MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2017

SUBJECT:	PHYSICS
DATE:	29th April 2017
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 $g = 9.81\ ms^{-2}$ unless otherwise stated.

SECTION A

Attempt all 8 questions in this section. This section carries 50% of the total mark for this paper.

Question 1

Some physical quantities are often paired together, one of them being a vector and the other a scalar.

a. Identify the vector quantity in each of the following pairs:
   i. pressure and force;
   ii. energy and velocity. (2)

b. If the Earth is taken to be a uniform sphere of radius r and density ρ, the gravitational field strength at the surface is given by the equation:

$$g = kr\rho, \qquad \text{where } k \text{ is a constant.}$$

   What are the units of k? (2)

(Total: 4 marks)

Question 2

A vehicle moving along a straight road starts from rest and accelerates at 1.5 ms^{-2} for 18 s. It then moves at constant velocity for the next 150 s, until it finally decelerates and stops after a further 20 s.

a. Sketch the velocity-time graph for the whole journey, labelling the sketch appropriately. (3)

b. Sketch the displacement-time graph for the whole journey, labelling the sketch and explaining its shape. (4)

(Total: 7 marks)

Please turn the page.

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Question 3

A truck and a motorcycle are involved in a head-on collision, as shown in Figure 1.

Figure 1

A student uses Newton's third law of motion to explain the forces involved in the collision.

a. State Newton's third law and explain whether the forces mentioned in the law can be said to cancel each other out, giving a resultant force of zero. Give a valid reason for your answer by referring to the truck and motorcycle collision. (2)

b. With reference to the head-on collision in part (a), assuming there are no external forces acting, state whether the following statements are TRUE or FALSE, giving a reason for your answer.
   i. The impulse experienced by the truck and the motorcycle respectively, is of the same magnitude. (2)
   ii. The change in momentum for both motorcycle and the truck is of the same magnitude. (2)

(Total: 6 marks)

Question 4

A racing car moves on a circular track with a speed of 25 ms^{-1}. The track is inclined and makes an angle of 30° with the horizontal as shown in Figure 2. It stays at the same level on the race track, as it completes revolutions without side-slipping.

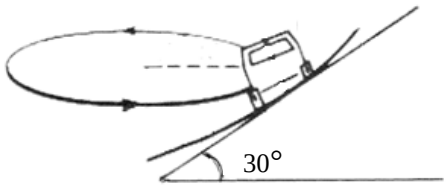

Figure 2

a. Identify the forces acting on the car as it moves in uniform circular motion. Explain your answer using a diagram to show these forces. Label all forces. (2)

b. What provides the centripetal force for the car to move in uniform circular motion? Label this force on the same diagram as in part (a). (1)

c. Calculate the radius of the circular path. (3)

(Total: 6 marks)

Question 5

a. Define Young Modulus. (2)

b. The graph in Figure 3 shows how the extension of a steel wire changes as the wire is loaded.

Use the graph to:

i. calculate the mechanical work done when stretching the steel wire from no extension to an extension of 1 mm; (3)

ii. estimate the permanent extension produced when a load of 200 N is hung on the steel wire and then taken off. Explain your reasoning carefully, including a diagram to help in your explanation. (2)

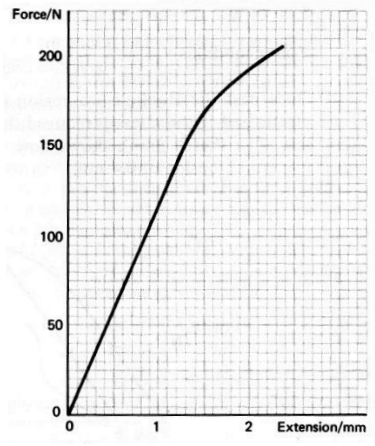

Figure 3

(Total: 7 marks)

Question 6

a. Define electromotive force. (2)

b. The graph in Figure 4 shows the I / V graphs for three electrical components X, Y, Z.

i. State which component obeys Ohm's Law and which one could be a filament lamp. Briefly explain your answers. (3)

ii. Estimate the resistance of component Z when the voltage across it is 4 V. Briefly explain the calculation. (2)

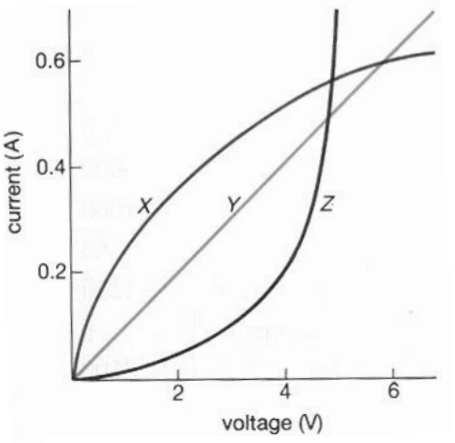

Figure 4

(Total: 7 marks)

Question 7

a. Gravitational forces exist between masses and electric forces exist between charged objects. State **ONE** other difference between gravitational and electric forces. (2)

b. The earth is at a distance of R_M from the moon and at a distance R_S from the sun. Given g_M is the gravitational field strength on the earth due to the moon and g_s is the gravitational field strength on the earth due to the sun, use Newton's law of gravitation to prove that,

$$\frac{g_M}{g_s} \propto \frac{R_S^2}{R_M^2}$$ (3)

(Total: 5 marks)

Question 8

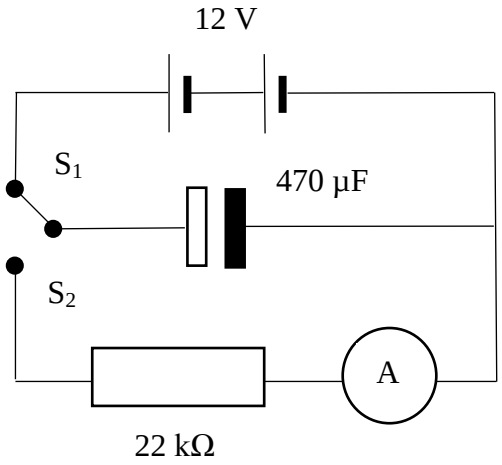

Figure 5

Figure 5 shows a 470 µF capacitor which can be charged and discharged using a two-way switch S. The capacitor is first charged using the 12 V battery and then discharged through the 22 kΩ resistor, which is connected in series with an ammeter A.

a. Calculate the charge on the capacitor when fully charged. (1)

b. Calculate the current read by the ammeter at the start of the discharge process. (2)

c. Sketch a labelled diagram to show the variation of the current during the discharge process, indicating the value of the time constant of the circuit. (2)

d. What changes should be made to the circuit to make the same capacitor discharge more slowly? (1)

e. Using the given data, calculate the p.d. across the capacitor after a time equal to the time constant has elapsed. (2)

(Total: 8 marks)

SECTION B

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

Question 9

Figure 6 shows a constant volume gas thermometer. The glass bulb containing the gas is placed in a water bath and heated. As the pressure inside the glass bulb increases, the mercury reservoir is raised so that the mercury level in the left limb of the manometer is maintained at the fixed reference level. In this way, the volume of gas inside the glass bulb remains constant. The pressure exerted by the gas is proportional to the difference Δh in height of the mercury levels in the left and right limbs of the manometer.

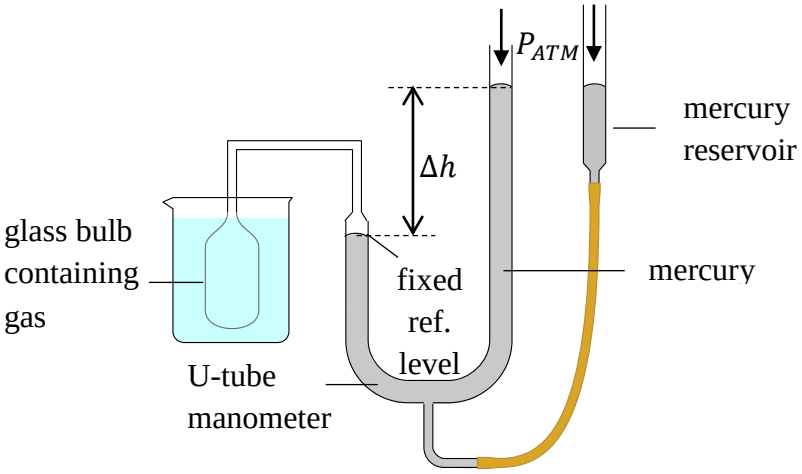

Figure 6

A student wants to use the data given in Table 1 to determine the pressure of the gas inside the bulb at 0 °C. The equation relating the pressure of gas, P_θ, in Pascals with temperature θ in degrees Celsius is given by:

$$\frac{\theta}{100} = \frac{P_\theta - P_0}{t}$$

where P_0 is the pressure of the gas at 0 °C and t is a constant. Assume that mercury has a density ρ of 13600 kgm^{-3} and that the atmospheric pressure P_{ATM} is 101 000 Pa. The pressure exerted by the mercury column is P_M, given by $\rho g \Delta h$ in Pa.

Table 1

θ / °C	Δh / m	$P_M = \rho g \Delta h$ / kPa	$P_\theta = P_M + P_{ATM}$ / kPa
12.7	0.17		
18.2	0.21		
23.6	0.23		
29.1	0.26		
34.6	0.30		
40.0	0.31		

a. Taking care to change ALL values of pressure from Pa to kPa, copy Table 1 and fill in the missing values. (3)

b. Plot a graph of P_θ on the y-axis against θ on the x-axis. (5)

c. Write the given equation, relating pressure P_θ and temperature θ, in the form $y = mx + c$, explaining your working. Use the graph to determine the value of the constant t and state its units. (2)

d. Without extrapolating your graph to $\theta = 0$ °C, determine the pressure of the gas at 0 °C, P_0. (2)

e. Suggest **ONE** correction you would make to obtain a more accurate value for θ. (2)

(Total: 14 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.

Question 10

a. An incident ray of light hits one face of a right-angled prism. A very thin plane mirror is positioned at the base of the prism. The ray follows the path shown in Figure 7. Assume that the prism has a refractive index of 1.5 and that the angle θ is 60°.

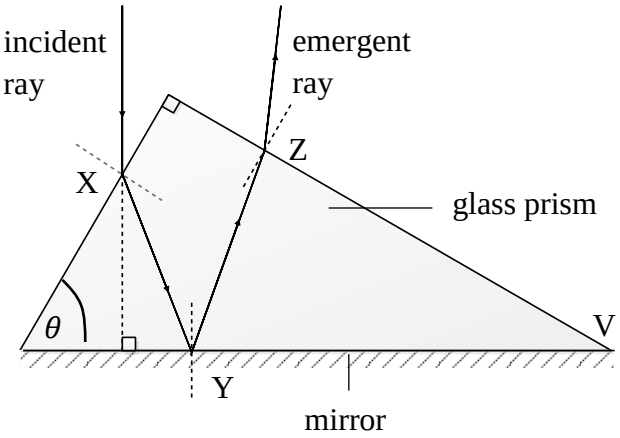

Figure 7

i. Calculate the angle of refraction at X? Explain your answer. (2)

ii. Calculate the angle of incidence at Y, inside the prism. (2)

iii. Show that this ray would not undergo total internal reflection at Y, and hence the need for the mirror. (2)

iv. Determine the angle that the emergent light ray makes with the normal at point Z. (3)

b. The use of a lens in an insect viewer (shown in Figure 8) can be described by the equation,

$$\frac{1}{u} - \frac{1}{2.5u} = \frac{1}{5.50\ \text{cm}}$$

Figure 8

i. Determine the object distance, u. (1)

ii. Calculate the image distance. (1)

iii. Determine the focal length of the lens. (1)

iv. Calculate the magnification of the lens. (1)

v. If the object height is 3 cm, draw a ray diagram, to scale, to show the correct setup of the lens, object and the produced image. (3)

vi. State **TWO** characteristics of the image produced. (2)

(Total: 18 marks)

Question 11

a. A jigsaw cutter is used to cut plane pieces of wood. It uses a similar mechanism to the one shown in Figure 9. An electric motor rotates a wheel with a fixed knob. The knob is constrained within a horizontal slot causing the saw blade to move up and down without moving left or right.

i. State **TWO** conditions necessary for simple harmonic motion. (2)

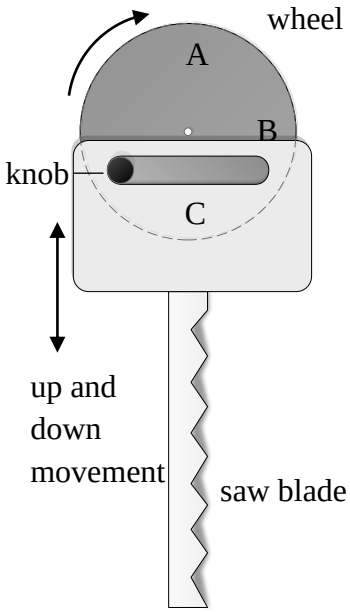

Figure 9

b. The knob is positioned 0.25 m from the centre of the wheel and it is moving with a tangential speed of 5 ms^{-1}. The mass of the saw blade is 200 g.

i. Calculate the time it takes for the knob to perform one rotation. (2)

ii. Determine the amplitude of the oscillations of the saw blade. (1)

iii. Identify the positions of the knob (A, B or C) where the saw blade experiences maximum acceleration. (2)

iv. Calculate the maximum acceleration of the saw blade. (2)

v. Sketch a graph that shows how the acceleration of the saw blade is related to its displacement from equilibrium position. (4)

vi. Calculate the maximum kinetic energy of the saw blade. (2)

c. An adult pushes a child on a swing, as shown in Figure 10. The adult exerts a timely push on the swing when it gets near. The amplitude of the swing increases with every push and reaches a maximum when the swing is making one oscillation every 0.25 seconds.

i. State the physical phenomenon that is responsible for the increase in the amplitude of the swing. (1)

ii. Sketch a graph of amplitude, *A*, against driving frequency, *f*. Label and indicate clearly the value of the frequency at which the amplitude is a maximum. (2)

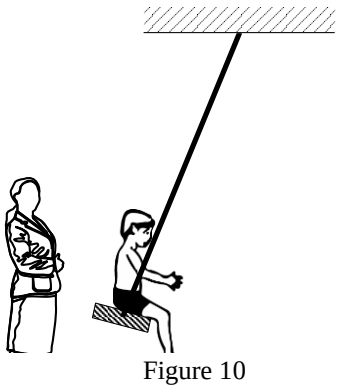

Figure 10

(Total: 18 marks)

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Question 12

a. Two identical blocks each of mass m hang, by means of strings of negligible mass, to the top of a lift, as shown in Figure 11. The lift moves upward with an acceleration a.

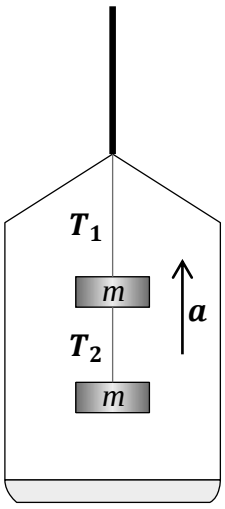

Figure 11

i. By considering the two masses as one single system, show that the $T_1 = 2m(a + g)$. (1)

ii. Derive an expression for the tension T_2. (2)

iii. Compare the two tensions and determine which string would break first if a is made sufficiently large. (2)

iv. If the value of m is 4.2 kg and the lift accelerates upwards at 1.5 ms^{-2}, calculate the tensions in the two strings. (2)

v. The strings can withstand a maximum tension of 120.0 N. What is the maximum acceleration that the lift can have before any of the strings breaks? (2)

vi. What are the tensions in the two strings if the cable supporting the elevator suddenly breaks? (2)

b. Figure 12 shows the forces acting on an object of mass 1.5 kg moving in the x-direction. The forces act on the moving object for a period of 5 seconds.

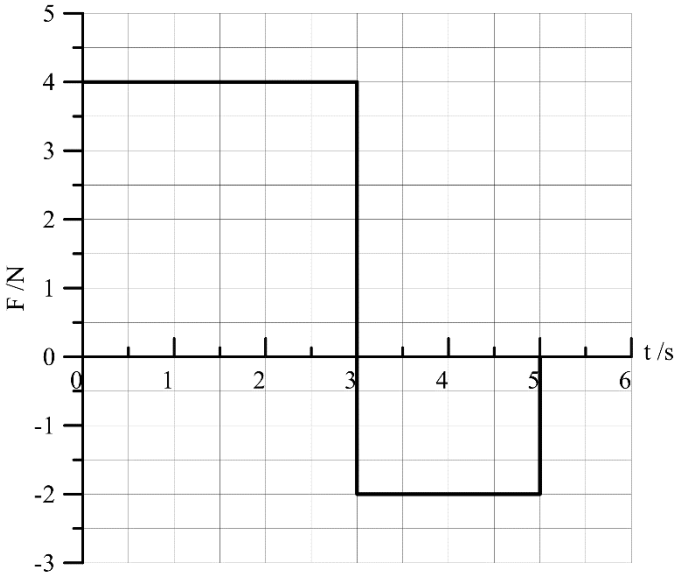

Figure 12

i. State Newton's second law in terms of the rate of change of momentum. (2)

ii. Explain the meaning of the term impulse. (2)

iii. Find the impulse for the time interval between 0 to 3 seconds. (1)

iv. If the forces act on the object that is initially moving at 2.0 ms^{-1}, calculate its final speed at the end of the 5 second time interval. (2)

(Total: 18 marks)

Question 13

a. A series of spectral lines in the hydrogen emission spectrum, called the *Balmer series*, is formed by electron transitions to energy level E_2, as shown in Figure 13. Only three transitions are shown in the diagram. The charge of an electron, $e = 1.6 \times 10^{-19}\ C$, the Planck's constant, $h = 6.63 \times 10^{-34}\ m^2 kgs^{-1}$ and speed of light $c = 3 \times 10^8\ ms^{-1}$.

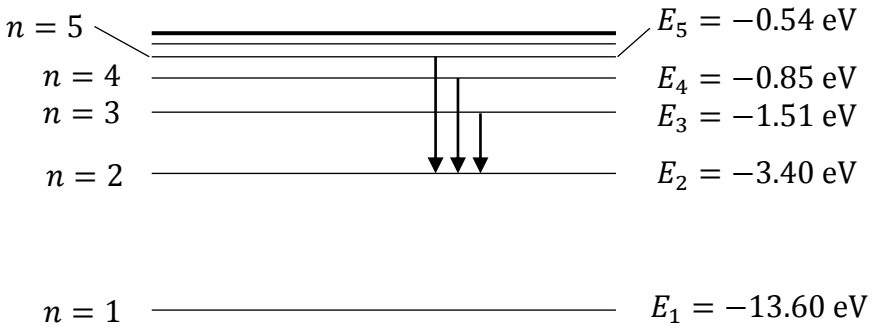

Figure 13

i. Explain how line spectra can be used to identify elements. (2)

ii. Calculate the maximum energy in Joules, that can be released from the transitions shown in Figure 13. (2)

iii. Calculate the longest wavelength of the spectral lines shown. (3)

iv. If the wavelength range of visible light is from 400 nm to 750 nm, determine in which part (infra-red, visible light or ultraviolet) can the three lines from the Balmer series be found. (2)

b. When a plant or an animal dies, its Carbon-14 ($^{14}_{6}C$) content decreases with time. An archaeologist finds an ancient site containing partially consumed firewood. The Carbon-14 content of the wood is only 12.5% that of an equal carbon sample from a present-day tree. Carbon-14 decays into Nitrogen through the emission of a Beta particle.

i. State the meaning of the term half-life. (2)

ii. Use the graph shown in Figure 14, to determine the half-life of Carbon 14. (2)

iii. Write down the nuclear equation that represents the decay of Carbon-14. (2)

iv. Calculate the age of the ancient site where the firewood was burnt. (3)

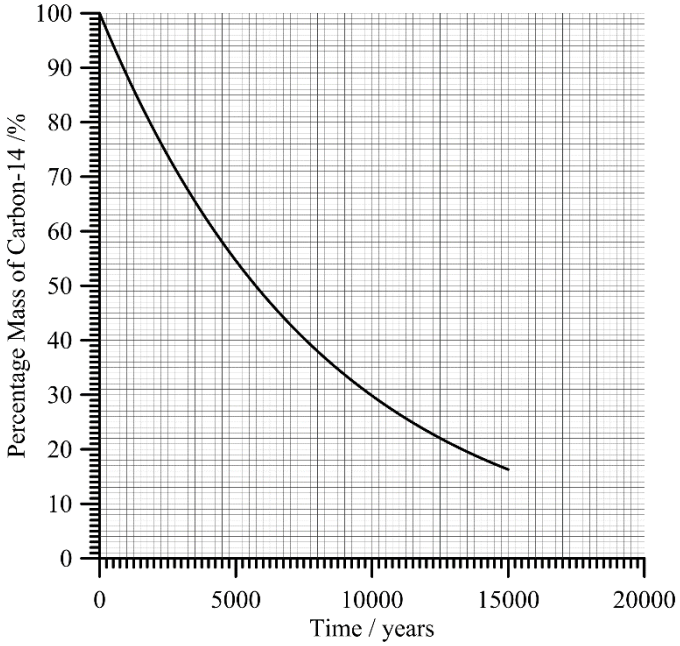

Figure 14

(Total: 18 marks)