MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2016

SUBJECT:	PHYSICS
DATE:	30th August 2016
TIME:	4:00 p.m. to 7:05 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. A roller coaster carriage of mass 1200 kg is driven to the launching platform with a force of 3,800 N acting along the inclined plane which is 12.5 m long (see Figure 1).

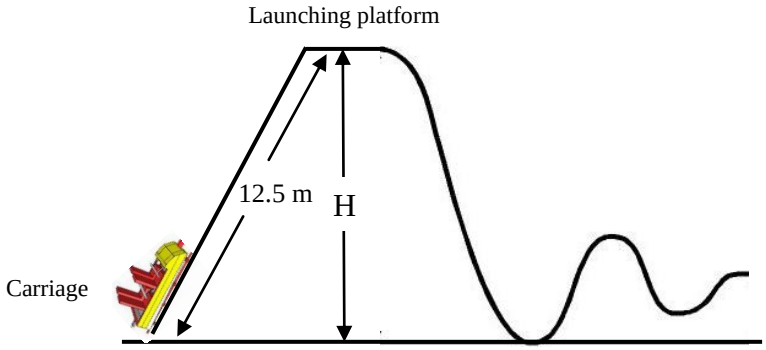

Figure 1

a. Calculate the work done in driving the carriage to the launching platform. **[2 marks]**
b. What is the value of H if the gravitational potential energy of the carriage when it reaches the launching platform is 120 kJ? **[3 marks]**

2. During a football match, two players, P and Q, hit the ball of mass 350 g simultaneously, with a force of 245 N and 215 N respectively (see Figure 2). The angle between the two forces is equal to 50^o.

a. Determine the magnitude of the resultant force acting on the ball.
b. Calculate the ball's initial acceleration.
c. Why are forces referred to as vector quantities?

[2, 2, 1 mark]

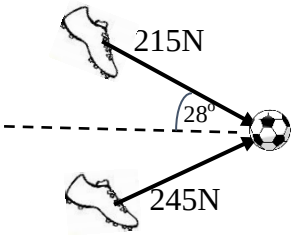

Figure 2

3. An actor was standing on a revolving stage. During a change of scene, the stage started rotating giving the actor a speed of 0.25 ms^{-1}.
   a. What is the magnitude of the force towards the centre, acting on the actor whose mass is 65 kg and who stands at a distance of 2.2 m from the centre? **[2 marks]**
   b. What is this force acting towards the centre called? **[1 mark]**
   c. Assuming that the stage rotates at the same rate as before, comment on the actor's speed if he now stands at a point closer to the centre of the stage. **[2 marks]**

4. a. Give an explanation, in terms of the latent heat of ice, of how a bottle of water cools down when immersed in a container full of ice cubes. **[1 mark]**
   b. A 200 g bottle of water at room temperature of 22 ^{o}C is cooled down by immersing it in ice cubes. It reaches a final steady temperature, θ. The energy lost by the water during the process is 15 kJ. Find the final steady temperature, θ, given that the specific heat capacity of water is 4200 J $kg^{-1}K^{-1}$. (Ignore the heat capacity of the bottle.) **[2 marks]**
   c. Assuming the same loss of energy, would you expect the final temperature of the bottle on a warmer day, to be the same as in part (b)? Explain. **[2 marks]**

5. Leonard has just bought a new car battery. The label indication shows that the battery has an e.m.f. of 12 V and negligible internal resistance.
   a. Give the meaning of *internal resistance*? **[1 mark]**
   b. If the electric circuits in the car offer a total resistance of 0.06 Ω and the current through the battery on starting the engine is 180 A, find the internal resistance of the battery. **[2 marks]**
   c. Use the answer obtained in (b) to explain why the internal 12 V lamps of a car, which were left ON, dim out when the driver starts the car engine? **[2 marks]**

6. The following diagram represents the setup of a simple generator consisting of a rectangular coil LMNO rotating on its own axis at constant speed, in a uniform magnetic field (see Figure 3).

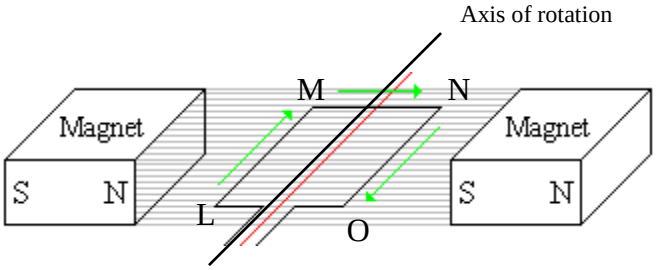

Figure 3

   a. Current is being generated in the coil of *N* turns and flows as indicated by the arrows, in the direction LMNO. Decide whether the coil is being rotated clockwise or anti-clockwise, explaining your answer. **[1 mark]**
   b. The coil is connected to an external resistance using slip rings. A sinusoidal alternating current is supplied by the generator. Sketch the sinusoidal current variation with time, clearly labelling the axes and indicating the position of the coil in relation to the magnetic field, for maximum induced current in the coil. **[2 marks]**
   c. State **two** possible changes that can be made to the above set up to allow a larger e.m.f. to be generated. **[2 marks]**

7. In the 1800s, Thomas Young carried out a number of experiments to investigate the nature of light. In one demonstration, a monochromatic source of light was used as shown in Figure 4.

   a. Draw a diagram to show what happens as the light passes through the slits and reaches the screen.
   b. What is seen on the screen and what is the phenomenon responsible for this result?
   c. What would be the difference in what is seen on the screen if a white light source was to be used instead of the monochromatic light source? **[1, 2, 2 marks]**

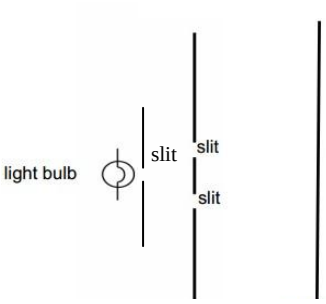

Figure 4

8. a. A small object is placed at a distance from a converging lens which is smaller than the focal length. Draw a ray diagram which clearly shows how an image of the object will be formed. **[2 marks]**
   b. Referring to part (a), would using a screen help to produce a more focused image? Explain. **[1 mark]**
   c. A converging lens has a focal length of 4 cm. An object which is 1.9 cm high is placed 2.3 cm away from the lens. Find the image distance from the lens and its magnification. **[2 marks]**

9. The Sun and other stars use nuclear fusion to generate energy. Consider the fusion of **two** Deuterium (^2_1H) nuclei in the Sun. The reaction produces a Helium (^3_2He) nucleus and a neutron.

   a. Use the data in Table 1 to calculate the amount of energy, in Joules, released during this reaction. **[4 marks]**
   b. Name another isotope of Hydrogen, stating its proton and mass numbers. **[1 mark]**

Atom	Mass (a.m.u.)
Hydrogen – 2	2.013553u
Helium – 3	3.016029u
Neutron	1.008665u

Table 1

10. a. State **two** differences between an electric and a gravitational field. **[2 marks]**
    b. Two charges of +8 nC and -3 nC are placed 15 cm apart as shown in Figure 5. What is the resultant electric field strength due to the charges at point Y? Your answer should clearly indicate both magnitude and direction.

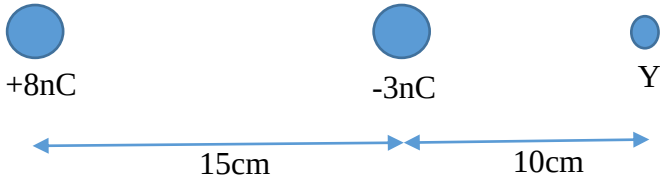

Figure 5

[3 marks]

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SECTION B

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

11. The circuit in Figure 6 was used to find the internal resistance, *r*, of battery E. The point C, on resistance wire AB, could be changed. S_1 was closed and C was moved along AB until the galvanometer, G, registered no reading. The length BC was measured and called L_0.

    Switch S_2 was then closed and the position of C was readjusted until G registered no reading again. The **new** length of BC was measured and now recorded as *L*. The procedure with S_2 closed was repeated for different values of resistors R. Table 2 shows the results.

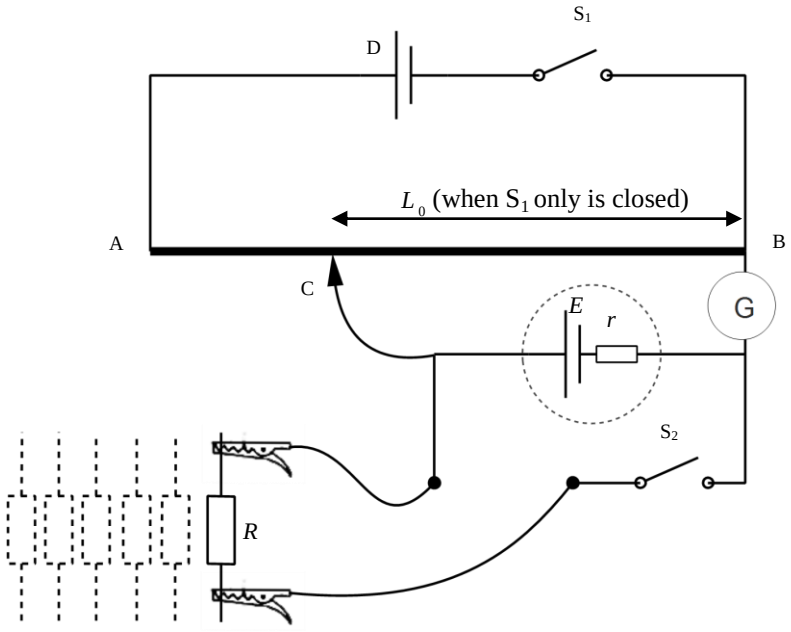

Figure 6

L and L_0 are related by the following equation: $\frac{L_0}{L} = \left(1 + \frac{r}{R}\right)$

R /Ω	$\frac{1}{R}$ /Ω^{-1}	L /m	$\frac{1}{L}$ /m^{-1}
1.0		0.29	
2.2		0.39	
3.3		0.45	
4.7		0.51	
5.4		0.54	
6.8		0.56	

Table 2

a. Copy Table 2 and fill in the missing values.

b. Plot a graph of $\frac{1}{L}$/m^{-1} on the y-axis against $\frac{1}{R}$/Ω^{-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 length L_0 and the value of the internal resistance r.

d. Write down one precaution that should be taken to obtain accurate results. **[4, 5, 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. Heat is supplied at a constant rate to a mass of ice, m, that is initially at -40 ^{o}C. The temperature change as heat is supplied is shown in the graph of Figure 7.

i. Explain why the temperature in part BC of the graph remains constant even if heat is still being supplied.

ii. Use the graph to determine the mass of the ice, *m*.

iii. Calculate the specific heat capacity of ice.

iv. Describe the state of the material being heated at point C.

(the specific latent heat of fusion of ice is 3.34×10^{5} J kg^{-1}) **[1, 2, 1, 1 mark]**

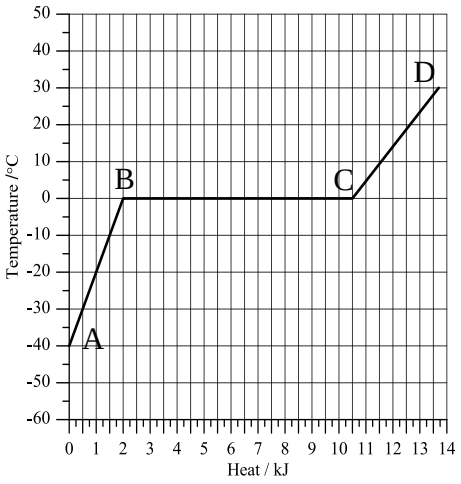

Figure 7

b. The first law of thermodynamics relates the change in the internal energy of a system to the heat supplied to the system and the work done on the system. The law can be applied to a system consisting of a filament lamp connected in series with a switch and a power supply.

i. Write down the mathematical representation of the first law of thermodynamics, explaining clearly any symbols used.

ii. By referring to each term in the equation, show how the first law of thermodynamics can be applied to the filament, as soon as the lamp is switched on. **[3, 2 marks]**

c. Figure 8 shows a P-V diagram illustrating two different paths that an ideal gas can follow, going from an initial state, *i*, to a final state, *f*.

i. Which path should be followed so that the system does more work? Explain your answer.

ii. Which path, if any, represents the greatest change in internal energy? Explain.

iii. For the path i-g-f, use the values in Table 3 to calculate the work done by the gas and the increase in internal energy of the gas.

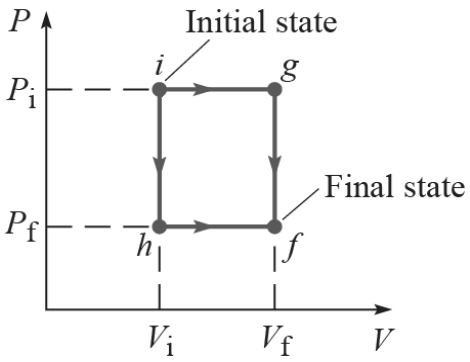

Figure 8

P_i /Pa	P_f /Pa	V_i /m^3	V_f /m^3	Heat Removed / J
500 000	150 000	0.0001	0.0003	60

Table 3

[2, 2, 4 marks]

Please turn the page.

13. When light from Helium gas is examined using a diffraction grating and spectrometer, it is seen to consist of well-defined separated lines. This emission spectrum is called *a line spectrum*.
    a. Explain how the existence of a line spectrum supports the view that electrons in atoms exist in discrete energy levels. **[2 marks]**
    b.
    i. Given that five energy levels of a Helium ion are: $-54.4\ \text{eV}$, $-13.6\ \text{eV}$, $-6.04\ \text{eV}$, $-3.40\ \text{eV}$ and $-2.18\ \text{eV}$, draw an energy-level diagram that shows these levels relative to the zero energy level, clearly labelling the levels with their respective energy values. **[4 marks]**
    ii. On the same diagram, draw an arrow to represent the electron transition with **an energy release** of 3.86 eV. **[2 marks]**

    c. An electron is accelerated through a potential difference of V volts. It collides with the Helium ion (see part b) and shortly afterwards a photon is emitted because of an electron transition from the -3.40 eV level to the -6.04 eV level. Assume that the Helium ion remains stationary after collision.
    i. Calculate the energy of the emitted photon, in Joules. **[2 marks]**
    ii. Calculate the wavelength associated with the emitted photon. **[2 marks]**
    iii. Given that the frequency range of the visible spectrum is from $4 \times 10^{14}\ \text{Hz}$ to $7.5 \times 10^{14}\ \text{Hz}$, determine whether the photon was emitted closer to the red or blue end of the visible spectrum. **[2 marks]**
    iv. What is the amount of energy lost by the colliding electron? Explain. **[2 marks]**
    v. Assuming the colliding electron lost all its energy on collision, calculate the potential difference V with which the colliding electron was accelerated. **[2 marks]**

14. A student is constructing a parallel plate capacitor using two similar flat plates of aluminium, each of area $120\ \text{cm}^2$. There are three types of dielectric which are available for the student to use. See Table 4 for the details.

Material	Thickness /mm	Relative Permittivity
Sheet of paper	0.1	3.5
Sheet of glass	2.0	7
Slab of paraffin	10.0	2

Table 4

a.

i. Write down the equation that relates the capacitance of a capacitor to its physical properties. Name all symbols used. **[2 marks]**

ii. Which one of the dielectrics indicated would provide the largest capacitance? Calculate this capacitance value. **[3 marks]**

b. Using no dielectric, the capacitor plates are adjusted so that there is an air gap between them. Using a **two-way switch**, the **capacitor** is initially charged by a **potential difference (p.d.) of 150 V** and then discharged through a **resistor with resistance** R. The voltage across the resistor is measured at regular intervals of time using a **voltmeter** and the results are plotted with time as shown in Figure 9.

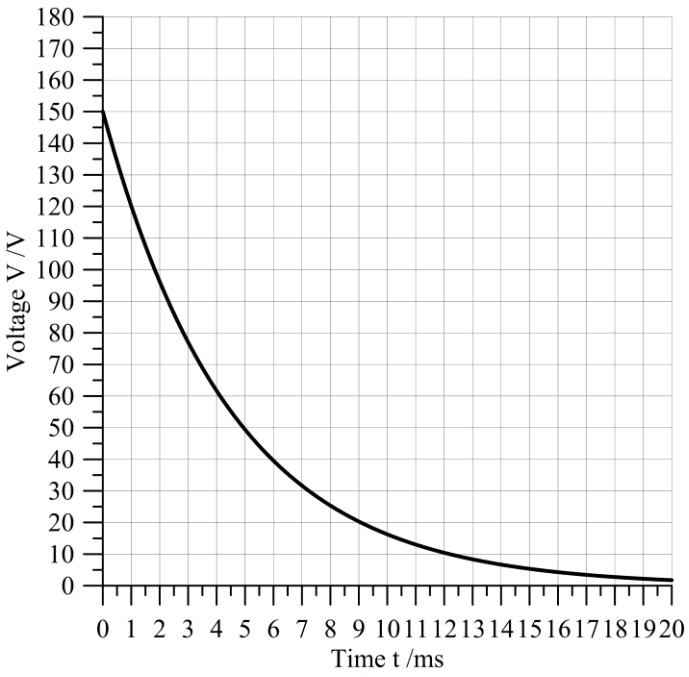

Figure 9

i. Draw a diagram of a circuit that can be used to charge and discharge the capacitor using the components identified in **bold**.

ii. Show that charge Q on the capacitor at any point during the discharging process is given by $Q = CRI$, where I is the current flowing through the resistor and C is the capacitance of the capacitor.

iii. Determine the time constant of the discharge circuit stating its unit.

iv. Given that the resistance of the resistor is $1500\ \Omega$, calculate the current flowing through the resistor after a time which is equal to the time constant has elapsed.

v. Determine a value for the charge on the capacitor at the time indicated in part iv.

vi. Determine the initial charge Q_0 on the capacitor before it started discharging.

[3, 2, 2, 1, 2, 3 marks]

Please turn the page.

15. The voltmeter, V, shown in Figure 10, reads 12.00 V on open circuit. When X and Y are connected by a piece of copper wire, the voltmeter reading changes from 12.00 V to 11.25 V.

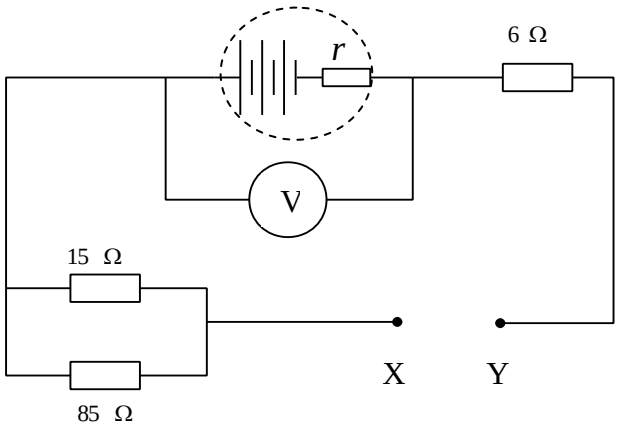

Figure 10

a. Explain the change in the voltmeter reading. **[1 mark]**

b. Calculate the current flowing through the copper wire. **[2 marks]**

c. Determine the value of the internal resistance of the battery. **[2 marks]**

d. The wire has 8.5×10^{28} conduction electrons per unit volume and a cross-sectional area of $2\ \text{mm}^2$.

i. Derive an equation for the drift velocity v_d of conduction electrons in the copper wire in terms of the cross-sectional area of the wire, A, the current I flowing through it and the electronic charge e. A diagram showing the flow of electrons through the wire, relating this to the current flow, is expected. Explain all symbols used in the derivation.

ii. Calculate the drift velocity of the electrons in the copper wire. **[4, 2 marks]**

e. When the wire linking X and Y is replaced by component P, the reading on the voltmeter increases to 11.6 V. This reading remains the same if the terminals of P are connected in reverse to X and Y.

i. Why does this suggest that component P is a resistor?

ii. Calculate the resistance of component P. **[1, 2 marks]**

f. Component P is now replaced by component Q. The voltmeter reading is initially 12.0 V but it is considerably lower when the terminals of component Q are connected in reverse to X and Y.

i. Identify component Q, giving reasons.

ii. Draw the current-voltage characteristic for component Q. **[2, 2 marks]**