MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION CERTIFICATE EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2012

SUBJECT:	PHYSICS
DATE:	10th September 2012
TIME:	9.00 a.m. to 12.00 noon

A list of useful formulae and equations is provided. Take the acceleration due to gravity as equal to 10 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. Consider the following homogeneous expression where t represents time, h represents a displacement while A and B are constants.

$$t^2 h = Ah^3 + B$$

Use base units to find:

a) the unit, if any, of the constant A; [3 marks]
b) the unit, if any, of the constant B. [2 marks]

2. A railway truck of mass 4 x 10^4 kg moving with a velocity of 3 m s^{-1} collides with another truck of mass 2 x 10^4 kg which is at rest. The couplings join and the trucks move off together.

a) Calculate the velocity of the two trucks after collision. [2 marks]
b) Have both momentum and energy been conserved during this collision? Support your answers by valid calculations. [3 marks]

3. In the circuit shown in Figure 1, the voltmeter V has a resistance of 20 kΩ.

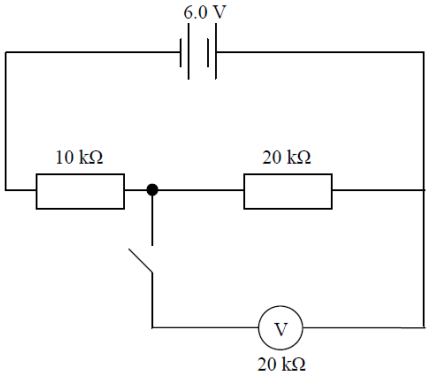

Figure 1

Calculate:

a) the p.d. across the 20 kΩ resistor when the switch is open; [2 marks]
b) the reading on the voltmeter when the switch is closed. [3 marks]

4. A body is made to move along a circular path.
   a) Draw a labelled diagram to clearly indicate the direction of the velocity of the body in relation to the unbalanced force required to keep the body in circular motion. Label also the direction of this unbalanced force. [2 marks]
   b) Io, one of Jupiter's many moons, orbits the giant planet in a nearly circular orbit of radius 4.22 x 10^5 km. The period for the orbit is 42 hours and 28 minutes. What is Io's average centripetal acceleration? [3 marks]

5. The graph in Figure 2 shows how the charge *q* on a capacitor varies with the p.d. *V* across it.

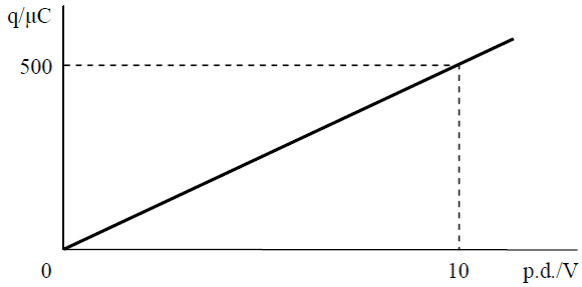

Figure 2

   a) Calculate the size of the capacitance; [1 mark]
   b) If the capacitor consists of two parallel plates, state **two** different ways how its capacitance can be increased. [2 marks]
   c) Copy the given graph and using the same scale and axes indicate, backing your reasoning, how the graph for a capacitor with twice the capacitance would appear. Carefully insert values on your axes. [2 marks]

6. A steel cable is to be used to accelerate a loaded lift of mass 1500 kg vertically upwards at a constant acceleration of 1.2 m s^{-2}. Young's modulus of steel is 2.0 x 10^{11} Pa and the limit of proportionality is at a stress of 2.4 x 10^8 Pa.
   a) Show that the tension in the cable is 16.5 kN. [2 marks]
   b) Given that the safe maximum working stress is one third of the limit of proportionality, calculate the extension of 100 m of steel cable when it is used to safely accelerate the loaded lift at 1.2 m s^{-2} upwards. [3 marks]

7. a) Define magnetic flux density. State whether it is a scalar or a vector quantity. [2 marks]
   b) At a point on the Earth's surface the Earth's magnetic field is inclined at 40^0 to the horizontal and has a value of 6.0 x 10^{-4} T.

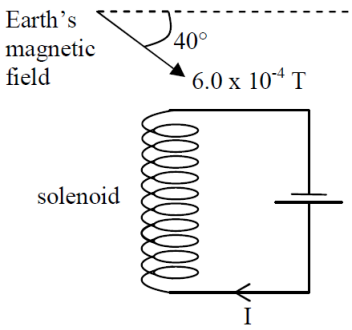

Figure 3

A solenoid of 4000 turns per metre is positioned as shown in Figure 3. The magnetic field due to the solenoid is given by $\mu_0 nI$, where *n* is the number of turns per unit length, *I* is the current and μ_0 is the permeability of free space. What value of current should flow in the solenoid to produce a resultant vertical field of zero? [Permeability of free space = $4\pi \times 10^{-7}$ H m^{-1}] [3 marks]

8. Two spherical dippers are placed 5 cm apart and just touch the surface of the water in a ripple tank.
   a) Sketch the wavefronts that result on the water surface when the frequency of the dippers is 3 Hz. Distinguish between crests and troughs. [1 mark]
   b) Clearly mark two points on your sketch to show,
      i) a position where constructive interference occurs (mark this point X);
      ii) a position where destructive interference occurs (mark this point Y).
      [2 marks]
   c) By referring to lines along which constructive interference takes place, explain any change in the pattern which would result if the spherical dippers are now placed 8 cm apart, without changing the frequency. [2 marks]

9. A 12 V electric heater draws 2.0 A for 12 minutes to raise the temperature of a 3.0 kg block of metal.
   a) If the initial temperature of the block is 20 degrees Celsius, calculate the final temperature of the block?
      [Specific heat capacity of the metal = 500 J kg^{-1} K^{-1}] [3 marks]
   b) State **one** assumption you have made in arriving at your answer. [1 mark]
   c) Considering practical issues, suggest **one** precaution to validate your assumption. [1 mark]

10. A stretched string has a vibrating length of 2.26 m. It is plucked to set it oscillating and it is observed to undergo oscillations, as illustrated in Figure 4.

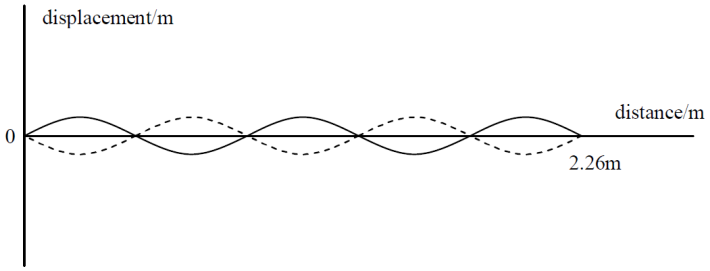

Figure 4

   a) State whether this wave is a progressive or a standing wave. [1 mark]
   b) State **two** differences between progressive and standing waves. [2 marks]
   c) If the velocity of the transverse wave along the string, forming the wave in Figure 4 is 76 m s^{-1}, what is the value of its frequency? [2 marks]

SECTION B

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

11. Figure 5 shows a U shaped manometer partly filled with water. It can be proved that when the water in the manometer is displaced a distance x to one side and released it performs simple harmonic motion about the rest position. A student is to investigate how the periodic time of the oscillations of the water in the manometer changes with the amount of water present in the manometer. He records the time T_5 in seconds for 5 oscillations to occur, with different lengths L of water in the manometer. The data is shown in Table 1.

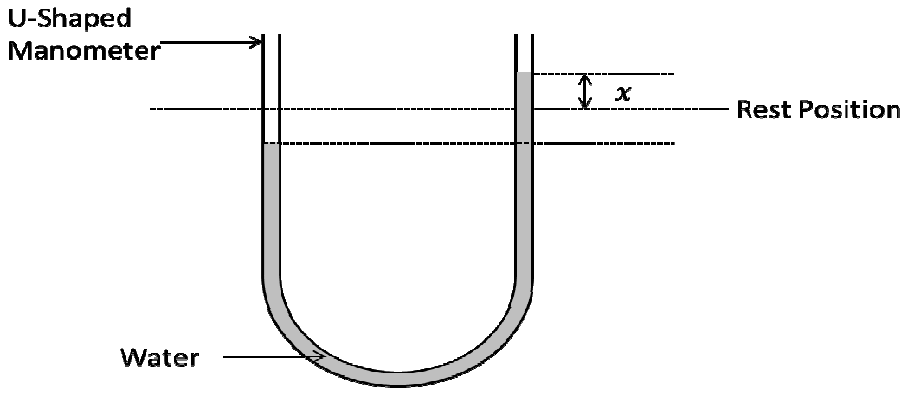

Figure 5

L /m	T_5 / s	T /s	T^2 /s^2
0.20	3.1		
0.25	3.6		
0.30	3.8		
0.35	4.1		
0.40	4.5		
0.45	4.9		
0.50	5.0		
0.55	5.2		
0.60	5.7		

Table 1

It is known that the periodic time T is related to the length of the water L by:

$$T^2 = \frac{4\pi^2 L}{2g}$$

a) Copy the table 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) Use the graph to determine a value for the gravitational acceleration g.
d) If the manometer were filled with mercury which has a density 13.6 times that of water, would this affect the periodic time of the oscillations? Explain briefly your conclusions.

[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.

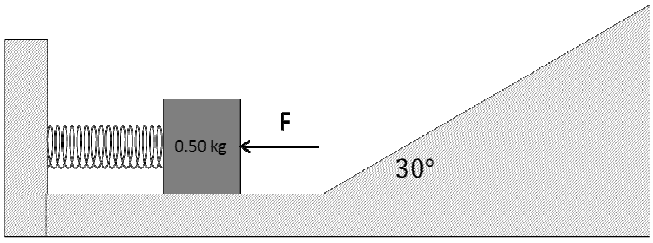

Figure 6

a) A 0.50 kg object is pressed against a spring as shown in Figure 6. The force applied and the corresponding compression of the spring are plotted in Figure 7.

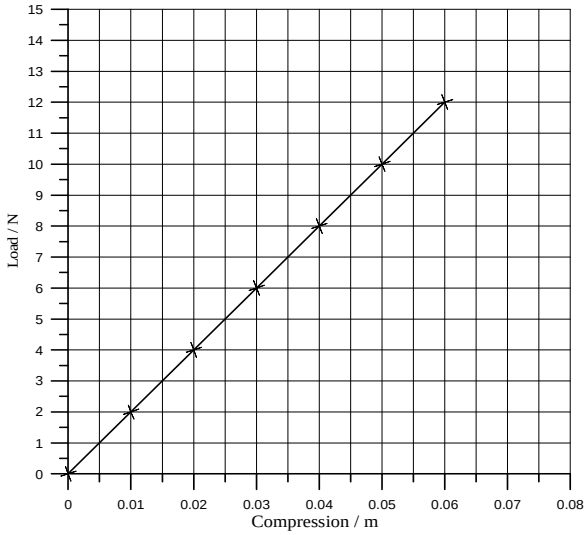

Figure 7

   i) Determine the value of the spring constant. [2 marks]
   ii) Calculate the energy stored in the spring at maximum recorded compression distance. [2 marks]
   iii) Copy the graph and on it sketch another two lines that represent a stiffer spring and a softer spring. Clearly distinguish between the two lines. [4 marks]

b) If the object is not attached to the spring, then it will move along the smooth base and smooth 30° incline when released. Calculate:
   i) the velocity of the block when it is moving on the base and no longer in contact with the spring; [3 marks]
   ii) the distance travelled up the incline before coming to rest. [4 marks]

c) Sketch on the same axes two graphs that show how the potential and kinetic energy change with height up the incline. Label clearly the maximum values of potential and kinetic energies. [3 marks]

Please turn the page.

13. a) When an electric field is set up across a conductor, a current flows through the conductor.

i) Show that from the microscopic aspect, the current flow I is given by $I = nAve$, where n is the number of charge carriers per unit volume, v is their drift velocity, A is the cross-sectional area of the conductor and e is the electronic charge. [4 marks]

ii) By referring to the equation $I = nAve$, briefly outline the difference between conductors, insulators and semiconductors. [3 marks]

b) Figure 8 shows a strip of doped silicon $360\,\mu$m wide containing 8.8×10^{22} conduction electrons per cubic metre and an insignificant number of holes.

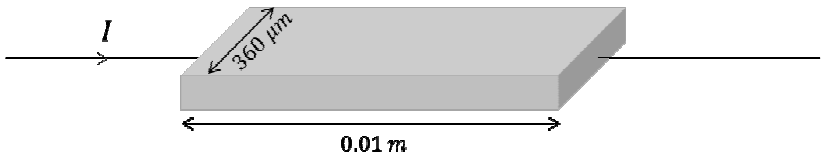

Figure 8

When the strip carries a current I of $130\,\mu$A, the drift speed of the electrons is 0.44 m s^{-1}.

i) How long would it take an electron to travel along 0.01 m length of silicon? [1 mark]

ii) Explain briefly why the drift velocity of electrons in silicon is relatively high when compared to drift velocities of electrons in metals of the same size, when the same current flows through both. [1 mark]

iii) Calculate the thickness of the strip. [3 marks]

c) The starter motor in a car draws 220.0 A of current from the 12.0 V battery for 1.2 s.

i) How much charge is pumped by the battery? [1 mark]

ii) How much electric energy is supplied by the battery? [2 marks]

iii) Sketch a labelled graph that shows the variation of charge (on the y-axis) with time (on the x-axis) for the period the starter motor was turned on. Insert on the graph, any known values. [3 marks]

[Charge on an electron equals $1.6x10^{-19}$ C]

14. a) A metal sphere of radius 0.15 m lies on an insulating stand, as shown in Figure 9. It is to be negatively charged using a glass rod.

i) Briefly explain how the metal sphere can be charged by induction. [2 marks]

ii) Briefly explain why the charging rod needs to be an insulator for it to be charged by friction. [2 marks]

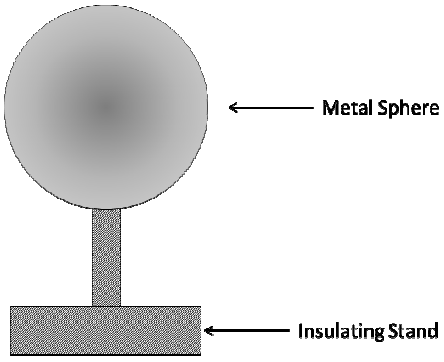

Figure 9

iii) On a copy of Figure 9, draw the electric field lines that surround the charged metal sphere, indicating their direction. [2 marks]

iv) Sketch a labelled graph that shows how the electric field strength changes from the centre of the sphere to a point distant 0.45 m from the centre of the sphere. [3 marks]

b) A small metal ball of mass 0.1 kg hangs from a string near the negatively charged metal sphere, as shown in Figure 10. The charge on the metal ball is $3\,\mu C$ while the charge on the metal sphere is $6\,\mu C$.

i) What is the type of charge on the small metal ball? [1 mark]

ii) Calculate the force of attraction between the metal ball and the sphere. [3 marks]

iii) Calculate the distance of the metal ball from the centre of the sphere. [3 marks]

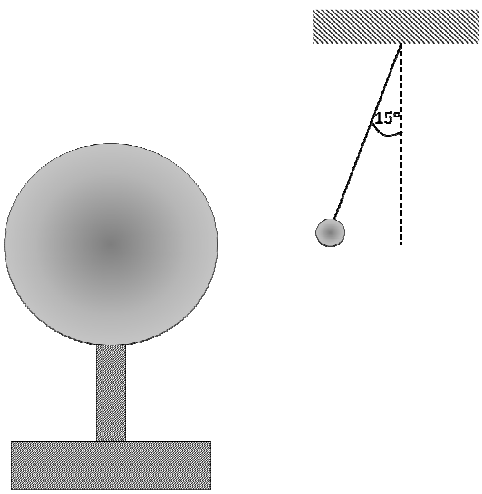

Figure 10

iv) Calculate the electric field strength due to the charged sphere at the point where the metal ball is placed. [2 marks]

[Permittivity of free space equals $8.85x10^{-12}$ F m^{-1}]

Please turn the page

15. a) In an alpha particle scattering experiment, most of the alpha particles pass straight through the gold metal foil, or are only slightly deflected. Occasionally an alpha particle and a gold nucleus collide head on and the alpha particle rebounds.
    i) Explain briefly what conclusions were made from the above experiment, about the structure of atoms. [2 marks]
    ii) State **three** properties that describe the nature of the alpha particle. [3 marks]
    iii) Explain briefly **one** precaution that must be taken in order to obtain accurate values for the activity of the radioactive sample emitting the alpha particles. [1 mark]

b) A sample of milk is to be tested for evidence of radioactive contamination with the radioactive ***isotope*** strontium $^{90}_{38}Sr$, whose ***decay constant*** is 7.75×10^{-10} s^{-1}.

    i) Explain what is meant by the terms ***isotope*** and ***decay constant*** of a radioactive sample. [2 marks]
    ii) Determine the half-life in ***years*** of the radioactive isotope. [2 marks]
    iii) Explain briefly why it is difficult to measure its half-life experimentally. [2 marks]
    iv) How long would it take the original activity of this radioactive isotope to be reduced to 25%? [2 marks]

c) The radioactive isotope $^{90}_{38}Sr$ decays in two stages. A beta decay in the first stage produces Yttrium (Y) which then decays to form stable $^{90}_{40}Zr$.

    i) State **two** properties of the β-particle. [2 marks]
    ii) Write down the two nuclear equations that represent the two stages of the above decay process. [2 marks]