L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2023 FIRST SESSION

SUBJECT:	**Physics**
DATE:	20th May 2023
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 8 questions in this section. This section carries 50% of the total mark for this paper.

1. Consider a sphere of radius *r* moving with constant velocity *v* through a liquid of density *ρ*. The force *F* acting on the sphere is given by the equation, $F = k\rho r^2 v^2$.
   a) Write down the base units of F, ρ, r and v. (2)
   b) Show that k is a dimensionless constant. (3)

   (Total: 5 marks)

2. Water is travelling through a hose pipe with cross-sectional area of 0.05 m^2. The water is ejected from the hose pipe at 5 m s^{-1} and allowed to hit a vertical wall. If the density of water is 1000 kg m^{-3}, work out:
   a) the mass of water flowing in the hose pipe in 1 second; (2)
   b) the momentum of the water per second; (1)
   c) the force exerted by the water on a vertical wall over a period of 1 second. (2)
   Assume that the speed of the water is zero after impact.

   (Total: 5 marks)

3. A firework of mass 450 g is shot at an angle of 25° from the vertical line. The magnitude of the thrust pushing the firework is 65 N.
   a) Calculate the resultant force on the firework. (3)
   b) The firework was faulty and it did not explode. It reached a maximum height of 52 m with a horizontal velocity of 6 m s^{-1}. Calculate how long it will take for the firework to fall back to the ground. (2)
   c) Calculate how far the firework travels horizontally after reaching the highest point. (1)

   (Total: 6 marks)

4. A car is moving at a constant velocity. When the brakes are applied, a frictional force is experienced by the brakes amounting to 0.2 MJ of energy. Once the brakes have a higher temperature than the surroundings, they lose 0.08 MJ of energy. By considering this process, evaluate the following quantities and provide a reason to your answer:
   a) ΔW; (2)
   b) ΔQ; (2)
   c) ΔU. (2)

   (Total: 6 marks)

Please turn the page.

5. A convex lens of focal length 5.2 cm is used to view an ant with a height of 0.80 cm. The lens is held 1.4 cm away from the ant.
   a) Draw a light ray diagram showing the location of the image of the ant formed by the lens. (3)
   b) Calculate the distance of the image from the lens. (2)
   c) Calculate the length of the magnified image of the ant. (2)

(Total: 7 marks)

6. Four identical light bulbs and a 15 V battery are connected in a circuit as shown in Figure 1. Each light bulb has a resistance of 3 Ω. Assume that the battery has negligible internal resistance and that the light bulbs obey Ohm's Law.

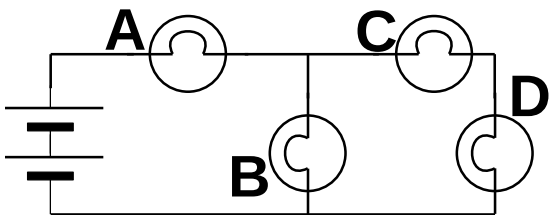


Figure 1

   a) Define Ohm's Law. (1)
   b) Compare the brightness of the four bulbs and give reasons for your answer. (3)
   c) Calculate the total resistance in the circuit. (3)
   d) Calculate the power of light bulb D. (3)

(Total: 10 marks)

7. Figure 2 shows a spring toy on an electronic digital balance. The toy consists of a ball attached to a helical spring. Once the ball is pushed downwards, the helical spring is compressed. Once the force is removed, the helical spring tries to regain its original length, pushing the ball upwards.

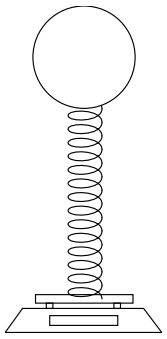


Figure 2

When the toy is placed on the electronic digital balance, it reads 11.8 g. The ball is pushed downwards such that the spring length is reduced by 2.8 cm. The new value on the electronic digital balance is 885.5 g.

   a) Calculate the spring constant of the helical spring. (3)
   b) Calculate the energy stored by the helical spring when it is compressed. (1)
   c) When the force is removed, the spring toy jumps to a height of 54 cm. Calculate the efficiency of this toy. (2)

(Total: 6 marks)

8. A load of 30 N is applied to a copper wire as shown in Figure 3. The wire has a cross-sectional area of 1.4×10^{-4} m^2, and extends by 0.003 m.

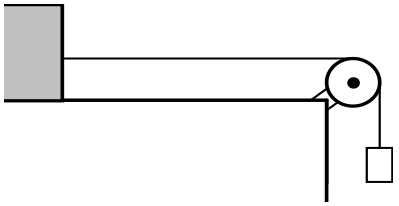


Figure 3

a) Find the length of the wire, given that Young's modulus for copper is 2×10^9 Pa. (2)

Figure 4 shows a stress-strain graph for two types of steel named A and B.

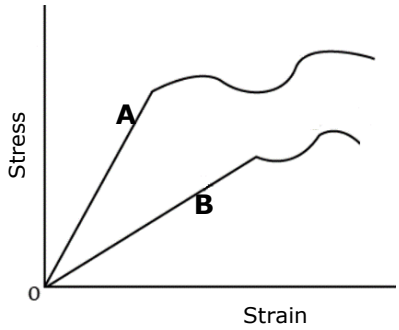


Figure 4

b) Identify which graph represents the steel with a higher Young's Modulus and provide a reason for your choice. (1)

c) Compare the properties of the two materials using the information presented in the stress-strain graph. (2)

(Total: 5 marks)

Please turn the page.

SECTION B

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

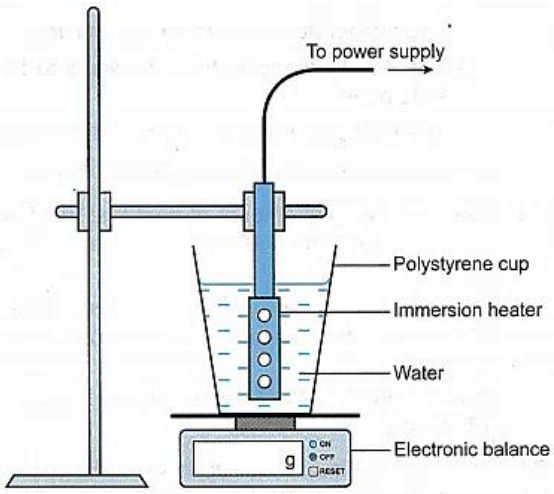
9. The following setup was used in the laboratory to determine the latent heat of vaporisation of water.

The immersion heater, of power 320 W, was turned on to start heating the water. When the water began boiling steadily, the stopwatch was started and the reading on the electronic balance was recorded as m_1 = 260 g. More readings of mass, m_2, were taken every 2 minutes. After 10 minutes, the heater was switched off.

The equation for the latent heat of vaporisation is:

$$Q = mL$$

where Q is the energy supplied in Joules, m is the mass of liquid which evaporates and L is the latent heat of vaporisation of water.



Adapted from: https://www.aplustopper.com
Figure 5

Table 1

Power, P	Time, T	Energy supplied, Q	Initial mass, m_1	Recorded mass, m_2	Mass of liquid which evaporates, m
W	s	kJ	g	g	$(m_1 - m_2)$/kg
320	0	0	260	260	0
320	120		260	247	
320	240		260	229	
320	360		260	206	
320	480		260	193	
320	600		260	176	

a) Define specific latent heat of vaporisation of a liquid. (1)
b) Copy and complete the Table 1 above. (2)
c) Plot a graph of Q in kJ against m in kg. (4)
d) Use the graph to:
   i. determine the mass of liquid which evaporated after 5 minutes. (2)
   ii. deduce the value of the specific latent heat of vaporisation of water. (3)
e) State **TWO** assumptions that are made when working out part (d)(ii). (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.

10. A student was working in the laboratory using circuits and various components. Figure 6 is a representation of one of the circuits. Positions A – E are possible locations where the student can connect circuit components. All the resistors have a resistance of 15 Ω.

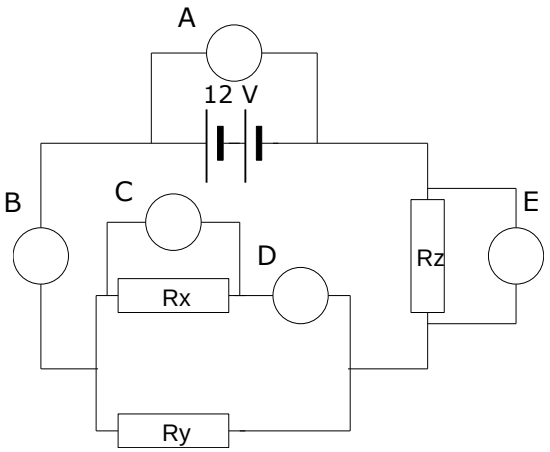


Figure 6

a) Indicate the position where an ammeter should be placed to measure the:
   i. total current in the circuit; (1)
   ii. current flowing through Rz. (1)

b) Indicate the position where a voltmeter should be placed to measure the:
   i. total voltage in the circuit; (1)
   ii. voltage across Rx. (1)

c) Explain what is an ideal:
   i. ammeter; (1)
   ii. voltmeter. (1)

d) The ammeter used to find the total current flowing in the circuit had a resistance of 2.3 Ω. Calculate the total current flowing in the circuit. (3)

Question continues on next page.

The student prepared a circuit to study discharging of parallel plate capacitors.

e) Draw a labelled diagram of a parallel plate capacitor. (2)

f) Figure 7 shows the graph obtained when a parallel plate capacitor P, was discharged through an 80 kΩ resistor.

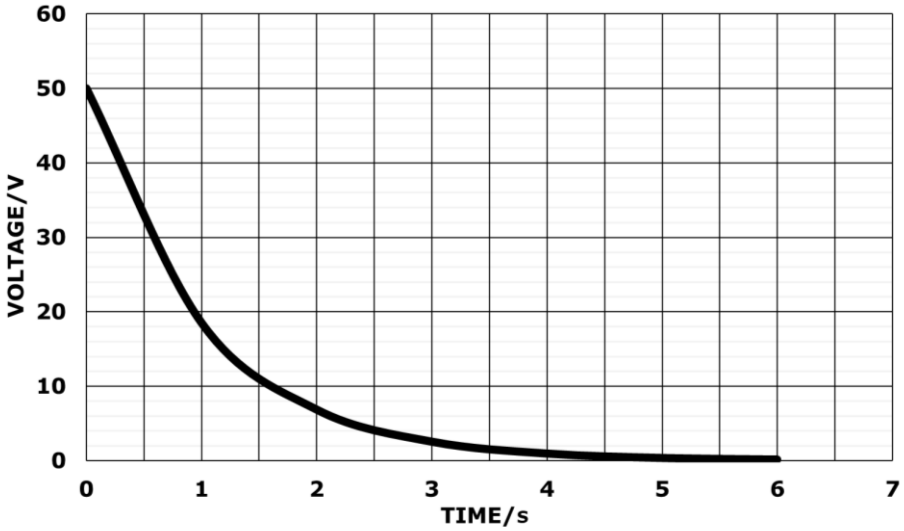


Figure 7

i. Find the approximate value of the time constant. (1)

ii. Determine the capacitance of the capacitor P. (2)

iii. Calculate the current flowing in the circuit used to discharge capacitor P after 4 s. (3)

g) The student found a 25 μF capacitor Q, in the laboratory. Which of the following graphs, 1 or 2, best represents the discharge of capacitor Q when compared to capacitor P? (1)

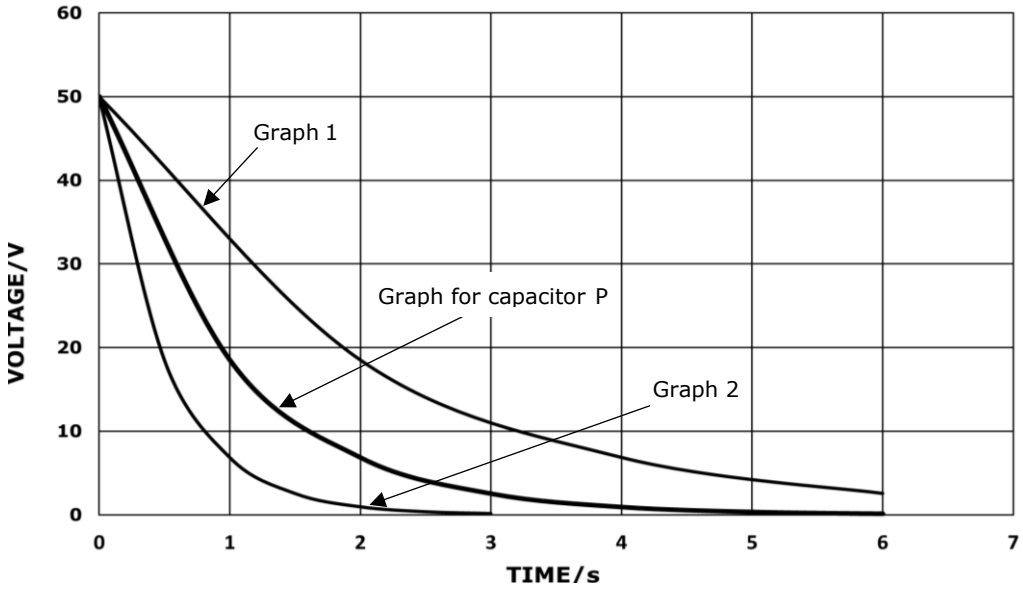


Figure 8

(Total: 18 marks)

11.

a) Show that the force F, acting on an individual charge q, moving at a velocity v, in a magnetic field B, is equal to Bqv. (3)

b) A particle G, of mass 3.85×10^{-26} kg and carrying a charge of 4.4×10^{-19} C, enters a magnetic field of 2.2 T as shown below.

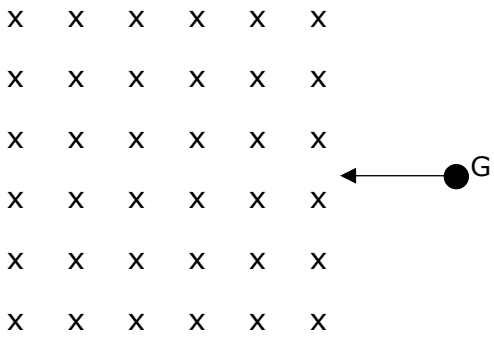


Figure 9

The particle follows a circular path of radius 0.12 m.

i. Copy the diagram and draw the path of particle G in the field. (1)

ii. Calculate the velocity of particle G when moving in the field. (2)

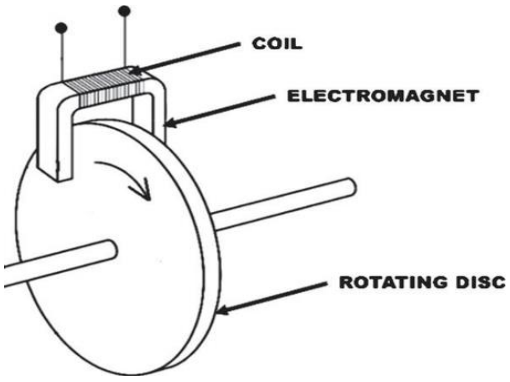
iii. Another particle H, of different mass, was moving in the same field and at the same velocity along a circular path of radius less than 0.12 m. Is particle H heavier than particle G? Explain. (2)

Trains have magnetic braking systems which rely on the principle of electromagnetic induction.

c) State Lenz's law of electromagnetic induction and explain its relation to energy conservation. (2)

d) Describe an experiment which can be done to verify Lenz's law. In your answer include:
- a labelled diagram of the apparatus used;
- the method which should be followed;
- the results/observations that are expected. (6)

e) The following is a simplified diagram of the electromagnetic braking system of a train. When brakes are applied, current flows through the coil and an electromagnetic force is created which helps to reduce the train speed. Suggest **TWO** ways in which the electromagnetic force required to stop the train can be stronger. (2)



Adapted from
https://content.iospress.com/articles
Figure 10

(Total: 18 marks)

Please turn the page.

12. A scent tree air freshener hanging from the rear-view mirror of a car (Figure 11) performs simple harmonic motion, while the car is moving.

Figure 11

a) State the **TWO** conditions which are necessary for the scent tree to perform simple harmonic motion. (2)

b) The following graph shows the variation of acceleration a, with displacement x, for the scent tree. Calculate the frequency of oscillation of the scent tree. (3)

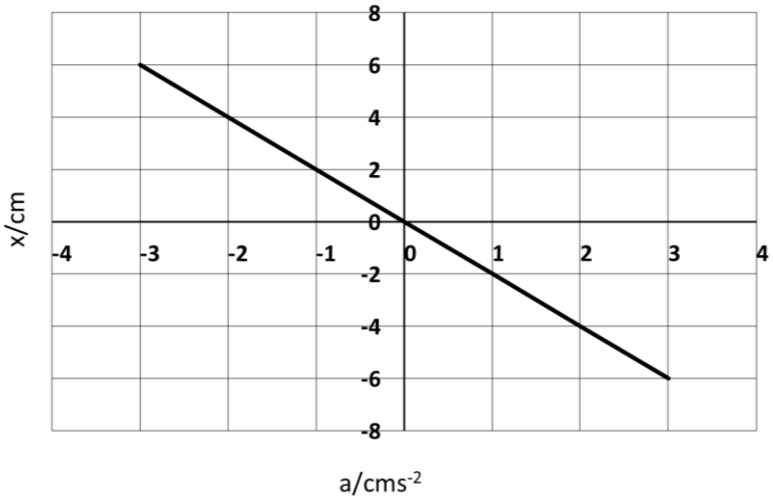


Figure 12

In Physics laboratories, ripple tanks are used to study the behaviour of water waves.

c) A straight wave generator is used to produce progressive waves in a ripple tank. The following are the displacement–time graph and the displacement–position graph of the waves produced.

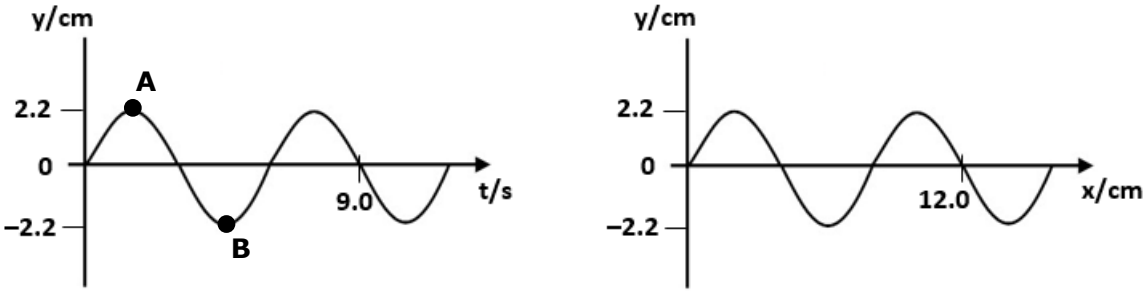


Figure 13

i. Name the points on the wave labelled A and B. (1)

ii. Explain what a progressive wave is. (1)

iii. Calculate the wave velocity in m s^{-1}. (3)

d) Two barriers were placed in the ripple tank to create a gap of 3 cm as shown below.

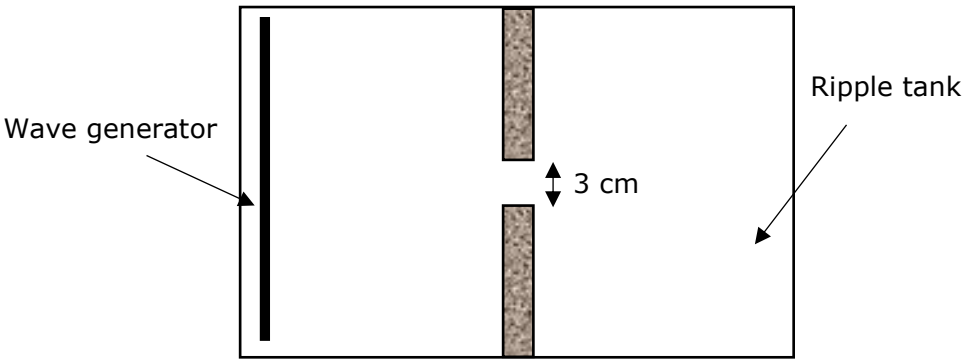


Figure 14

i. Copy the diagram and draw the wavefronts before entering the gap and after they pass through the gap. (1)

ii. The gap was widened to 15 cm. Describe the shape of the wavefronts after they pass through the gap and explain why this happens. (2)

e) Two point generators, G_1 and G_2, which are in phase, are used to produce water waves of wavelength 3.5 cm and amplitude 1.1 cm. The distance between G_1 and G_2 is 30 cm.

i. Explain the term in phase. (1)

ii. Explain the type of interference which occurs at point K which is 35 cm away from both G_1 and G_2. Hence give a value of the amplitude of the resultant wave at K. (2)

iii. Point L is 17.50 cm away from G_1 and 29.75 cm away from G_2. Explain the type of interference that occurs at L and hence give a value of the amplitude of the resultant wave at L. (2)

(Total: 18 marks)

Please turn the page.

13.

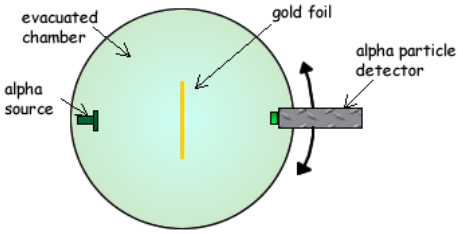
a) Distinguish between alpha, beta and gamma radiation in terms of their nature and **ONE** physical property. (3)

b) The radioactive isotope of Actinium, $^{228}_{89}\text{Ac}$ decays by emitting a beta particle and leaving an unstable product P_1, which further decays into product P_2 while emitting an alpha particle in the process.

i. Represent this process in **TWO** nuclear equations. (2)

ii. Calculate the energy released when P_2 was produced. (2)

c) Ernest Rutherford wanted to determine the nature of atoms and he carried out an experiment where he fired alpha particles at a thin gold foil. Describe **TWO** observations noted during the experiment and explain the conclusion derived from each observation. (4)



Adopted from: https://www.cyberphysics.co.uk
Figure 15

d) The activity of a radioactive isotope containing 7.11×10^{16} undecayed nuclei is 6.25×10^{9} Bq. Calculate the:

i. decay constant; (2)

ii. half-life of the nucleus; (1)

iii. approximate number of undecayed nuclei after 1 year. (3)

e) The decay of some radioactive isotopes is used to determine the age of a sample. State the reason why the age obtained may not be accurate. (1)

(1 a.m.u. = 1.6605×10^{-27} kg, mass of P_1 = 228.0287 u, mass of P_2 = 224.0202 u, mass of alpha particle = 4.0026 u)

(Total: 18 marks)