MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2016

SUBJECT:	PHYSICS
DATE:	23rd April 2016
TIME:	9:00 a.m. to 12:05 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. Given the equation: $\mathbf{c} = \sqrt{\frac{K_S}{\rho}}$ where ***c*** represents the velocity of sound in a medium, ***ρ*** represents the density of the medium and ***K_s*** is a constant:
   a. Write down the base units of c and ρ; **[2 marks]**
   b. Given that the above equation is homogenous, use base units to confirm that the SI unit of the constant K_s is Pascal (*Pa*). **[3 marks]**

2. One vehicle of mass 4200 kg moving at 25 ms^{-1} collides with another vehicle of mass 2800 kg moving in the same direction at 14 ms^{-1}. After the collision, the vehicles stick together and move with a common velocity V.
   a. Find the value of V.
   b. State the principle you used to arrive at your answer in part (a) of the question.
   c. State one assumption you made to find V. **[3, 1, 1 mark]**

3. a. "When one touches a stainless steel table, it feels cold since coldness flows to one's hand." Is this statement correct? Explain. **[2 marks]**
   b. Platinum resistance thermometers can be used by pottery manufacturers to read the temperatures in the kiln where clay products are being fired. The resistance of one such thermometer is 0.85 kΩ at 0 ^oC and 1.7 kΩ at 100 ^oC. When at one point the thermometer is inserted in the kiln, it gives a reading of 7900 Ω. What is the temperature in the kiln at this point? **[3 marks]**

4. a. What is the average electric current flowing in a conductor made from material X, if a charge of 600 C passes in 2.5 minutes? **[2 marks]**
   b. The above conductor has a cross sectional area of $1.80 \times 10^{-2}\,cm^2$ and the average *drift velocity* of electrons is $2.45 \times 10^{-4}\,ms^{-1}$. Calculate the number of free electrons per unit volume found in the material X. Clearly indicate the units of your answer. **[3 marks]**

5. a. Use the First Law of Thermodynamics to explain how there are **two** ways which can be used to alter the internal energy of a fixed mass of gas. **[2 marks]**

   b. A fixed mass of gas is contained in a cylinder. The piston is pushed inwards with a force of 340 N for a distance of 9.4 cm. At the same time 1200 J of heat energy are transferred to the gas.

   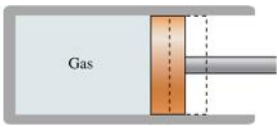

   Figure 1

   i. Calculate the work done on the gas.

   ii. Find the change in internal energy of the gas.

   iii. If the work done calculated in b (i) was done by the gas while expanding, find the change in internal energy of the gas in this case. **[3 marks]**

6. Two thin rods G and H have the same dimensions. They are individually loaded. Rod G is made up of a material with a Young Modulus of 20×10^{10} Pa while rod H is made up from a material with Young Modulus of 60×10^{9} Pa. Forces are applied to each rod and the respective extensions for each material are recorded.

   a. On the same scale and axes, sketch two force-extension graphs, labelling them G and H respectively, showing the variation of force with extension for each rod. **[2 marks]**

   b. Rod G is originally 20 cm long. Calculate the strain on rod G when its extended length is 21.5 cm. Also express the extension as a percentage of the original length. **[3 marks]**

7. A new TV Channel is planning to launch Sportlite, an Earth-orbiting satellite, to start transmitting sports events from all over the world. Sportlite will be placed in a geostationary orbit at a distance of 3.6×10^{7} m above sea level, in the plane of the Earth's equator.

   
   Figure 2

   a. What is the mass of the satellite if the force acting on it is of 13.5 kN? **[3 marks]**

   b. In which way, if any, is the force acting on a satellite affected if:

   i. a satellite of larger mass is launched in the same orbit?

   ii. a similar satellite is launched in an orbit at a distance of 2×10^{7} m above the Earth's surface? **[2 marks]**

8. Figure 3 shows a Displacement – Time (x-t) graph of a system oscillating in simple harmonic motion (SHM).

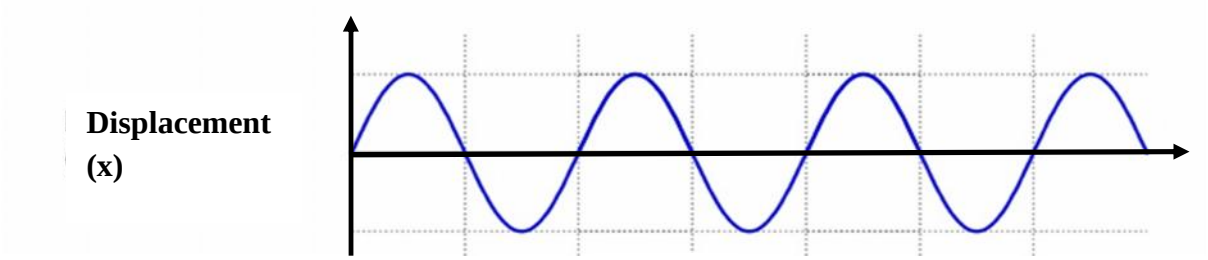

Figure 3

a. Copy the diagram and on the same axes draw the Velocity – Time (v-t) graph for the system. **[2 marks]**

b. Explain how the Kinetic Energy and the Gravitational Potential Energy (GPE) of a simple pendulum change when this is oscillating. Indicate the relation between the two forms of energy, making reference to the total energy of the pendulum. **[3 marks]**

9. A parallel-plate capacitor is a device which stores electric charge.

a. State **two** factors which affect the capacitance of the capacitor, indicating clearly how the capacitance changes as each factor is increased. **[2 marks]**

b. A 60 kΩ resistor is connected in series with a charged 75 μF capacitor. The capacitor is discharged through the resistor. Calculate:

i. the time constant for the circuit; **[1 mark]**

ii. the p.d. across the resistor after 13.5 seconds, if the initial p.d. was 230 V. **[2 marks]**

10. Two students are discussing electrons in atoms and allowed energy levels. They draw the diagram shown in Figure 4.

i. Which arrow represents the least absorption of energy? Explain.

ii. Which arrows represent electron transitions accompanied by light emissions? Explain.

iii. Calculate the longest wavelength in the emission spectrum, that would arise from the energy levels with the values shown. **[1, 2, 2 marks]**

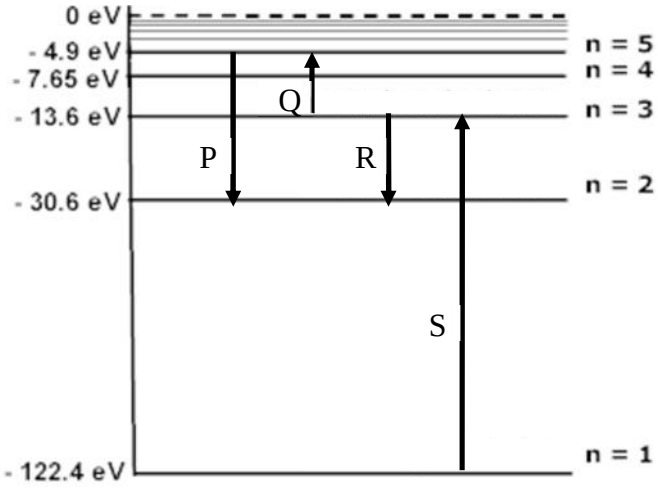

Figure 4

SECTION B

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

11. Figure 5 shows a flywheel that is free to rotate about a horizontal axle. Small magnetic washers are attached to the outside rim of the flywheel. The flywheel is turned through a small angle such that the washers are displaced to one side of the vertical. Once released, the flywheel performs simple harmonic motion. The average time, T_{20}, for the flywheel to do 20 complete oscillations is recorded. The experiment is repeated, changing the mass m of the washers.

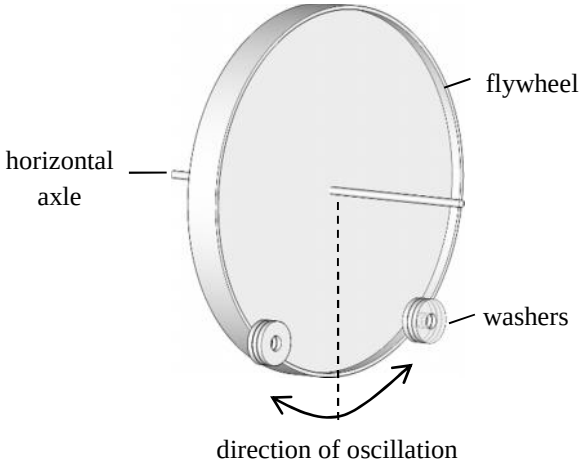

Figure 5

The equation relating the periodic time T of the system and the mass of the washers m is given by:

$$g = \frac{4\pi^2}{RT^2}\left(\frac{k}{m} + R^2\right)$$

where k is a constant related to the mass and dimensions of the flywheel and R is the radius of the flywheel. The radius of the flywheel, R, is 0.10m.

m /kg	$\frac{1}{m}$ /kg^{-1}	T_{20} /s	T /s	T^2 /s^2
0.015		127.2		
0.030		92.2		
0.045		71.9		
0.060		64.9		
0.075		60.0		
0.090		49.9		

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 $\frac{1}{\text{m}}$/kg^{-1} on the x-axis.

c. Write the given equation in the form $y=mx+c$, explaining your working. Use the graph to determine the value of the constant k, stating its units.

d. Write down one precaution that is necessary to obtain accurate results. **[4, 5, 4, 1 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. Two parallel sided slabs, A and B, made from transparent material are placed one on top of the other (see Figure 6). A red laser beam is incident on slab A making an angle of 35^o with the horizontal. The ray passes through the layers A and B. The angle of refraction is equal to 28^o in material A, and is 26^o in material B.

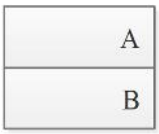

Figure 6

i. Draw a clear ray diagram that shows the incident, the reflected and the refracted light rays. Include values for the angle of incidence and the angles of refraction in A and B. Assume no reflection takes place at the upper face of slab A and at the interface between slabs A and B.

ii. Which material has the larger refractive index? Explain your answer.

iii. Calculate the refractive index of transparent layer A. **[2, 3, 2 marks]**

b. Figure 7 shows a cross-sectional view of a right angled isosceles prism with light falling normally on it.

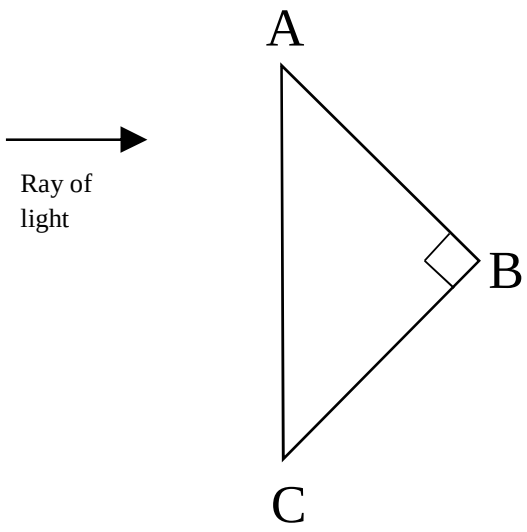

Figure 7

i. Copy the diagram and assuming total internal reflection, show how the light ray behaves after entering the prism, indicating its path after it leaves the prism.

ii. Through what angle is the light ray rotated because of passing through the prism?

iii. What is the angle of incidence at the face AB? Explain your answer.

iv. Draw another diagram to compliment the one in part (i), showing how the ray can be made to move in the same direction and parallel to the original path, by using a second similar right angled isosceles prism in combination with the first. **[2, 1, 1, 2 marks]**

c. A convex lens has a focal length of 12 cm. An object of height 3 cm is placed at a distance of 8 cm away from the lens.

i. Calculate the height of the image produced by the lens.

ii. What happens to the height of the image if the object is moved to a distance of 24 cm from the lens? Explain your answer, stating whether the image should keep the same height, or is longer or shorter than the image in (i). **[3, 2 marks]**

13.

Figure 8

a. A small positively charged steel sphere is suspended by an insulating thread from a fixed support, as shown in Figure 8. Sketch a diagram that shows the electric field surrounding the steel sphere. **[2 marks]**

b. The charge on the sphere is $+q_1$. A second negatively charged steel sphere is now brought close to the hanging sphere. The second charge is $-q_2$. The centres of the spheres are x/m apart. The magnitude of the force acting between the spheres is F.

i. Sketch a diagram that shows the electric field surrounding both spheres when they are close to each other.

ii. On which sphere does the force described above act? Explain your answer indicating which one of Newton's laws of motion holds in this case.

iii. Explain by what factor the force on the second sphere will decrease if it is moved to a distance of $3x$ from the first sphere? Give your answer in terms of F. **[3, 2, 3 marks]**

c. In the famous Millikan's oil drop experiment, charged oil drops were sprayed over a pair of metal discs, as shown in Figure 9. Millikan was able to adjust the potential difference between the plates to balance the weight of the oil drop by the electric force on the drop. In one such experiment, a charged oil drop of mass $4x10^{-15}$ kg, carrying a charge of $-9.6x10^{-19}$ C was held motionless between two metal plates set at a distance of 0.02 m apart.

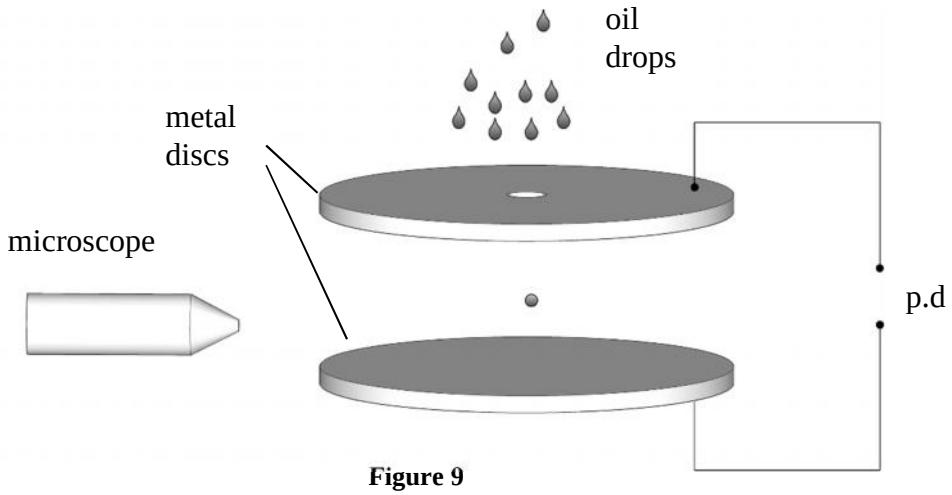

Figure 9

i. Determine the electric field strength between the plates, indicating the direction of the electric field.

ii. Calculate the potential difference across the metal plates.

iii. Calculate the work done on the oil drop if the potential difference between the metal plates is increased by 500 V such that the oil drop moves in the upward direction from one plate to the other.

iv. Calculate the velocity with which the oil drop reaches the top metal plate.

[3, 1, 2, 2 marks]

14.

a. The graph in Figure 10 is the result of a computer simulation that models the vertical velocity of a ball from the moment it is projected vertically upwards from ground level and its subsequent motion as it bounces off the ground. The software simulates this under the gravitational conditions of the moon. The velocity is considered positive when the ball is moving upwards.

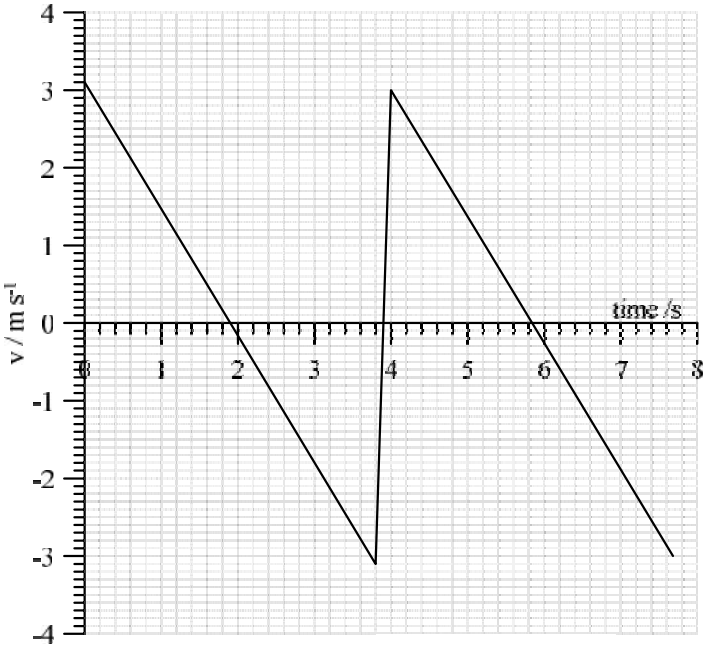

Figure 10

i. Determine the time it takes the ball to hit the ground for the first time.

ii. For how long is the ball in contact with the ground?

iii. Calculate the acceleration of the ball while in mid-flight.

iv. Calculate the maximum height reached when it is initially projected upwards.

v. Calculate the percentage energy loss by the ball during rebound. **[1, 1, 2, 2, 3 marks]**

b. Computer software is then used to model a horizontally projected ball from a platform that is 7.5 m above the ground. The software is set to ignore air resistance and to use a gravitational acceleration value of 0.50 ms^{-2}. Two seconds into its flight, the ball is moving with a velocity of 2.0 ms^{-1} at an angle of 30° to the horizontal, as shown in Figure 11.

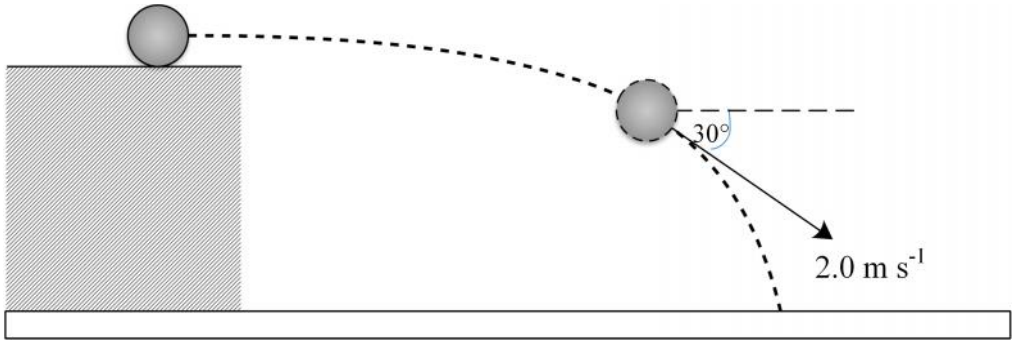

Figure 11

i. Determine the speed with which the ball was projected horizontally.

ii. Determine the time it takes the ball to reach the ground.

iii. Calculate the magnitude of the vertical velocity just before the ball hits the ground.

iv. Calculate the horizontal distance covered by the ball before it hits the ground.

v. On a copy of the diagram of Figure 11, draw the path the ball would have taken if the gravitational acceleration was equal to that on Earth. Explain. **[1, 2, 2, 2, 2 marks]**

15.

a. Describe an experiment which can be used to study the voltage-current characteristics of a lamp. The investigation should include:
   - a list of the circuit components needed;
   - a diagram of the circuit to be set up;
   - a description of the method to follow;
   - a sketch of the graph that is expected. **[5 marks]**

b. A student wishes to investigate the properties of a 12 V car headlamp bulb. A circuit is set up by connecting two separate similar lamps to a switch and a battery. The lamps can be turned on and off simultaneously, and one lamp can still light even if the other burns out. Draw a diagram of the circuit that is set up by the student. **[2 marks]**

c. The student now uses a power source of electro-motive-force (emf) ε, having an internal resistance r and **removes** one of the lamps from the circuit.
   i. Write down an expression for the terminal p.d. across the source when a current I flows in the circuit.
   ii. Show that the net power P used by the lamp when a current I flows, is given by $P = \varepsilon I - I^2 r$.

[1, 2 marks]

d. The power source in part (c) is a battery with an emf of 24 V and an internal resistance of 1.50 Ω. The student now decides to set up a potential divider, as shown in Figure 12. The lamp is rated at 60 W, 12 V. The switch S is open and ammeter A_2 reads 2 A.

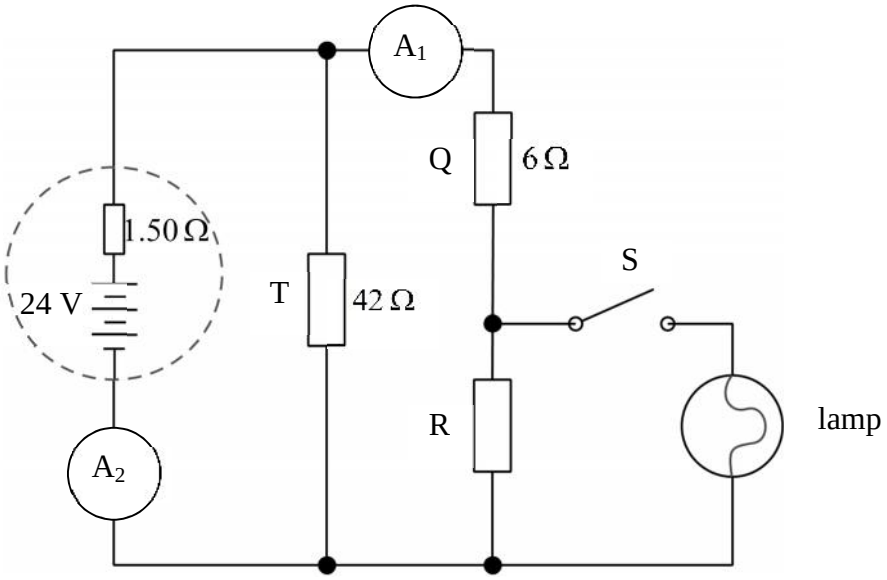

Figure 12

   i. Find the terminal potential difference across the source.
   ii. Hence, determine the reading on A_1.
   iii. Find the value of the resistance R.
   iv. What happens to the reading on ammeter A_2 when the switch S is closed? Explain your answer. **[2, 2, 2, 2 marks]**