MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2013

SUBJECT:	PHYSICS
DATE:	24th May 2013
TIME:	4.00 p.m. to 7.00 p.m.

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. A mountain climber of mass $67.5\,kg$ is using a rope to hang horizontally against a vertical cliff, as in Figure 1. The tension in the rope is $729.0\,N$ at an angle of $27.0°$ to the horizontal.
   a. On a free body diagram, draw and label all forces acting on the climber.
   b. Determine the force exerted by the cliff on the climber's feet.

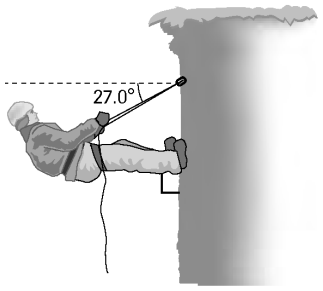

Figure 1

[3, 2 marks]

2. A marble is projected horizontally off a table with a velocity of $1.93\,m\,s^{-1}$. The tabletop is $76.5\,cm$ above the floor. If air resistance is negligible, determine:
   a. how long the marble takes to reach the ground;
   b. the horizontal range;
   c. the resultant velocity at impact, including the angle this makes with the horizontal.

[2, 1, 2 marks]

3. A small charge of $6.2\,nC$ is moved at constant velocity, a distance of 2.0 mm from one conducting plate to another, against a field of $20{,}000\,N\,C^{-1}$ (see Figure 2).
   a. Find the work done on the charge.
   b. Calculate the potential difference between the plates.

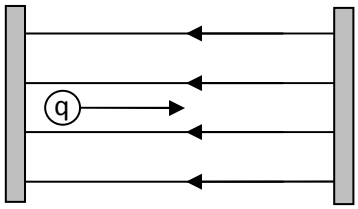

Figure 2

[3, 2 marks]

4. A trolley of mass $1.20\,\text{kg}$ is moving at $3.60\,\text{m s}^{-1}$ along a horizontal laboratory desk. It collides head on with a spring bumper that has a spring constant of $2.00\times10^{2}\,\text{N m}^{-1}$.
   a. By considering energy changes at the point of impact, find the maximum compression of the spring.
   b. Find the speed of the trolley when the spring bumper is compressed by $0.10\,\text{m}$.
   c. Find the acceleration of the trolley when the spring bumper is compressed by $0.10\,\text{m}$.

[1, 2, 2 marks]

5. A gas is enclosed in a container fitted with a piston of cross-sectional area $0.15\,\text{m}^2$ (see Figure 3). The pressure of the gas is maintained constant at $6000\,\text{Pa}$ as the piston is lowered $0.20\,\text{m}$.
   a. Calculate the work done on the gas.
   b. If the internal energy of the gas decreases by $8.00\,\text{J}$, find the amount of energy lost as heat by the system during the compression.

[2, 3 marks]

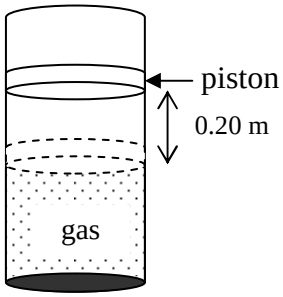

Figure 3

6. A standard "35-mm" slide measures 24.0 mm by 36.0 mm. Suppose a slide projector produces a 60.0 cm by 90.0 cm image of the slide on a screen. The focal length of the converging lens in the projector is 12.0 cm.
   a. Calculate the magnification of the lens.
   b. If u and v are the object and image distances respectively, use your answer to part (a) to write down an expression for v in terms of u.
   c. Calculate the distance between the slide and the lens.

[2, 1, 2 marks]

7. An electron moves with a horizontal velocity v as it enters a vertical magnetic field B, as shown in Figure 4.
   a. Show that the force on the electron when travelling in the magnetic field is $F = Bev$ where e is the electronic charge.
   b. The magnetic field has a flux density of $1.2\,\text{T}$ and the electron has a speed of $0.3\,\text{mm s}^{-1}$. Explain why the electron travels along a circular path in the magnetic field and calculate the radius of this path.

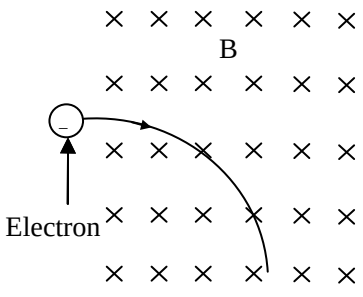

Figure 4

[2, 1, 2 marks]

8. Two identical masses A and B are attached to two identical springs and both perform simple harmonic motion. Their displacement-time graphs are shown in Figure 5.

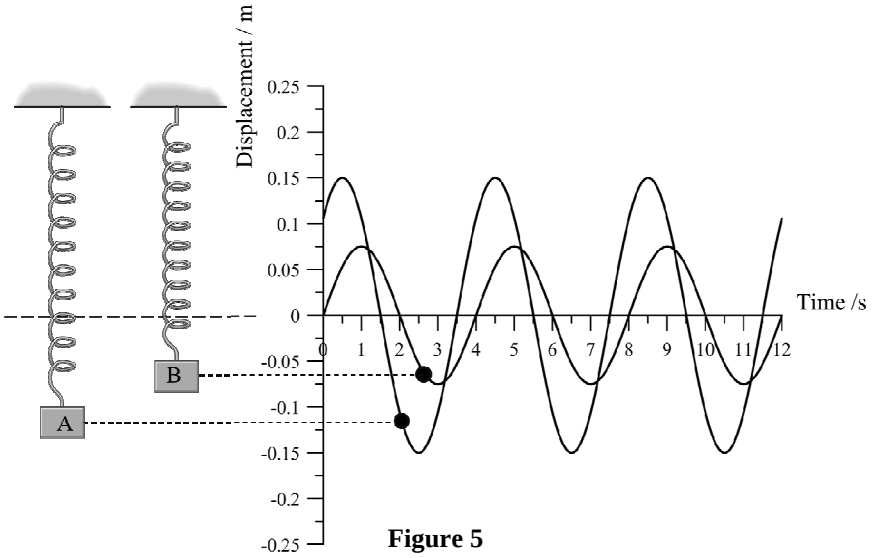

Figure 5

a. Which of the two masses experiences the greatest acceleration? Explain.
b. Masses A and B are oscillating at the same frequency. Explain why this is so and determine this frequency.
c. Determine the phase difference between the two oscillatory motions as a fraction of the periodic time, T.

[2, 2, 1 mark]

9. In the circuit shown in Figure 6, the reading on ammeter A_1 is $0.40\,A$ and that on ammeter A_2 is $0.64\,A$. R1 is the internal resistance of the battery. Using the given data calculate:
   a. the resistance of R5;
   b. the potential difference across the battery;
   c. the value of the internal resistance R1.

[2, 1, 2 marks]

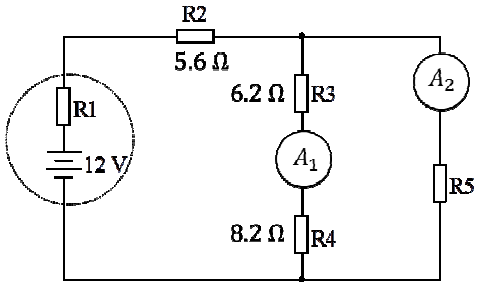

Figure 6

10. Figure 7 shows four discrete energy levels for the hydrogen atom.
    a. Describe how the presence of discrete energy levels is used to explain the formation of line spectra.
    b. Determine the number of different spectral lines that can be produced from the energy levels shown.
    c. Determine the longest and shortest wavelengths that can be produced.

[2, 1, 2 marks]

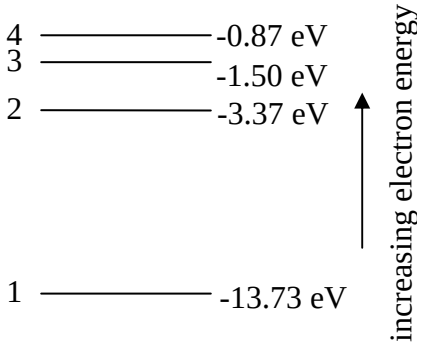

Figure 7

SECTION B

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

11. Figure 8 shows the setup of an experiment used to investigate how the resistance R of a wire changes with temperature. A coil of wire which is connected to a resistance meter is immersed in water which partly fills a beaker. The water is heated using a Bunsen burner and the resistance of the coil of wire is recorded as it changes with the temperature, T, read from the thermometer.

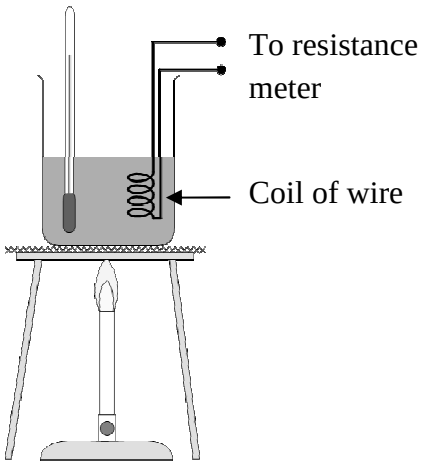

Figure 8

The equation relating the resistance of the wire, R, with the change in temperature, ΔT, is given by

$$R = R_0(1 + \alpha\Delta T)$$

where R_0 is the resistance of the wire at a temperature T_0, and α is the temperature coefficient of resistance. $R_0 = 15\,\Omega$ and T_0 = 273.16 K.

R / Ω	T /K	$(R - R_0)$ / Ω	$\Delta T = (T - T_0)$ / K
17.3	304.0		
17.9	311.5		
18.5	328.4		
20.6	348.1		
23.5	373.0		

Table 1

a. Copy Table 1 and fill in the missing values.
b. Plot a graph of $(R\text{-}R_0)\,/\Omega$ on the y-axis against ΔT / K on the x-axis.
c. Write the given equation in the form $y = mx + c$, explaining your working. Use the graph to determine the temperature coefficient of resistance, α. Clearly state the unit of α.
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. Two gliders A and B of mass 0.30 kg and 0.40 kg respectively are placed on an air-track and are held together by a piece of string which in turn is compressing a spring between the gliders. The gliders are initially at rest. A student holds a lit match under the string and burns it, letting the spring force the gliders apart. Glider B is then observed to move to the right at $1.30\ \text{m s}^{-1}$.

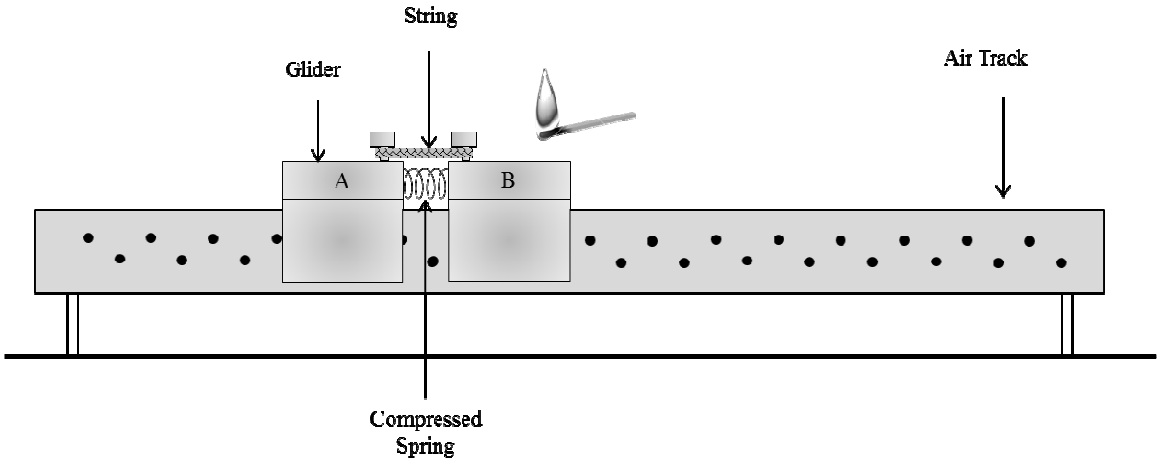

Figure 9

a. State the law of conservation of linear momentum.

[2 marks]

b. Calculate the momentum of glider B after the string is burnt.

[2 marks]

c. Find the velocity of glider A after the string is burnt. State any assumptions made.

[3 marks]

d. Sketch **two** velocity-time graphs that show how the velocity of each glider changes with time. Assume it took negligible time for the spring to fully force the gliders apart.

[4 marks]

e. Calculate the total kinetic energy of the gliders after the string is burnt.

[3 marks]

f. Compare the total kinetic energy of the trolleys before and after the string is burnt.

[2 marks]

g. Can the answer to part (f) indicate whether energy was conserved in the experiment with the two gliders? Explain your answer.

[2 marks]

13. The graph in Figure 10 shows how the extension of a steel rod changes as the rod is loaded to a maximum tension of 1250 N. The steel rod is 0.50 m long and has a cross-sectional area of 3.0 mm^2.

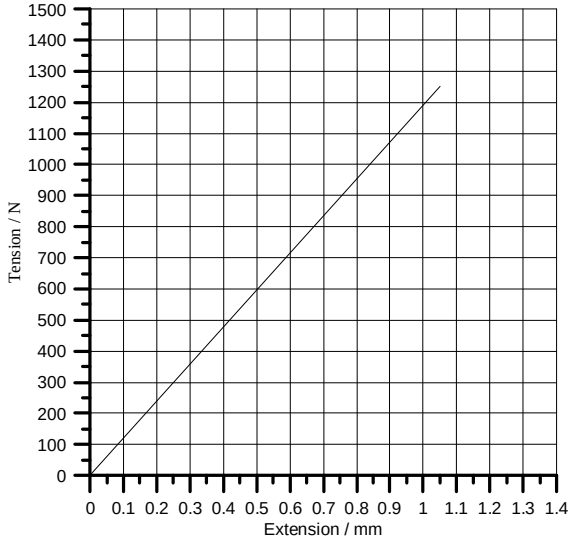

Figure 10

a. Determine the maximum stress in the rod.

[2 marks]

b. Determine the maximum strain.

[2 marks]

c. Calculate the Young modulus of steel.

[3 marks]

d. Calculate the energy stored in the rod when the stress is a maximum.

[3 marks]

e. The Young modulus for brass is less than that of steel. Which would stretch more easily for the same cross-sectional area, length and tension, a brass or a steel rod? Explain your reasoning.

[2 marks]

f. Copy Figure 10 and on it sketch a typical force-extension graph for **brass**, labelling it **B**.

[2 marks]

g. Consider two brass wires, X and Y, of the same length but different cross-sectional area. The wires are equally loaded and the resulting extensions are recorded. On the same scale and axes, sketch two force – extension graphs to represent the behaviour of the wires X and Y, labelling the graphs carefully, indicating which wire has the smaller cross-sectional area, justifying your reasoning.

[4 marks]

14. A student wishes to investigate the rate of charging and discharging of a parallel plate capacitor. The apparatus available are a power source of 100 V, a switch, a 1 MΩ resistor and some connecting wires.

    a. Draw a diagram of the circuit which the student needs to set up for this investigation and list any additional apparatus which may be required.

    [4 marks]

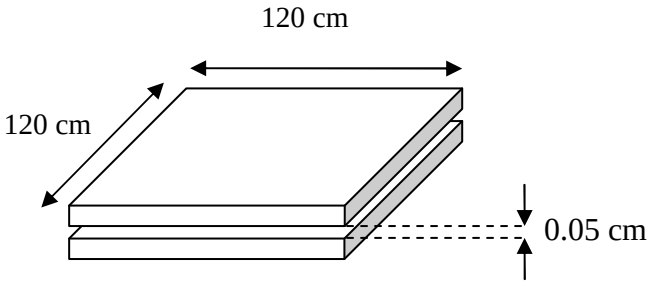

Figure 11

    b. The plates of the capacitor are placed on top of each other and separated by a layer of air as shown in Figure 11. Calculate:

        i. the magnitude of the electric field intensity between the plates when connected to the 100 V supply;

        [2 marks]

        ii. the capacitance of the capacitor;

        [2 marks]

        iii. the charge stored on the capacitor plates when fully charged.

        [1 mark]

    c. The student notices that the rate of discharge is very high and that it is impossible to take any measurements. He soaks the plates in water so that a layer of water now fills the gap between the capacitor plates. The dielectric constant of water is 80.4.

        i. Calculate the new capacitance of the capacitor.

        [1 mark]

        ii. Suggest one other way of increasing the capacitance of the capacitor.

        [1 mark]

        iii. Calculate the time constant of this new setup, when the capacitor is discharged through the 1 MΩ resistor.

        [2 marks]

        iv. Calculate the amount of charge that remains on the capacitor after a time equal to the time constant has elapsed.

        [2 marks]

        v. Sketch a graph that shows how the charge on the new capacitor changes with time during the discharge process. Mark the maximum charge on the graph and indicate the time constant.

        [3 marks]

15.

a. A vibrating motor generates waves on a stretched rubber cord (see Figure 12).

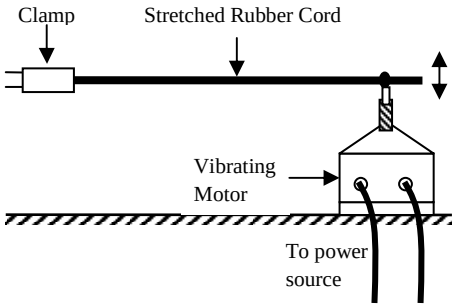

Figure 12

i. Are the waves generated transverse or longitudinal?

[1 mark]

ii. Explain why stationary waves can be produced using this setup?

[1 mark]

iii. State two differences between progressive and stationary waves.

[4 marks]

b. Figure 13 shows the result of the superposition of two waves of the same frequency and amplitude which are moving in opposite directions on a string.

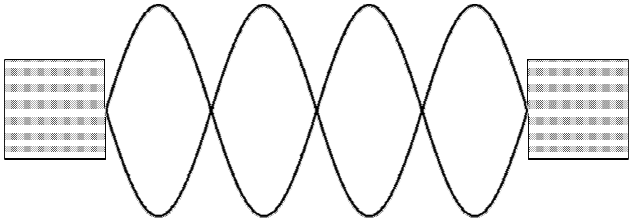

Figure 13

i. On a copy of the diagram, indicate an antinode with the letter A, and a node with the letter N.

[2 marks]

ii. If the result shown is observed at a frequency of 100 Hz, calculate the frequency required to produce 5 loops.

[2 marks]

c. In Young's double slit experiment, ***monochromatic*** light is used to illuminate two slits, thus producing two ***coherent*** light sources. Fringes are observed on a screen placed 3.30 m away from the slits. When light of wavelength 690.00 nm is used, the distance between the centre fringe and the second bright fringe on either side is 3.60 cm.

i. Explain the meaning of the terms ***monochromatic*** and ***coherent***.

[2 marks]

ii. Why are two coherent light sources needed for this experiment to work?

[2 marks]

iii. Explain with the help of a diagram how it can be ensured that the two light sources are coherent.

[2 marks]

iv. Calculate the distance between the slits.

[2 marks]