MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2015

SUBJECT:	PHYSICS
DATE:	4th September 2015
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. The speed of sound v in a vibrating metal rod is related to the Young modulus Y of the rod and its density ρ by the expression

$$v = \sqrt{\frac{Y}{\rho}}$$

a. Write down the units Y and ρ.

[2 marks]

b. Show that the equation is homogenously correct.

[3 marks]

2. A train is travelling at a constant speed of $25\,m\,s^{-1}$. On approaching a tunnel, it slows down with a constant deceleration of $1.5\,m\,s^{-2}$.

a. Calculate the speed of the train after 8 seconds from when it started slowing down.

[**2 marks]**

b. Sketch a speed-time graph that shows the train's speed at 2.0 second intervals, starting 6 seconds before the train started to decelerate and ending at 8 seconds after it started to slow down.

[3 marks]

3. A daring 510 N swimmer dives off a cliff with a running horizontal leap, as shown in Figure 1. What must his minimum speed be just as he leaves the top of the cliff so that he will miss the ledge at the bottom, which is 1.75 m wide and 9.00 m below the top of the cliff?

[5 marks]

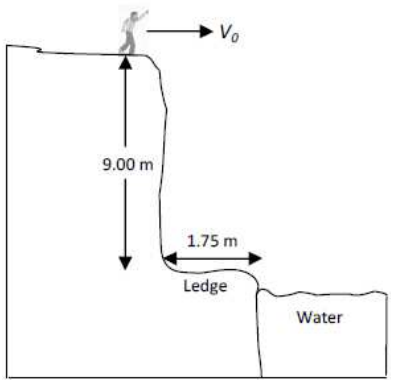

Figure 1

4. A 120 N weight is attached to one end of a copper wire of length 3.0 m. The other end of the wire is firmly attached to a fixed support. It is observed that the copper wire stretches by 2.1 mm with the load attached. The Young modulus of copper is 117×10^9 Pa .
   a. Calculate the stress in the wire.
   b. Determine the cross-sectional area of the copper wire.
   c. If the ultimate tensile stress of copper is 220×10^6 Pa , determine the maximum weight that may be hung from this wire.

[2, 1, 2 marks]

5. In an experiment to determine the specific heat capacity of 2 kg solid block of copper, the change in temperature of the block, $\Delta\theta$, is recorded as heat energy, ΔQ, is supplied to the block. Figure 2 shows how $\Delta\theta$ changes with ΔQ.

   Using the graph:
   a. Determine the rate of change of ΔQ with $\Delta\theta$, clearly indicating the units.

   [3 marks]
   b. Find the specific heat capacity of the copper block.

   [2 marks]

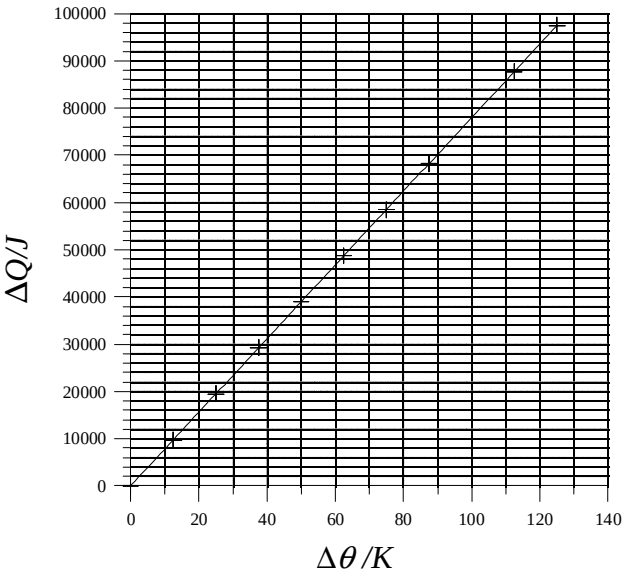

Figure 2

6. A 12.0 V battery inside the engine compartment of a truck can supply a current of 1 A for 180 hours, through the electric circuit connected to it.
   a. Calculate the charge in Coulombs that can flow in the circuit.

   [2 marks]
   b. Assuming the terminal potential difference of the battery remains at 12 V, determine the amount of electrical energy that the battery can deliver.

   [3 marks]

7. A few years ago, NASA commissioned a privately owned company called SpaceX to deliver cargo to the International Space Station (ISS) orbiting around the Earth at an altitude of 400 km. If the capsule delivering the cargo had a total mass of 4200 kg, calculate:
   a. the gravitational force acting on the capsule while in the same orbit as the ISS;
   b. the speed with which it orbits the Earth.

[2, 3 marks]

8. When two particles enter a region of uniform magnetic field pointing out of the plane of the paper, they follow the paths shown in Figure 3.

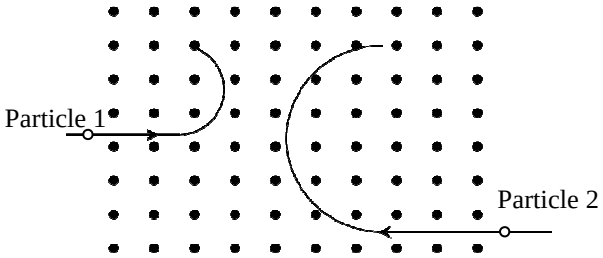

Figure 3

   a. State whether the charge on each particle is positive or negative. Explain your reasoning, indicating any rule used to come to a conclusion.

[2 marks]

   b. The two particles carry a charge of the same magnitude and enter the magnetic field with the same speed. Which of the two has the greater mass? Explain.

[2 marks]

   c. Write down an equation which relates the radius of curvature to the velocity of projection of the charge into the magnetic field region.

[1 mark]

9. In an Optics Lab a student uses a light source that emits light rays with a wavelength of 563 nm. Light from the source first falls on a double slit, with a slit separation of 0.05 mm, and then fringes are formed on a screen 120 cm away from the double slit.

   a. Give **one** word that describes the **two sources** receiving the light from the main source, for fringes to be formed.

[1 mark]

   b. Calculate the minimum width of the screen required if the student is to display five interference bright fringes on either side of the central bright fringe.

[2 marks]

   c. State **two** ways in which the student can reduce the width of the screen without changing the light source.

[2 marks]

10. Figure 4 shows the three lowest energy levels for electrons in the hydrogen atom, with E_0 being the ground state.

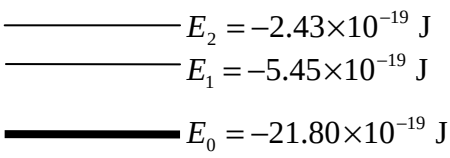

Figure 4

   a. Indicate a transition between two of the energy levels shown, which results in the emission of light with the shortest wavelength. Explain your answer.

[2 marks]

   b. Calculate the wavelength of the spectral line resulting from the transition between the levels E_2 and E_1.

[3 marks]

SECTION B

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

11. Figure 5 shows the setup of an experiment used to determine the rigidity modulus of a copper wire. The metal disc hanging at the end of the copper wire is rotated and the time T_{20}/s for 20 oscillations is recorded. The rotational oscillations are repeated for a number of times, as the length of the copper wire is changed. T_{20}/s is recorded for each length.

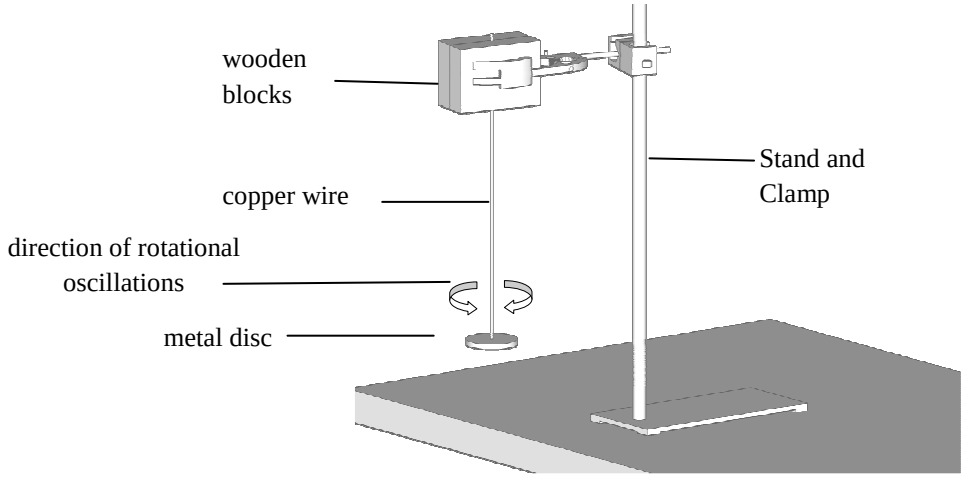

Figure 5

The equation relating the periodic time T of the oscillations, the length L of the copper wire and the rigidity modulus η is given by

$$\eta = \frac{4\pi ML r^2}{a^4 T^2}$$

where M is the mass of the metal disc, r is the radius of the metal disc and a is the radius of the copper wire. It is given that $M = 0.350\,\text{kg}$, $r = 0.015\,\text{m}$ and $a = 0.00025\,\text{m}$.

L /m	T_{20} /s	T /s	T^2 /s^2
0.4	31.0		
0.6	37.2		
0.8	40.1		
1.0	47.5		
1.2	49.9		
1.4	56.1		

Table 1

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

b. Plot a graph of T^2 /s^2 on the y-axis against L /m on the x-axis.

c. Write the given equation in the form $y = mx + c$, explaining your working.

d. Use the graph to determine a value for the rigidity modulus η, including the relevant units.

e. Suggest **one** reason why it is more valid to conduct the experiment using the changes in T/s with changes in the length of the copper wire, rather than using changes in T/s with the changing mass of the hanging disc. **[3, 5, 1, 4, 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.

a. The keys on a computer keyboard are attached to a parallel plate capacitor with a flexible insulator between the plates. The metal plate attached to the key moves with each key press while the other metal plate is fixed in position (see Figure 6). The capacitor is maintained at a constant potential difference of 5 V by a separate circuit. When a key is pressed the separation between the top metal plate and the lower metal plate changes from 4.0 mm to 1.2 mm.

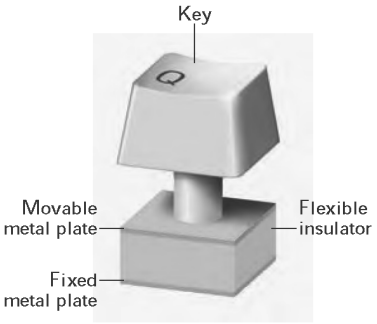

Figure 6

Assuming that there is air between the capacitor plates:

i. Explain what happens to the capacitance of the capacitor as the key is pressed.

[2 marks]

ii. If each metal plate is a square of side 5 mm, calculate the charge on the capacitor when the key is not pressed.

[2 marks]

iii. Calculate the charge that flows through the circuit when the key is pressed.

[4 marks]

iv. If the key is pressed in 1.2 ms, calculate the current flow through the circuit.

[2 marks]

v. How will the magnitude of the current be affected if the flexible insulator between the plates is oiled paper? Explain.

[2 marks]

b. When the keyboard is powered up, charging of the capacitor under the key occurs through a resistor that is connected in series with the capacitor. The graph in Figure 7 shows how the charge on the capacitor changes with time while charging.

i. Give a valid reason to explain why the time-axis scale is in microseconds (μs).

[3 marks]

ii. From the graph determine the time it takes the capacitor to charge to 63% its full capacity.

[3 marks]

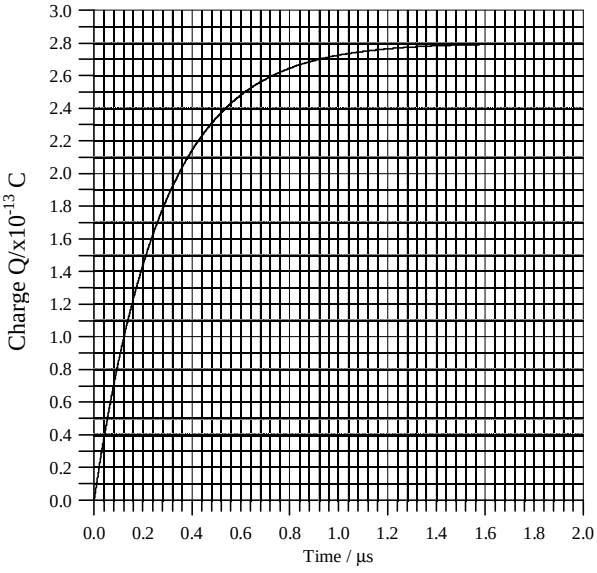

Figure 7

13.

a. A horizontal ray of white light ray is incident on a triangular glass prism as shown in Figure 8. The angle of incidence is 15°. A spectrum of colours is formed after the light passes through and out of the prism. Only the red and blue rays are shown. The red light has a wavelength of 660 nm and the blue light has a wavelength of 470 nm.

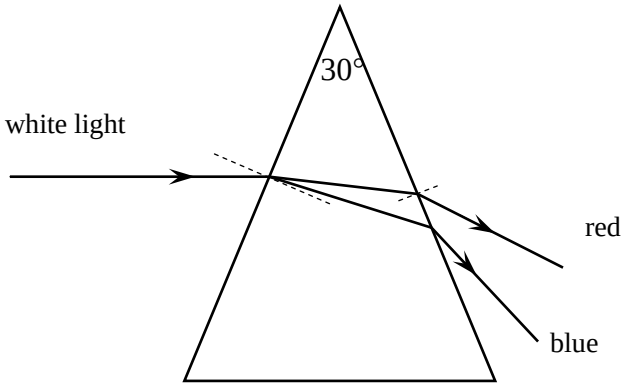

Figure 8

i. What is this phenomenon called?

[1 mark]

ii. If the red light and blue light are refracted an angle of 10.48° and 10.33° respectively as they enter the prism, calculate the refractive index for the red and blue light.

[2 marks]

iii. Calculate the ratio of the speed of the red light to the speed of blue light in glass.

[2 marks]

b. A glass block is placed in a liquid. A ray of light inside the glass block reaches the glass-liquid boundary at the critical angle, and is just about to be totally internally reflected.

i. Draw a diagram illustrating the situation, labelling the glass, the liquid and the angles at the glass-liquid boundary.

[2 marks]

ii. Is the refractive index of the liquid, larger, equal to, or smaller than the refractive index of glass? Explain.

[1 mark]

iii. Write down an equation relating the critical angle, *c*, to the refractive indices η_{glass} and η_{liquid}.

[2 marks]

c. A thin convex lens is placed 7 cm from an object that is 1.5 cm high. The lens has a focal length of 4 cm.

i. Sketch a well labelled ray diagram to show how the image is formed.

[3 marks]

ii. State **two** properties of the image formed.

[2 marks]

iii. Calculate the height of the image.

[3 marks]

14.

a. A diode allows the flow of current in one direction only.

i. Draw a circuit that can be used to investigate the current-voltage characteristics of a diode in forward-bias mode. Carefully label all symbols used.

[3 marks]

ii. Sketch a graph that shows the current-voltage characteristics of a diode.

[2 marks]

b. A torchlight is powered by **two** $1.5\,\text{V}$ batteries that are connected in series. Each battery has an internal resistance of $0.10\,\Omega$. The wires and connections have a total resistance of $0.40\,\Omega$. At normal operating temperature, the resistance of the torch bulb is $10.8\,\Omega$.

i. Draw a circuit diagram that shows all the components that make up the circuit. In your diagram include a switch and a resistor that represents the total resistance of the wires and connections.

[2 marks]

ii. Calculate the current flowing through the filament lamp.

[2 marks]

iii. Calculate the terminal potential difference across both batteries.

[2 marks]

iv. Determine the power dissipated by the wires and connections and the total power supplied by the batteries, when the current in (ii) is flowing.

[2 marks]

c. A light dependent resistor (LDR) is connected as shown in Figure 9.

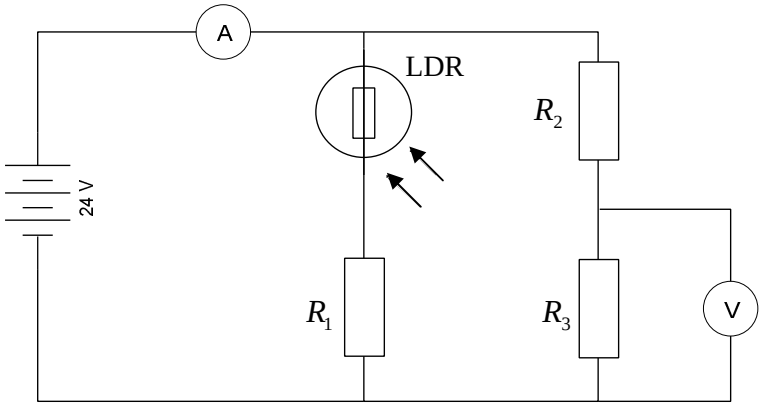

Figure 9

i. What will happen to the ammeter and voltmeter readings when the LDR is covered? Give a reason for each answer.

[3 marks]

ii. Given that the resistance of R_3 is three times that of R_2, calculate the voltage read by the voltmeter.

[2 marks]

15.

a. A blacksmith has just cast a red hot 2.0 kg horseshoe into the desired shape. When he places the horseshoe which is at a temperature of $1400°C$ into 0.75 kg of water in a bucket, steam rises from the water in the bucket. Given that the temperature of the water was initially at $35°C$, calculate:

i. the heat energy lost by the horseshoe when its final temperature is 100 ^{o}C;

[2 marks]

ii. the heat energy gained by the water to reach $100°C$;

[2 marks]

iii. the mass of steam produced.

[3 marks]

[specific heat capacity of water $= 4186\ \text{J kg}^{-1}\ \text{K}^{-1}$; specific heat capacity of iron $= 450\ \text{J kg}^{-1}\ \text{K}^{-1}$; latent heat of evaporation of water $= 2.26\times10^{6}\ \text{J kg}^{-1}$]

b. The equation $\Delta U = \Delta Q + \Delta W$ represents the first law of thermodynamics.

Explain the meaning of each term in the equation when this is applied to an ideal gas enclosed in a cylinder with a moveable piston.

[3 marks]

c. A fixed mass of Helium gas is trapped inside a cylinder fitted with a moveable piston. The piston has a mass 8 kg (see Figure 10). The gas is first heated from $20°C$ to $100°C$ during which it expands at constant pressure and the piston rises by 0.20 m. The piston is then locked in place and the gas is cooled back to $20°C$.

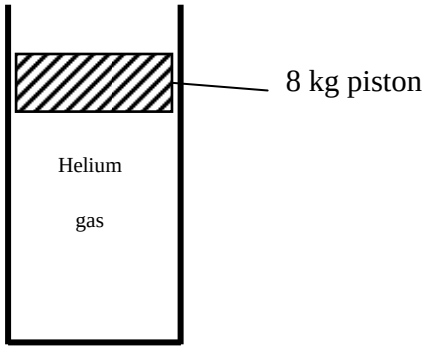

Figure 10

Given that the atmospheric pressure is 100 kPa, and the piston has an area of 5×10^{-3} m :

i. Calculate the **total** pressure exerted on the gas during the heating process;

[2 marks]

ii. Calculate the work done by the gas as it is heated;

[2 marks]

iii. Describe what happens to the pressure of the gas as it is cooled down back to 20°C;

[2 marks]

iv. Draw a well labelled pressure-volume diagram to explain the processes taking the gas from the initial, (I), to the final state, (F). Include I and F in your diagram.

[2 marks]