MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2015

SUBJECT:	PHYSICS
DATE:	11th May 2015
TIME:	9.00 a.m. to 12.00 noon

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ m\ s^{-2}$ ***unless otherwise stated.***

SECTION A

Attempt all <u>10 questions</u> in this section. Each question carries 5 marks. This section carries 50% of the total marks for this paper.

1. The weight W is being supported by ropes as shown in Figure 1.
   a. If W is 180 N, find the tension in rope A and B respectively. **[3 marks]**
   b. Assuming B cannot withstand a tension larger than 250 N, and that the ropes stay as shown, calculate the maximum weight that rope B can support. **[2 marks]**

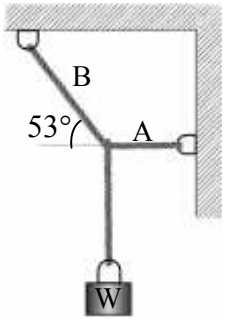


Figure 1

2. A man is driving home in his car. He stops at the traffic lights. Another car collides in the rear of his car and causes it to accelerate from rest to a speed of 6 m/s in 0.40 s.
   a. Calculate:
      (i) the impulse on the man if he has a mass of 85 kg; **[1 mark]**
      (ii) the average force exerted on the man by the car seat. **[2 marks]**
   b. In terms of impulse, explain the importance of wearing seatbelts. **[2 marks]**

3. A 10 g metal ball bearing moves along a horizontal circular path of radius 0.03 m on the inside of a glass funnel (see Figure 2).
   a. Draw a free body diagram showing the forces acting on the ball bearing (Ignore any frictional forces). **[2 marks]**
   b. If the centripetal force acting on the ball bearing is 0.37 N, calculate the speed with which the ball bearing must be moving to maintain this horizontal circular path. **[3 marks]**

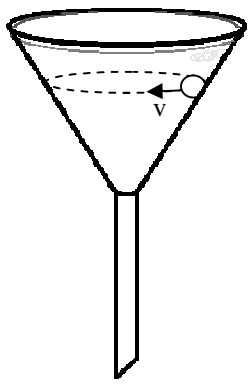


Figure 2

4. A student sets up the potential divider circuit shown in Figure 3 to light up a 6 V bulb. He uses a 24 V power supply.
   a. If the voltmeter shown reads 6 V when switch S is open, calculate the resistance of R_2.
   b. When switch S is closed, the student notices that the reading on the voltmeter decreases to 4.5 V. Show that the resistance of the bulb at this voltage is $225\,\Omega$. **[2, 3 marks]**

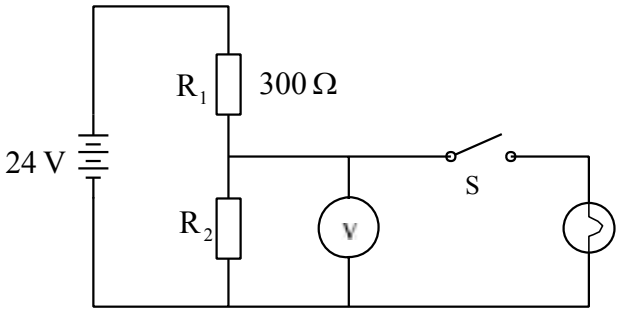
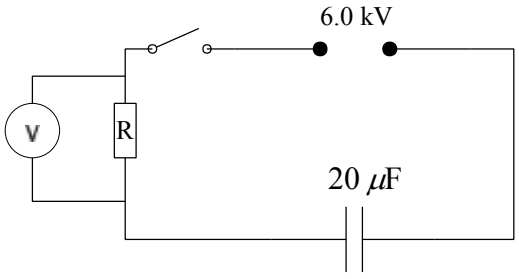


Figure 3

5. A toy pistol uses a compressed spring as the firing mechanism of 3 g plastic pellets. The pellets exit the nozzle with a speed of 85 m/s. The pistol is reloaded by compressing the spring by 8 cm. Assuming that no energy is lost as the pellet moves down the barrel:
   a. calculate the energy of the pellet just as it is released;
   b. determine the spring constant of the spring. **[2, 3 marks]**

6. A student places a mass m of water in a container and uses a 60 W immersion electric heater to heat the water. The student finds that it takes 20 minutes for the temperature of the water inside the container to rise from 20°C to 100°C, and a further 3 minutes for 45 g of the water to evaporate.
   a. Draw a diagram of a suitable electric circuit which can be used in this experiment, including a voltmeter, an ammeter and a variable resistor. **[2 marks]**
   b. Given the specific heat capacty of water = 4200 J/kg K and assuming no heat losses,
      (i) calculate the mass of water, m, inside the container; **[2 marks]**
      (ii) find the specific latent heat of vaporization of water. **[1 mark]**

7. The circuit shown in Figure 4 (a) is used to investigate the charging of a capacitor.



(a)

(b)

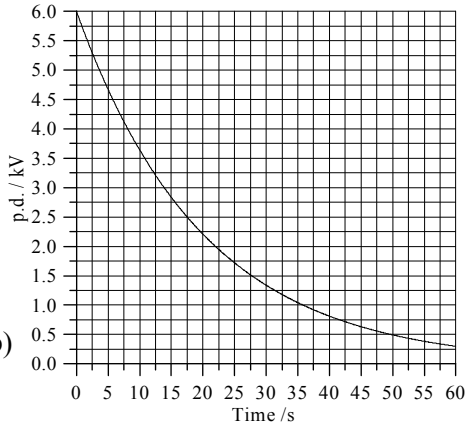


Figure 4

The graph in Figure 4 (b) shows how the potential difference V across the resistor varies with time t, after the switch is closed.
   a. Determine the voltage across the capacitor 50 s after the start of the charging process;
   b. At what time was the voltage across the capacitor equal to that across the resistor?
   c. Determine the resistance of the resistor used in the experiment. **[2, 1, 2 marks]**

8. Figure 5 shows two straight wire conductors separated by a distance r. Wire X is carrying a current I_X and wire Y is carrying a larger current I_Y.

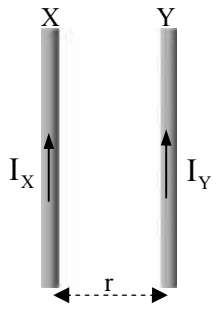


Figure 5

   a. Draw the magnetic field pattern surrounding the two conductors, clearly marking the positions of X and Y respectively.
   b. Draw a sketch showing the directions of the current, field and force acting on wire X. Label your diagram carefully.
   c. Calculate the magnitude of the force acting on a 0.5 m section of wire X when a current of 5 A flows through it, given that the magnetic field at a distance r from wire Y is 2 T. Hence, state the magnitude of the force experienced by wire Y.

[2, 1, 2 marks]

9. Figure 6 shows a section of an optical fibre made from a glass core of refractive index 1.47. It is surrounded by cladding made of a different type of glass. Light incident at an angle ***i*** at one end, is refracted, hits the core - cladding boundary at an angle θ, and is totally internally reflected.

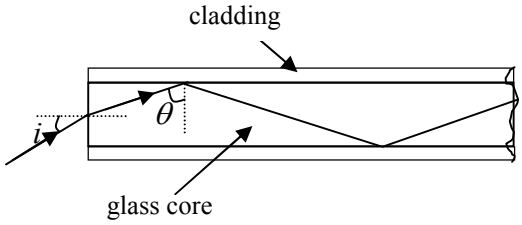


Figure 6

   a. Two different types of glass, A and B, can be used for the cladding material. A has a refractive index of 1.45 and B has a refractive index of 1.49. Which of these would be fit for use in this optical fibre? Give a reason for your answer.
   b. Given that θ is equal to 82°, find the value of ***i***, the angle of incidence.

[2, 3 marks]

10. A few years after the discovery of radioactivity in 1896, Ernest Rutherford used alpha particles to investigate the atom. Under his guidance, two of his students carried out the famous Rutherford alpha scattering experiment.
   a. Briefly describe **one** result that emerged from the observations made during this experiment, and its implication on the structure of the atom.
   b. In Rutherford's alpha scattering experiment radium $^{226}_{88}Ra$ decayed by emitting an alpha particle to form Radon (Rn).
      i. Write down the nuclear equation representing the decay.
      ii. The atomic mass of Radium is 226.0254 u and it has a half-life of 1600 years. Calculate the activity of 0.05 g of Radium.

[1, 1, 3 marks]

SECTION B

This question carries 14% of the total mark of this paper and must be attempted.

11. Figure 7 shows the setup (not to scale) of an experiment used to determine the atmospheric pressure. A column of air is entrapped by a thread of mercury in a uniform glass tube. The length X of the entrapped air is recorded as the tube is tilted through an angle θ.

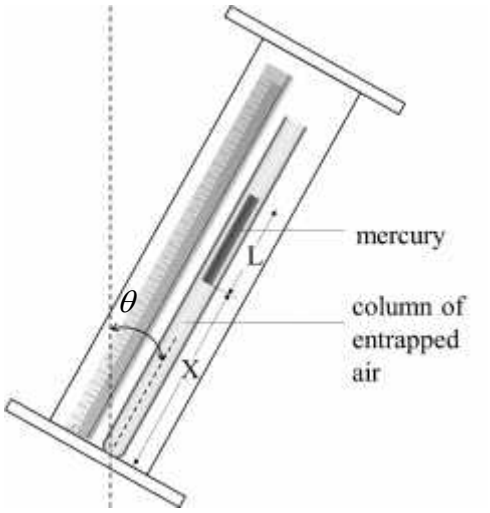


Figure 7

The equation relating the length X of the entrapped air and the angle θ is given by

$$\cos\theta = \frac{k}{L}\left(\frac{1}{X}\right) - \frac{H}{L} \quad \text{---------- (i)}$$

where L is the length of the mercury thread and H is the equivalent in length (in cm) of a mercury column for atmospheric pressure. The length of the mercury thread is 35 cm.

θ / °	$\cos\theta$	X /cm	$\frac{1}{X}$ /cm^{-1}
0		24.9	
15		25.5	
30		26.5	
45		28.2	
60		29.5	
75		33.0	

Table 1

a. Copy Table 1 and fill in the missing values.

b. Plot a graph of $\cos\theta$ on the y-axis against $\frac{1}{\mathrm{X}}$ / cm^{-1} on the x-axis.

c. Write equation (i) in the form $y = mx + c$, explaining your working. Use the graph to determine the value of the constant k, including the relevant units.

d. Find the value of H. **[4, 5, 3, 2 marks]**

SECTION C

Answer any two questions from this section. Each question carries 18 marks. This section carries 36% of the total mark for this paper.

12. A heavy mallet of mass M (see Figure 8) is dropped and moves through a vertical distance y before it hits the top of a tent stake of mass m, driving it into the ground a distance d. Assume that the ground offers a constant resistance to the motion of the tent stake and mallet, which move together after impact.

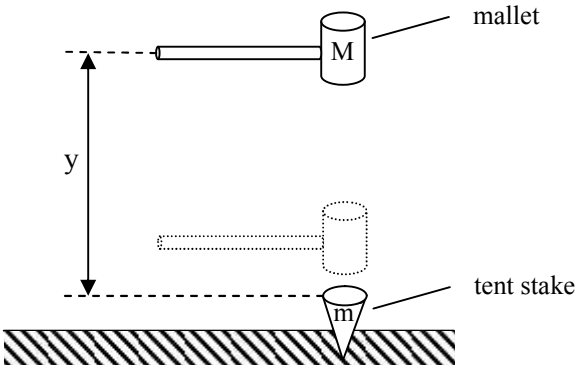


Figure 8

a. Show that the velocity, v, with which the mallet hits the stake is given by $v = \sqrt{2gy}$. **[2 marks]**

b. Show that the combined velocity, v_c, of the mallet and the tent stake after the impact in terms of the mass of the mallet M, the mass of the stake m and the velocity of the mallet before impact v is given by $v_c = \dfrac{v}{1+\dfrac{m}{M}}$ **[3 marks]**

c. Calculate the combined velocity for a 2 kg mallet falling from a height of 1.2 m on a stake of mass 0.2 kg. **[3 marks]**

d. Find the kinetic energy lost on impact. **[3 marks]**

e. Calculate the average resultant force acting on the tent stake if it penetrates the ground a distance of 0.05 m. **[4 marks]**

f. Determine the time the stake is in motion. **[3 marks]**

13.

a. Figure 9 shows a metal conductor of cross sectional area A. The conductor has n charges per unit volume. Each charge carrier has a charge e and moves with a drift velocity v_d. A current I flows through the conductor.

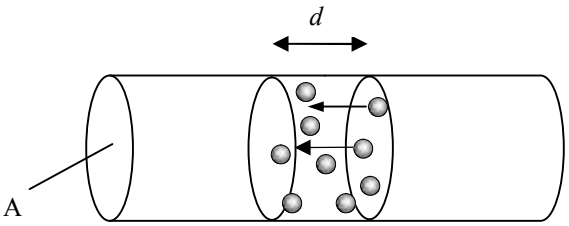


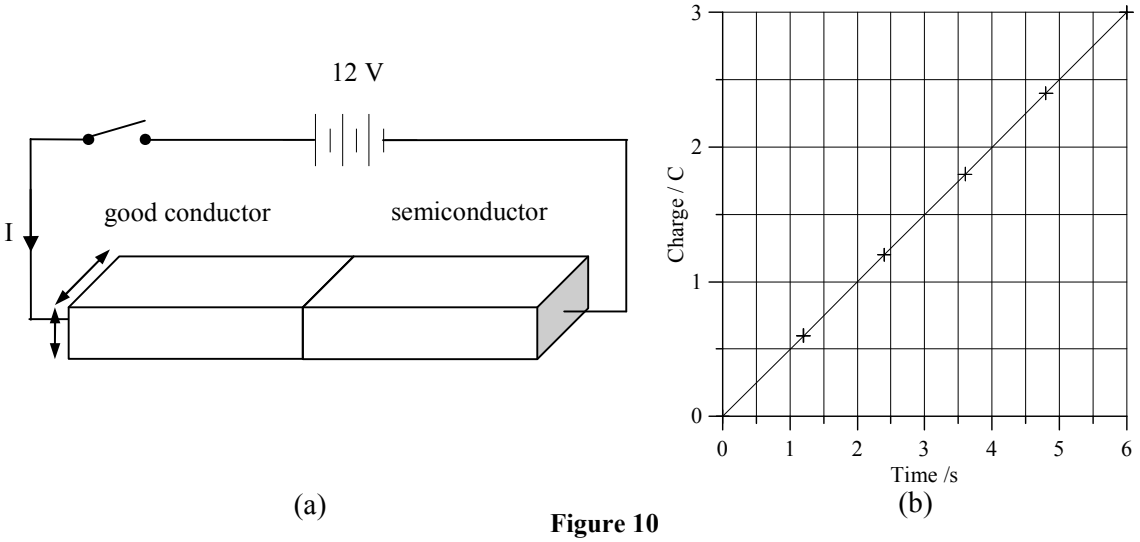
Figure 9

i. Is the direction of the conventional current to the right or to the left of the diagram? **[1 mark]**

ii. Show that the total charge Q in length d of the conductor is given by $Q = neAd$, explaining your answer. **[3 marks]**

iii. Derive an equation for the drift velocity v_d in terms of I, n, e and A. **[3 marks]**

b. Figure 10 (a) shows a 12 V supply connected across a rectangular section of a good conducting material in contact with a semiconducting material. Figure 10 (b) is a graph that shows the amount of charge which flows in the first 6 seconds after the circuit is switched on.



(a) (b)

Figure 10

i. Is the current in the conductor equal, larger or smaller than that in the semiconductor? Explain your answer. **[2 marks]**

ii. Is the drift velocity in the conductor equal, larger or smaller than that in the semiconductor? Explain your answer. **[2 marks]**

iii. What is the current flowing through the good conductor? **[2 marks]**

iv. Calculate the work done by the battery in moving charge carriers along the circuit in 6 seconds. **[2 marks]**

v. Given that the good conductor has 10^{27} charge carriers per unit volume and has a cross-sectional area with dimensions 5 mm by 3 mm, calculate the drift velocity of the charge carriers. **[3 marks]**

14.

a. In an experiment, an oscillating mass is fitted with a pen and set to oscillate in simple harmonic motion in a vertical direction. The pen touches a sheet of paper which is rolled at a constant rate, leaving a pattern as shown in Figure 1.

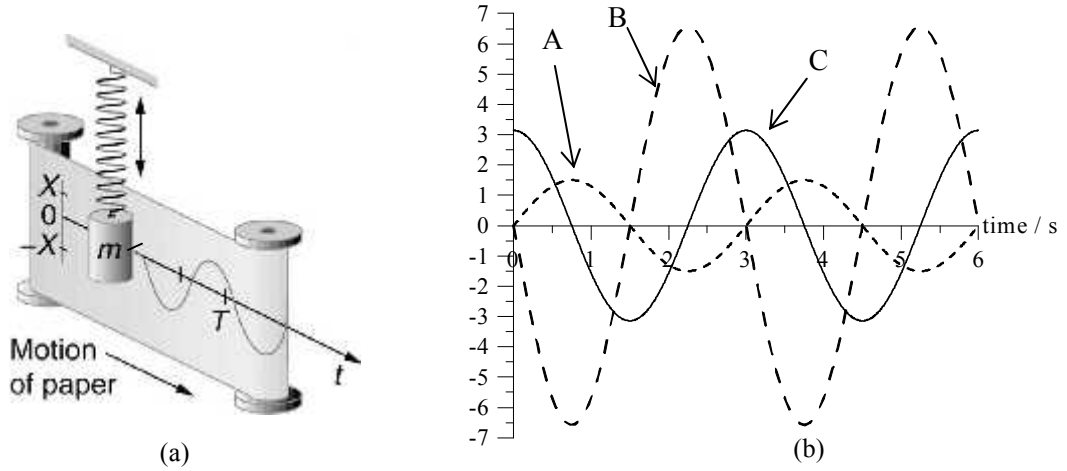


Figure 11

i. Define simple harmonic motion. **[2 marks]**

ii. In Figure 11 (b), graph A shows the displacement-time graph of the mass on the spring. Which one of the two graphs, B or C, represents the corresponding acceleration-time graph for the oscillating mass? Explain your answer. **[2 marks]**

iii. Calculate the magnitude of the acceleration of the oscillating mass when it is at its maximum displacement from equilibrium position. (Note: For Graph A assume that the scale shown on the y-axis is in cm). **[4 marks]**

iv. What is the phase difference between graph A and graph C? Express your answer as a fraction of the periodic time. **[2 marks]**

v. Briefly, describe how the displacement time graph would appear if the sheet of paper were to stop moving. Draw a sketch of the result. **[2 marks]**

b. In a second experiment, laser light having a wavelength of 630 nm is incident on a pair of slits and produces an interference pattern with bright fringes being 8.3 mm apart. A second laser light produces an interference pattern in which the bright fringes are separated by 7.6 mm.

i. Briefly describe one condition necessary to obtain visible interference patterns. **[2 marks]**

ii. Calculate the wavelength of the light from the second laser. **[4 marks]**

15.

a. State Faraday's and Lenz's laws of electromagnetic induction. **[2, 2 marks]**

b. Give two examples of electrical devices which operate on the basis of these laws. **[2 marks]**

c. A metal aircraft with a wing span of 40 m is flying at a constant altitude with a speed of 900 km/h in a direction due East. The Earth's resultant magnetic field B is acting at an angle of 71.6° to the horizontal (see Figure 12).

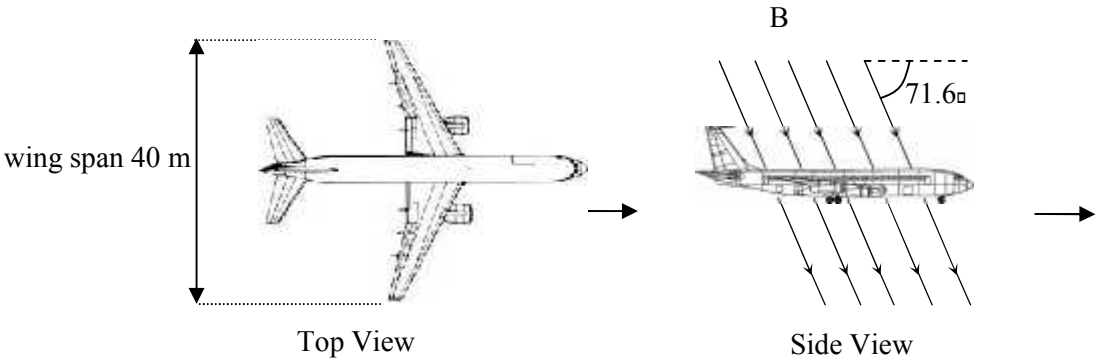


Figure 12

i. State which wing tip is at the higher potential, explaining your answer.

ii. The magnitude of the horizontal component of the magnetic field is 1.6×10^{-5} T. Calculate the magnitude of the vertical component of the magnetic field.

iii. Find the area traversed by the wing span in 1 second.

iv. Find the potential difference that exists between the wing tips.

[3, 3, 1, 2 marks]

d. The aircraft in part (c) is equipped with an air turbine that is used in the event that an airplane loses normal power. It can provide sufficient power to keep the cockpit instruments operational. The graph in Figure 13 shows the alternating current

e. produced by one of these wind turbines.

i. What is the peak value of the current generated? **[1 mark]**

ii. Calculate the root mean square value of the current. **[2 marks]**

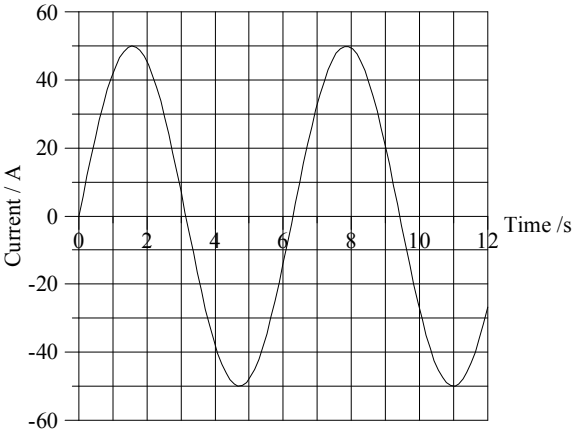


Figure 13