MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2013

SUBJECT:	PHYSICS
DATE:	7th September 2013
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. Surface tension, γ, can be described as the force per unit length exerted by the particles at the surface of a material. It is related to the speed c of ripples forming at the surface of the material by the equation $c = \sqrt{\left(\frac{2\pi\gamma}{\rho\lambda}\right)}$, where ρ is the density of the material and λ is the wavelength of the ripples.
   a. Write down the units of γ and ρ.
   b. Using units, show, that the equation is homogeneous.

[2, 3 marks]

2. Figure 1 shows compressor blades in a jet engine. The blades have a diameter of $42.0\,cm$ and turn at 15960 revolutions per minute. Determine:
   a. the linear speed of the tip of the blades;
   b. the magnitude of the centripetal acceleration at the tip of the blades.

[3, 2 marks]

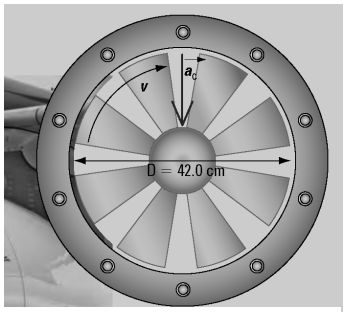

Figure 1

3.
   a. Show that for a copper wire carrying a current I and having n conduction electrons per unit volume, the drift speed v of the electrons is given by $v = \frac{I}{nAe}$, where A is the cross-sectional area of the wire and e is the electronic charge.
   b. A silver wire has a diameter of $2.588\,mm$ and contains 5.80×10^{28} conduction electrons per cubic metre. A charge of $880\,C$ passes through the wire in 45 minutes. Find:
      i. the current;
      ii. the drift speed in the wire.

[2, 1, 2 marks]

4. Genesis I is an experimental space habitat satellite orbiting around the Earth at an altitude of $7000\,\text{km}$ and a speed of $7567\,\text{m s}^{-1}$.
    a. Show that the period of revolution around the Earth is 96.87 minutes.
    b. Determine the mass of the Earth.
    c. Sketch the gravitational field surrounding the Earth.

[2, 2, 1 mark]

5. A car of mass $1360\,\text{kg}$ is moving at $10\,\text{m s}^{-1}$ to the right when it collides head-on with a van of mass $3300\,\text{kg}$. Figure 2 shows the horizontal forces exerted on the car before, during, and after the collision.
    a. Determine the duration of the impact.

    [1 mark]
    b. State a reason why, in Figure 2, the vertical axis shows negative values of the force.

    [1 mark]
    c. Calculate the car's velocity after the collision.

    [3 marks]

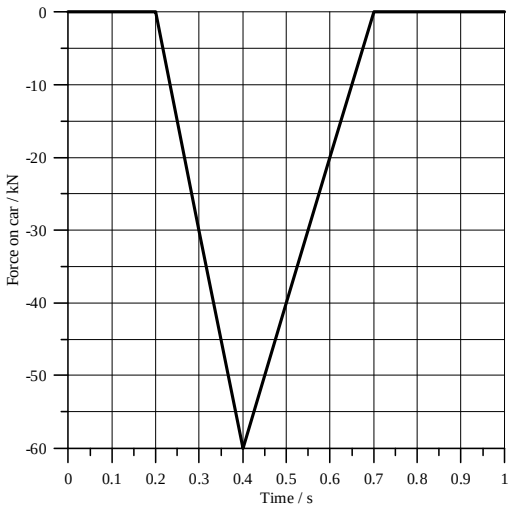

Figure 2

6. A student connects a resistance thermometer to an ohmmeter. He places the thermometer in a beaker with warm water at $77°\text{C}$ and waits until thermal equilibrium is achieved. Data is given to the student showing that when water boils at $100°\text{C}$ the resistance of the thermometer is $23\,\Omega$. At the freezing point of water the resistance is $6\,\Omega$.
    a. Explain what is meant by the term *thermal equilibrium*.
    b. Calculate the resistance of the resistance thermometer when the water temperature is $77°\text{C}$.

[2, 3 marks]

7. In an experiment to test the mechanical properties of materials, a rubber cord and a copper wire both of length $2.0\,\text{m}$, have one of their ends fixed to a rigid support. Weights are attached to the other end of each wire.
    a. Sketch the force – extension graphs to show the behaviour of rubber and copper as these are loaded. Assume that the copper wire remained within the elastic region. Clearly label the graphs, distinguishing between them.
    b. The copper wire extends by $3.0\,\text{mm}$ when the load is 10 kg. Given that the Young modulus for copper is $1.17\times10^{11}\,\text{Pa}$, determine the diameter of the wire.

[2, 3 marks]

8. A student plans to construct a parallel plate capacitor using two flat plates of aluminium of area $120\,\text{cm}^2$, and one of the materials shown in Table 1 acting as a dielectric.

Material	Thickness/mm	Dielectric constant
Sheet of paper	2.00	3.5
Sheet of glass	2.00	7.0
Slab of paraffin	10.00	2.0

Table 1

a. Which of the materials should the student use to obtain the largest capacitance possible? Explain your answer.
b. Calculate the charge the capacitor in part (a) can store, when 150 V are applied across the plates.

[2, 3 marks]

9. Figure 3 shows the displacement – time graph of a body undergoing simple harmonic motion.

a. State two conditions that are necessary for motion to be simple harmonic.

[2 marks]

b. Sketch the corresponding graph showing the variation of the acceleration of the body with time.

[1 mark]

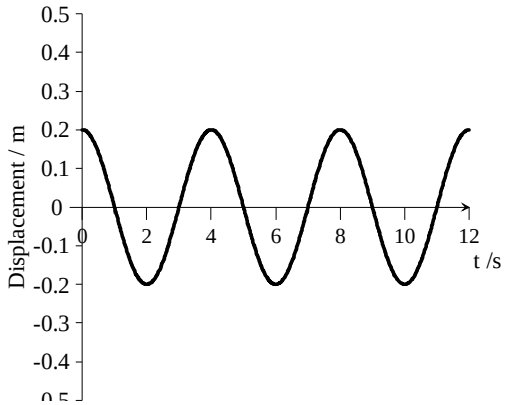

Figure 3

c. Given that the maximum displacement of the body from the equilibrium position is $0.20\,\text{m}$, calculate the magnitude of the maximum acceleration that the body experiences.

[2 marks]

10.

a. Briefly outline the conclusions from the results of Rutherford's alpha scattering experiment.

[2 marks]

b. With reference to the alpha scattering experiment, explain:
   i. why the foil at which the alpha particles are projected should be thin;

[1 mark]

   ii. how the scattered alpha particles may be detected.

[2 marks]

SECTION B

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

11. Figure 4 shows the setup used to investigate the oscillations of a pendulum. A loop of string is threaded through a nut which acts as a pendulum bob. The pendulum oscillates in a direction perpendicular to the plane of the loop.

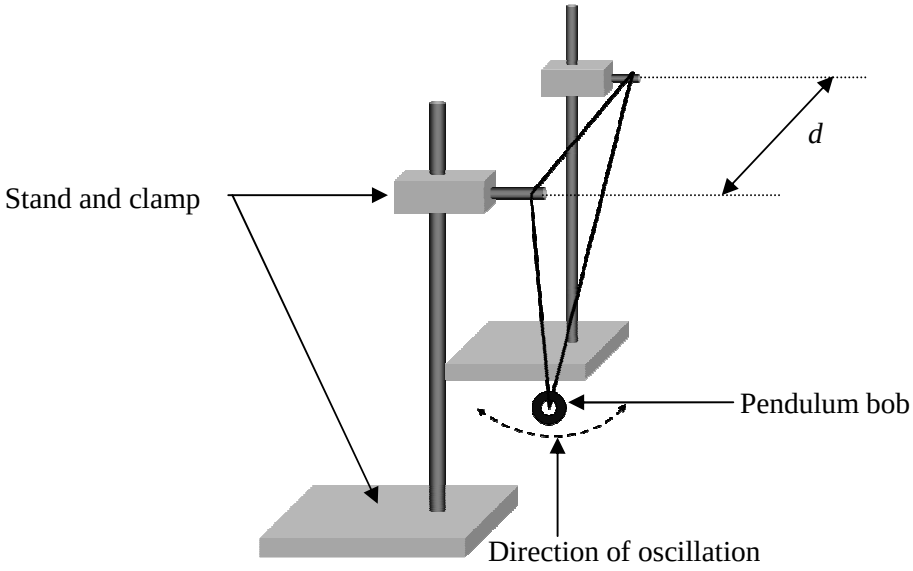

Figure 4

The equation relating the periodic time T of the pendulum and the distance d between the supports is given by:

$$T^4 = \frac{4\pi^4}{g^2}K - \frac{8\pi^4}{g^2}d$$

where g is the acceleration due to gravity and K is a constant. The time for 20 oscillations, T_{20}, for different distances, *d*, was recorded and the results are shown in Table 2 below.

d / m	T_{20} / s	T / s	T^4 / s^4
0.15	29.84		
0.30	27.77		
0.45	25.10		
0.60	21.10		
0.70	16.03		

Table 2

a. Copy the table and fill in the missing values.
b. Plot a graph of T^4 / s^4 on the y-axis against d / m on the x-axis.
c. Use the graph to find a value for the gravitational acceleration g and the constant K. Clearly state the unit of K.
d. Write down one precaution that should be taken during this experiment.

[5, 5, 3, 1 mark]

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. In a hit-the-target game between two friends, a ball of mass $0.07\,\text{kg}$ is pushed against a spring and released. The ball moves with constant velocity across a frictionless surface and is projected horizontally from the edge of a table with the aim of hitting the target on the floor $0.50\,\text{m}$ away from the table, as shown in Figure 5. The spring has an uncompressed length of $0.10\,\text{m}$ and a spring constant of $12\ \text{N m}^{-1}$.

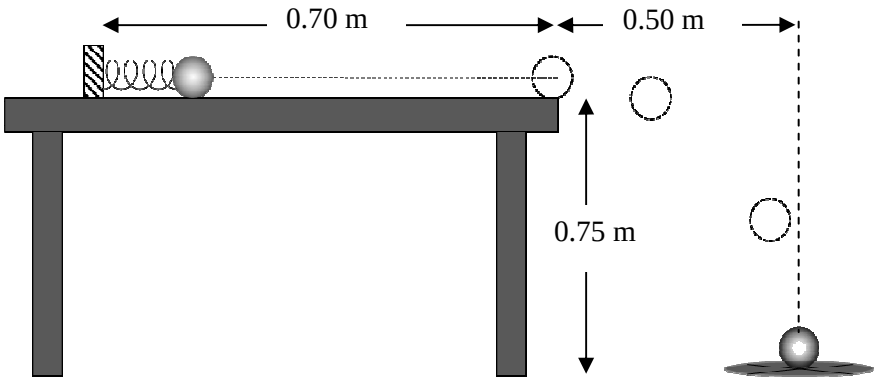

Figure 5

a. In one attempt to hit the target, the spring is compressed 0.06 m and released. Calculate:

   i. the force the spring exerts on the ball when compressed;

   [2 marks]

   ii. the energy stored in the spring when compressed;

   [2 marks]

   iii. the velocity with which the ball leaves the spring;

   [2 marks]

b. The ball is projected horizontally from the edge of the table. Calculate:

   i. the time it takes to reach the ground;

   [2 marks]

   ii. the resultant velocity just before impact and the angle this makes with the vertical;

   [3 marks]

   iii. the horizontal distance it lands away from the table, stating whether it hits the target or not.

   [3 marks]

c. Sketch two velocity – time graphs, one that shows the horizontal velocity and the other that shows the vertical velocity of the ball from the moment it is compressed against the spring till it lands on the floor. Clearly indicate any known values of the velocity.

   [4 marks]

13. A calorimeter contains $100\,\text{g}$ of water at $12.5°\text{C}$ and a heater which can be connected to a 12 V supply. To speed up the heating process a student initially adds $21\,\text{g}$ of hot water at $60°C$ to the $100\,\text{g}$ of water already in the calorimeter, and the mixture reaches a final temperature of θ. The calorimeter has a heat capacity of $280\,\text{J K}^{-1}$. The specific heat capacity of water is $4200\,\text{J kg}^{-1}\,\text{K}$.

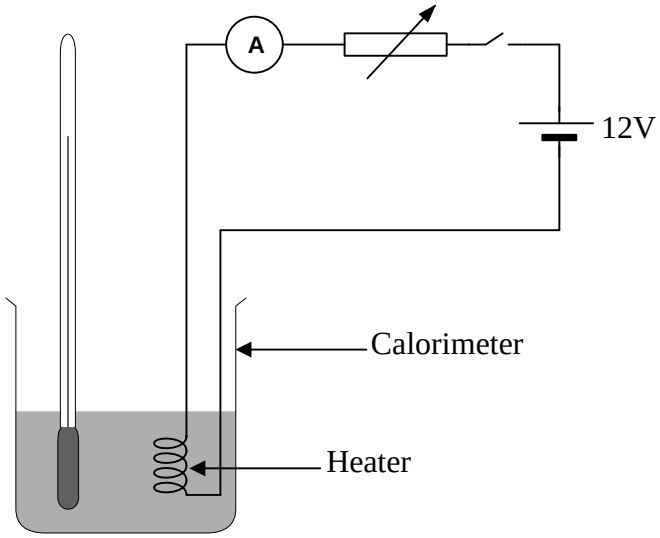

Figure 6

a. Write down an expression in terms of θ for the heat energy lost by the water which is initially at $60°\text{C}$, including relevant given data in the final answer.

[3 marks]

b. Determine the final temperature θ reached by the mixture.

[4 marks]

The student <u>now turns on the heater.</u> The ammeter reads $2.5\,\text{A}$. The heater is left turned on for 40 minutes. The latent heat of vaporisation of water is $2.26\times10^{6}\,\text{J kg}^{-1}$. Assume that there are no heat losses.

c. Explain what is meant by the latent heat of vaporisation of a liquid.

[2 marks]

d. Determine the power of the heater.

[1 mark]

e. Calculate the amount of heat energy that is required to bring all the water in the calorimeter to the boiling point at $100°\text{C}$.

[4 marks]

f. Determine the time it took the water to reach the boiling point.

[1 mark]

g. Hence, calculate the mass of water that changed into steam.

[3 marks]

14. A student is asked to investigate the current-voltage characteristics of a filament lamp and a diode.

a. Draw a diagram of the circuit needed for this investigation, suggesting a value for the power supply voltage.

[4 marks]

b. Sketch two separate graphs showing the current–voltage characteristics of a filament lamp and a diode.

[2 marks]

c. A student connects the circuit shown in Figure 7. A length of resistance wire is placed between the terminals A and B. The resistance of R is in the range 0 – 6 Ω.

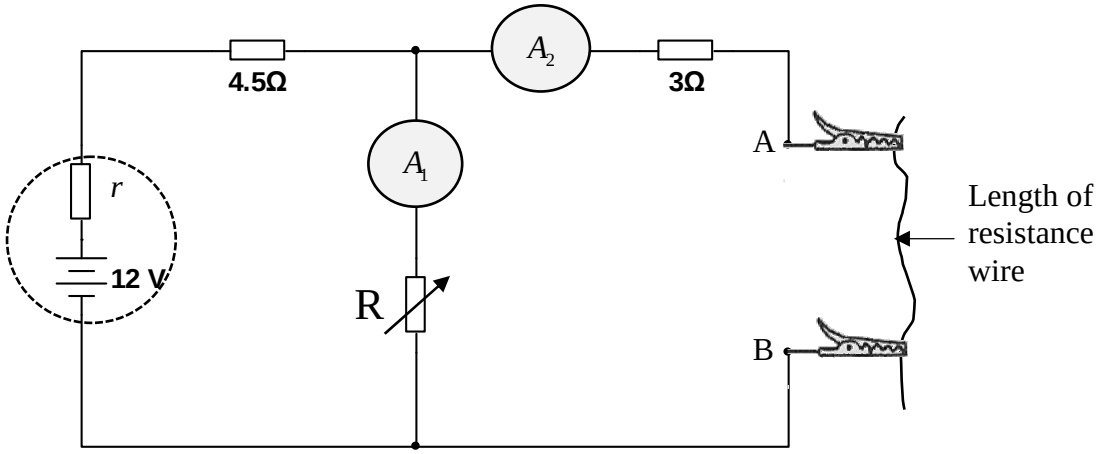

Figure 7

R is adjusted to its minimum value.

i. What is the reading on ammeter A_2?

[2 marks]

ii. If ammeter A_1 reads a current of $2\,\text{A}$, calculate the internal resistance r of the battery.

[3 marks]

d. Using the same circuit shown in Figure 7, the variable resistor R is now adjusted to $3.5\,\Omega$ and the reading on ammeter A_1 drops to $1.0\,\text{A}$. Calculate:

i. the reading on ammeter A_2;

[4 marks]

ii. the voltage across the $3\,\Omega$ resistor;

[1 mark]

iii. the resistance of the length of wire

[2 marks]

15. a. State Faraday's and Lenz's laws of electromagnetic induction.

[2, 2 marks]

b. In Figure 8, a magnet is falling vertically through a solenoid.

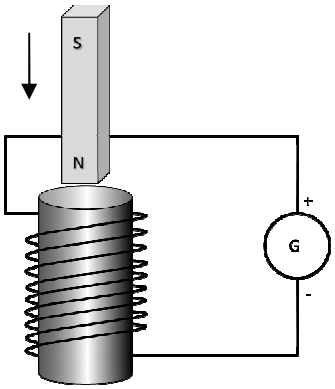

Figure 8

i. Explain why the needle of the galvanometer suddenly deflects as the magnet approaches the upper part of the solenoid.

ii. What pole is induced on the lower end of the solenoid as the magnet leaves the solenoid? Give a reason for your answer.

iii. If the galvanometer needle deflects to the right when the current passes from its positive to its negative terminal, indicate in which direction the needle will deflect as the magnet leaves the solenoid.

[2, 2, 2 marks]

c. A horizontal conducting rod PQ of length $0.5\,\text{m}$, is perpendicular to a uniform vertical magnetic field B of $30\,\text{mT}$ directed into the paper (see Figure 9).

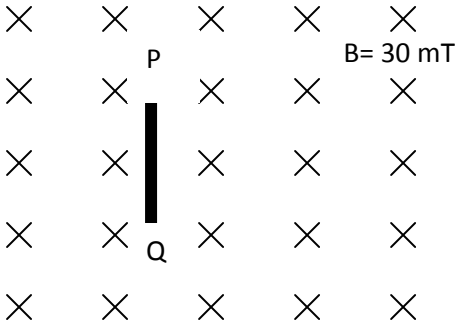

Figure 9

i. In which direction must the rod be moved to generate a maximum current? Explain how you arrived at your answer.

ii. Indicate clearly the direction of current flow along the rod when it is moved in the direction suggested in (i).

iii. Calculate the induced e.m.f., if any, in PQ when the rod is moved through the field with a velocity of $4\ \text{ms}^{-1}$ in the direction of B.

iv. Calculate the induced e.m.f., if any, in PQ when the rod is moved through the field with a velocity of $4\ \text{ms}^{-1}$ sideways perpendicular to B.

[2, 2, 2, 2 marks]