how much time elapses before the current drops to 160 mA? **(3 marks)**

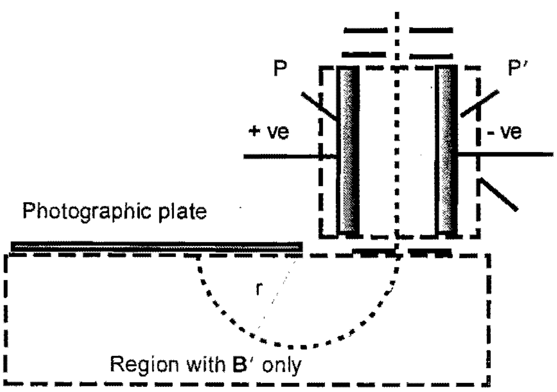

Figure 5.

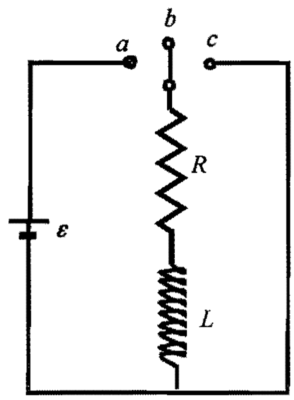

Figure 6.

QUETSION 5

(a) A company at an isolated location produces its own electricity to supply its plant and the company-village a short distance away. The plant and the company village are supplied with 20 MW of power. The resistance of the wires is 2 Ω. The voltage is generated at 22 kV and transmitted at 230 kV. The generation cost is 95 cents per kWh.

(i) What is the energy in kW-h lost per day. **(4 marks)**

(ii) What is the cost of the electricity lost per day? **(2 marks)**

(iii)If the company were to deliver the power at the production voltage of 22 kV, how much money would the company loose per day? **(3 marks)**

(b) A step-down transformer is used for recharging a battery. The turns ratio of primary to secondary in the transformer is 24.4:1 and is used with a 220 V (rms) household service. The transformer draws a current of 50 mA rms from the house outlet.

(i) What is the rms voltage supplied to the battery? **(2 marks)**

(ii) What is the rms current supplied to the battery? **(2 marks)**

(c) An inductor (l = 500 mH), a capacitor (C = 3.48 μF) and a resistor (R = 470 Ω) are connected in to a 50.0 Hz power source with a peak voltage of 450 V (not rms).

(i) Find the impedance of the network. **(6 marks)**

(ii) What is the power factor for this circuit? **(2 marks)**

(iii)Find the actual power and apparent power consumed by the network? **(4 marks)**

DATA SHEET

General data

Air refractive index = 1.00
Avogadro's number $N_A = 6.022 \times 10^{23}$ mol^{-1}
Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ J/K
Density of mercury = 1.36×10^4 kg/m^3
Gas constant $R = 8.314$ J/(mol.K)
Gravitational acceleration $g = 9.80$ m/s^2
Standard atmospheric pressure = 1.013×10^5 Pa
Speed of light in vacuum $c = 2.997\,8 \times 10^8$ m/s
Speed of sound in air $\upsilon_s = 343$ m/s
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ $W/(m^2.K^4)$
Threshold of hearing $I_0 = 10^{-12}$ W/m^2
Universal gravitational constant $G = 6.67 \times 10^{-11}$ $N.\,m^2/kg^2$
1 calorie = 1 c = 4.186 J
1 food calorie = 1 Calorie = 1C = 10^3 calories = 4.186×10^3 J

Water data

$c(water) = 4186$ J/(kg.K)	$c(ice) = 2090$ J/(kg.K)	$c(steam) = 2079$ J/(kg.K)
$L_f(ice) = 3.33\times10^5$ J/kg	$L_v(water) = 2.260\times10^6$ J/kg	
ρ (water) = 1000 kg/m^3	refractive index $n_w = 1.333$	

Electricity and nuclear data

Alpha particle mass = $6.644\,657 \times 10^{-27}$ kg
Charge of an electron = -1.6×10^{-19} C
Charge of a proton = $+1.6 \times 10^{-19}$ C
Coulomb's constant $k_e = 8.987\,5 \times 10^9$ Nm^2/C^2
Deuteron mass = $3.343\,583 \times 10^{-27}$ kg
Electron mass, $m_e = 9.109 \times 10^{-31}$ kg
Neutron mass $m_n = 1.675 \times 10^{-27}$ kg
Proton mass, $m_p = 1.673 \times 10^{-27}$ kg
1 atomic mass unit = 1 amu = 1 u = 1.66×10^{-27} kg
$\epsilon_0 = 8.85 \times 10^{-12}$ $C^2(N.m^2)$
1 Ci = 3.7×10^{10} decays/s
1Bq = 1 decay/s