UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2007/08

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 IN THE RIGHT HAND MARGIN

GIVE CLEAR EXPLANATIONS AND USE CLEAR DIAGRAMS 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 DATA THAT MAY BE USEFUL IN SOME QUESTIONS

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

QUESTION 1

a. A wave is described by the following equation: $x = 15\sin(2\pi t + \pi/8)$ m. Answer the following equations and give the correct units in each case.

i. What is the amplitude of the wave? **(1 mark)**
ii. What is the angular velocity? **(1 mark)**
iii. Find the frequency of the wave. **(1 mark)**
iv. Find the period for the wave. **(1 mark)**
v. What is the phase angle? **(1 mark)**
vi. Convert the wave into a cosine function. **(3 marks)**

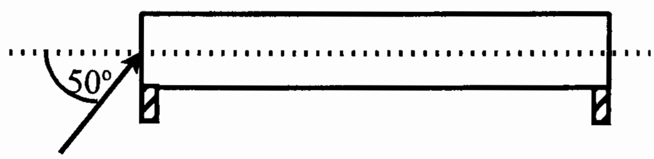
b. Calculate the velocity of sound in sea water of bulk modulus 2.1×10^9 N/m^2 and density 1.03×10^3 kg/m^3? **(2 marks)**

c. An industrial machine generates 500 W of isotropic acoustic power.

i. At what distance is the sound level 100 dB? **(5 marks)**
ii. If the sound level is to be reduced to 80 dB at the distance obtained from i, by how much must the acoustic power be reduced? **(5 marks)**

d. Light enters a slab of flint glass of refractive index 1.66 at an angle of 50° with the normal as shown in Figure 1. The slab is surrounded by air. Determine whether the light ray is transmitted to air on the sides or is trapped in the slab so that it escapes at the other end. **(5 marks)**

Figure 1.



QUESTION 2

Three charges are arranged at the vertices of a triangle as shown in Figure 2.

a. Write the unit vectors for the directions from q_1 to q_3 and q_2 to q_3, $\hat{r}_{13}$ and $\hat{r}_{23}$, respectively? **(2 marks)**

b. What is the of the force on q_3 due to q_1? **(2 marks)**

c. What is the of the force on q_3 due to q_2? **(2 marks)**

d. What are the x- and y-components of the force on q_3 due to q_1 and q_2? **(4 marks)**

e. What is the electric potential at the origin O due to all three charges? **(3 marks)**

f. What is the electric field at the origin due to each? **(6 marks)**

g. What are the x- and y-components of the electric field at the origin due to all three charges? **(2 marks)**

h. What must q_3 be replaced by to make the electric potential 100 V at the origin? **(4 marks)**

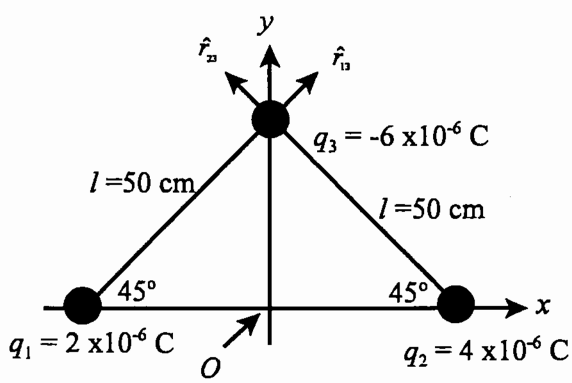


Figure 2.

QUESTION 3

a. State Kirchoff's laws. **(2 marks)**

b. In the circuit shown in Figure 3,
   i. use Kirchoff's laws and a diagram to obtain three equations to determine the currents I_1, I_2, and I_3, and **(6 marks)**
   ii. determine the currents I_1, I_2, and I_3. **(9 marks)**

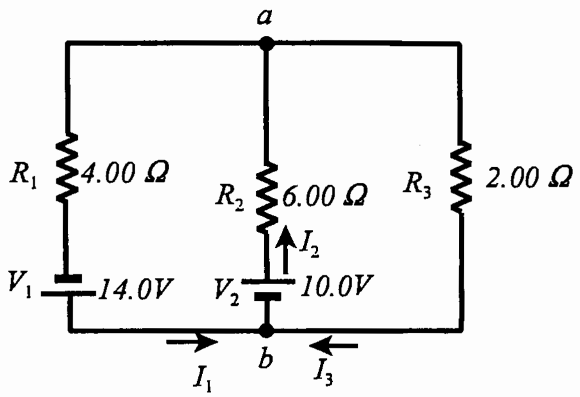


Figure 3.

c. In Figure 4 the galvanometer of internal resistance 50 Ω is to be used as an ammeter and requires a current of 0.500 mA for full scale deflection. What should be the shunt resistor R_s to make an ammeter with a full-scale deflection of 0.500 A? **(4 marks)**

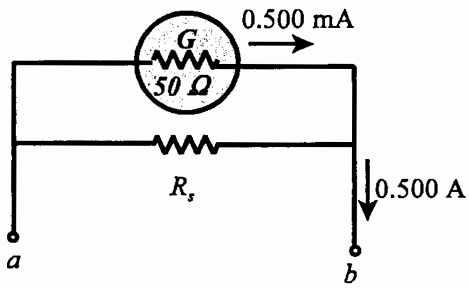


Figure 4.

d. What is the ideal resistance of an ammeter and how is it connected to measure the current through a device? **(2 marks)**

e. What is the ideal resistance of a voltmeter and how is it connected to measure the voltage drop across a device? **(2 marks)**

QUESTION 4

a. A capacitor of capacitance $C = 6.70\ \mu F$ is connected in series with a resistor of resistance $R = 4.7 \times 10^6\ \Omega$, a battery of *emf* $\varepsilon = 24.0$ V

   i. What is the general equation for the charge q in a capacitor of capacitance C after timer t of charging the capacitor with a battery of *emf* ε, through a resistor of resistance R? **(1 mark)**

   ii. Sketch a diagram for the equation in i, and indicate the charge after one time constant in your graph. **(3 marks)**

   iii. What is the general equation for the charge left in a capacitor after discharging a fully charged capacitor as described in i for a time t. **(1 mark)**

   iv. Sketch a diagram for the equation in iii and indicate the charge after one time constant. **(3 marks)**

   v. In the capacitor described in the problem what is the energy stored in the capacitor when fully charged? **(1 mark)**

   vi. What is the percentage of the energy left after one time constant? **(3 marks)**

b. Figure 5 is a diagram of the 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 down the page (minus z). The charged particles come at a velocity of 6.5×10^4 m/s. The magnitude of the magnetic field ***B*** is 0.9 T. The particles are singly ionized nickel ions, ^{58}Ni, ^{60}Ni, and ^{62}Ni.

   i. Calculate the magnitude of the electric field of the charged particles. **(1 mark)**

   ii. What is the radius of motion of each nickel isotope in the electric field free region, assuming that the magnetic field $\boldsymbol{B}' = 0.4$ T? **(6 marks)**

c. The rectangular wire loop shown in Figure 6 carries a current I in the anticlockwise direction. It is placed in a magnetic field ***B*** in the negative y-direction. Use the cross product to determine how the wire will move if it will move at all. **(6 marks)**

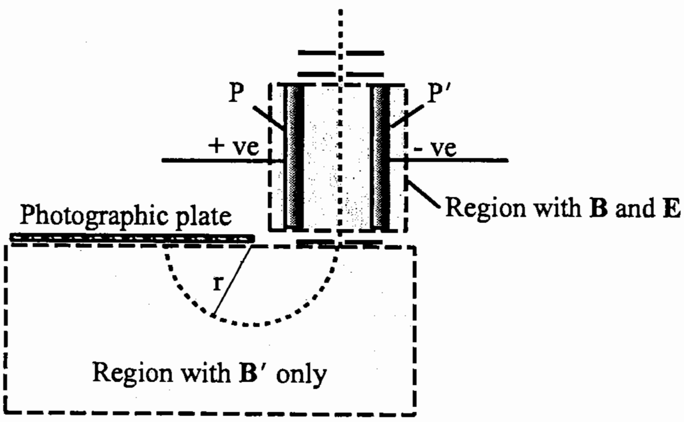


Figure 5.

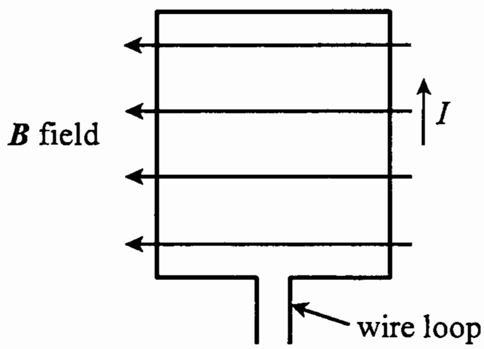


Figure 6.

QUESTION 5

a. An electric kettle is rated at 1500 W at 220 V(rms).

i. What is the rms current is drawn by the kettle? **(1 mark)**

ii. What is the resistance of the filament? **(1 mark)**

iii. If the kettle is kept on for 10 minutes what is the cost of the electricity consumed assuming that electrical energy cost 54 cents per kilowatt-hour. **(3 marks)**

b. A company generates 40 MW of electricity at a cost of 40 cents per kilowatt-hour at a voltage of 25 KV to supply a small city. The resistance of the transmission wires is 500 Ω. The voltage is transmitted to the city at 230 kV rms.

i. Find the turns ration of the step-up transformer used $N_{secondary}/N_{primary}$? **(2 marks)**

ii. What is the current through the transmission wires? **(1 mark)**

iii. How much energy is lost in transmission over 24 hours? **(2 marks)**

iv. What is the cost of the energy lost over 24 hours? **(2 marks)**

v. If the power were to be transmitted at the voltage at which it is generated, how much current would be drawn? **(1 mark)**

vi. What would be the cost of the energy lost if the power were to be transmitted at the voltage at which it is generated over 24 hours? **(3 marks)**

c. A machine is supplied with a peak voltage V_{max} = 440 V and draws a current of I_{max} = 30 A. The current lags the voltage by 20 degrees.

i. What is the apparent power consumed by the machine? **(1 mark)**

ii. What is the reall power consumed by the machine? **(2 marks)**

d. A certain sample has an initial number $N_0 = 8.55 \times 10^{24}$ radioactive nuclei and has a decay constant $\lambda = 5.66 \times 10^{-4}\ s^{-1}$.

i. Find the number of nuclei left after 4 hours. **(3 marks)**

ii. What is the half life in minutes for this isotope? **(3 marks)**

<u>**GENERAL DATA SHEET**</u>

Speed of light in vacuum $c = 2.9978 \times 10^8$ m/s
Speed of sound in air $\upsilon_s = 343$ m/s
Gravitational acceleration = 9.80 m/s^2
Universal gravitational constant $G = 6.67 \times 10^{-11}$ N. m^2/kg^2
Density of mercury = 1.36×10^4 kg/m^3
Density of water = 1000 kg/m^3
Standard atmospheric pressure = 1.013×10^5 Pa
Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ J/K
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/(m^2.K^4)
Gas constant $R = 8.314$ J/(mol.K)
Avogadro's number $N_A = 6.022 \times 10^{23}$ mol^{-1}
$I_0 = 10^{-12}$ W/m^2
1 calorie = 1 c = 4.186 J
1 food calorie = 1 Calorie = 1C = 10^3 calories = 4.186×10^3 J

c(*water*) = 4186 J/(kg.K) c(*ice*) = 2090 J/(kg.K) c(*steam*) = 2079 J/(kg.K)
L_f(*ice*) = 3.33×10^5 J/kg L_v(*water*) = 2.260×10^6 J/kg

$$k_e = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ N.m}^2/\text{C}^2$$

Charge of an electron = -1.6×10^{-19} C
Charge of a proton = $+1.6 \times 10^{-19}$ C
1 atomic mass unit = 1 amu = 1 u = 1.66×10^{-27} kg
Electron mass, $m_e = 9.109 \times 10^{-31}$ kg
Proton mass, $m_p = 1.673 \times 10^{-27}$ kg
Neutron mass $m_n = 1.675 \times 10^{-27}$ 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