L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2022 SECOND SESSION

SUBJECT:	**Physics**
DATE:	2nd September 2022
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.

1. Car A travels at a constant speed of $12.5\ ms^{-1}$ on a straight level road. Car B is initially at rest and is on the same road as Car A, facing the same direction in which Car A is moving. As soon as Car A is in line with Car B (see Figure 1), Car B accelerates at $0.8\ ms^{-2}$ and catches up with Car A after travelling a distance *d*.

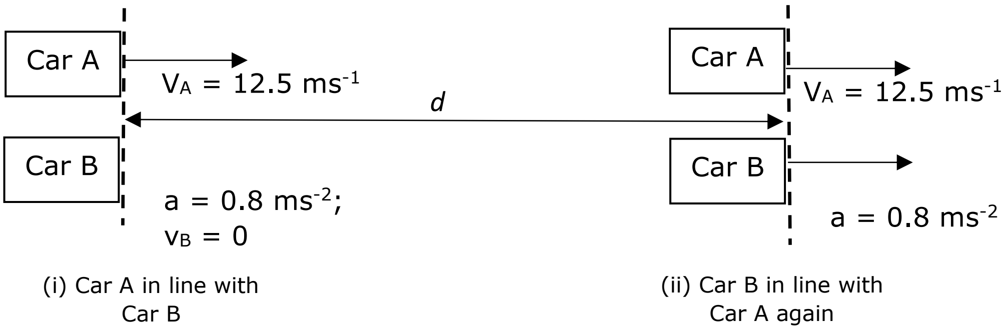

Figure 1

(a) How long does it take Car B to catch up with Car A? (2)
(b) Calculate distance *d*, the distance Car B travels until it catches up with Car A. (1)
(c) Calculate the velocity of Car B when it is in line with Car A again. (1)
(d) Draw a labelled velocity-time graph showing changes in the velocity of Car B during the time it takes it to be in line with Car A again. (1)

(Total: 5 marks)

2. A fixed mass of an ideal gas is enclosed in a cylinder fitted with a moveable piston, as shown in Figure 2. During the first part of an experiment, the gas performs 340 J of work, as it is allowed to expand with no change in temperature.

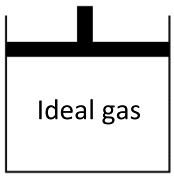

Figure 2

(a) Use the first law of thermodynamics to find:
   i) the change in internal energy of the gas; (1)
   ii) the thermal energy being absorbed by the gas during the process. (2)

(b) During the second part of the experiment, 80 J of heat energy are supplied to the gas. As a result, the gas expands, doing 25 J of work.
   i) Calculate the change in internal energy of the gas. (1)
   ii) Briefly explain how an increase in the temperature of an ideal gas gives rise to an increase in the internal energy of the gas. (1)

(Total: 5 marks)

3. Current flows through a cylindrical wire of diameter 5×10^{-4} m. The wire contains 8.0×10^{28} free electrons per m^3 and the mean drift velocity of electrons in the wire is 8.7×10^{-4} ms^{-1}.
   (a) Calculate the value of the current in the wire. (2)
   (b) Determine the time a free electron takes to travel from one end of the wire to the other, given that the wire is 5 m long. (1)
   (c) The wire forms part of a simple series circuit which includes a bulb. Explain why once the circuit is switched on, there is no time delay for the bulb to light up. (1)
   (d) The wire is now replaced by two pieces of wire, X and Y, made of the same material but having different diameters. The wires are connected in series and current flows. If the cross-sectional area of X is twice that of Y, calculate the ratio $v_X : v_Y$, where v_x and v_y are the drift velocities of the charge carriers in wire X and wire Y, respectively. (3)

(Total: 7 marks)

4. (a) The Moon orbits the Earth and at the same time it also rotates on its own axis. The time taken for the Moon to complete one rotation on its axis is 27.4 days. The gravitational field strength at the surface of the Moon is 1.62 Nkg^{-1} and the Moon's radius is 1740 km. $[G = 6.7 \times 10^{-11} Nm^2 kg^{-2}]$

   i) Show that the mass of the Moon is 7.32×10^{22}kg. (1)
   ii) A satellite orbits the Moon maintaining a circular path of radius r. A second satellite has a larger speed and still needs to be maintained in circular orbit around the Moon. Will the radius of orbit of the second satellite be larger or smaller than r ? Explain your answer. (3)

   (b) The Earth and the Moon can be considered as two spheres, isolated in space, having their masses concentrated at their centres. The distance from the centre of Earth to that of the Moon is $60R_E$ where R_E is the radius of the Earth (see Figure 3).

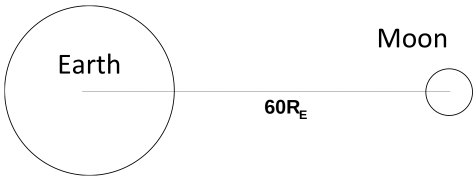

Figure 3

   $[M_{Earth} = 5.98 \times 10^{24}\text{kg}]$

   i) There is a point between the Earth and the Moon where the gravitational field strength is zero. Explain. (1)
   ii) Determine the distance of this point, from the centre of the Earth, in terms of R_E. (3)

(Total: 8 marks)

5. (a) Two identical conducting spheres carry the same charge and are 8 mm apart. The force of repulsion between the charged spheres is 2.1×10^{-3} N.

   i) Calculate the charge on one of the spheres. (2)
   ii) Calculate the number of electrons required to produce the charge in part (i). (1)
   iii) By what factor will the force between the spheres change, if their separation:
      - is increased to 12 mm; (1)
      - is decreased to 4 mm. (1)

   (b) A charged oil drop is placed in a vertical electric field such that it just manages to remain stationary and afloat in the field. The drop carries six electric charges, each of value 1.6 x 10^{-19} C. If the mass of the oil drop is 4×10^{-15} kg, calculate the electric field intensity. (2)

(Total: 7 marks)

6. (a) What is the peak value of an alternating current which produces two times the heat per second as a direct current of 3 A in a resistor R? (3)
   (b) On the same set of axes, sketch a current-time graph showing any changes in the current flow through resistor R, when this forms part of:
      i) a simple d.c. circuit. Label this graph (i); (1)
      ii) a simple a.c. circuit. Label this graph (ii); (1)
      iii) the a.c. circuit in part (ii) when a diode is connected in series with R. Label this graph (iii). (1)

(Total: 6 marks)

7. A simple pendulum, P, oscillates in simple harmonic motion (SHM). Figure 4 shows P in three different positions as it oscillates.
   (a) Define SHM. (1)
   (b) On the same scale and axis, sketch **TWO** velocity-time graphs to show how the velocity changes over two complete oscillations for P starting from:
      i) maximum displacement; (1)
      ii) the equilibrium position. (1)
   (c) What is the phase difference between the two graphs in part (b)? (1)

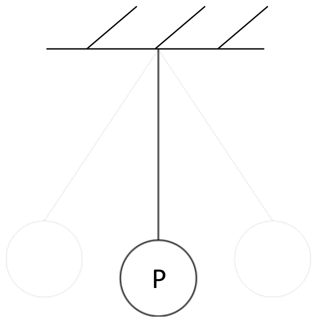

Figure 4

   (d) Another pendulum, Q , oscillates in SHM with the same maximum displacement as pendulum P, but at twice the frequency. What is the ratio of the maximum acceleration of pendulum P, to that of pendulum Q? Show **all** your working. (2)

(Total: 6 marks)

8. Radium is a radioactive element first discovered by Marie and Pierre Curie. One isotope of Radium is Radium-226.
   (a) Briefly explain what is:
      i) a radioactive element; (1)
      ii) an isotope. (1)
   (b) A sample of 3.2×10^{22} radium-226 atoms has an activity of 4.44×10^{11} Bq. Determine the decay constant for Radium-226. (2)
   (c) Radium-226, a solid at room temperature, decays to Radon-222 which is a colourless and odourless radioactive gas at room temperature. Based on this information and considering samples of Radium-226 and Radon-222, with the same number of atoms of each element initially available, which one of the two radioactive elements offers more risk of contamination? Give a valid reason for your answer. (2)

(Total: 6 marks)

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

9. The apparatus shown in Figure 5 is used to investigate the relationship between the current flowing through a conductor placed in a magnetic field and the force acting on it.

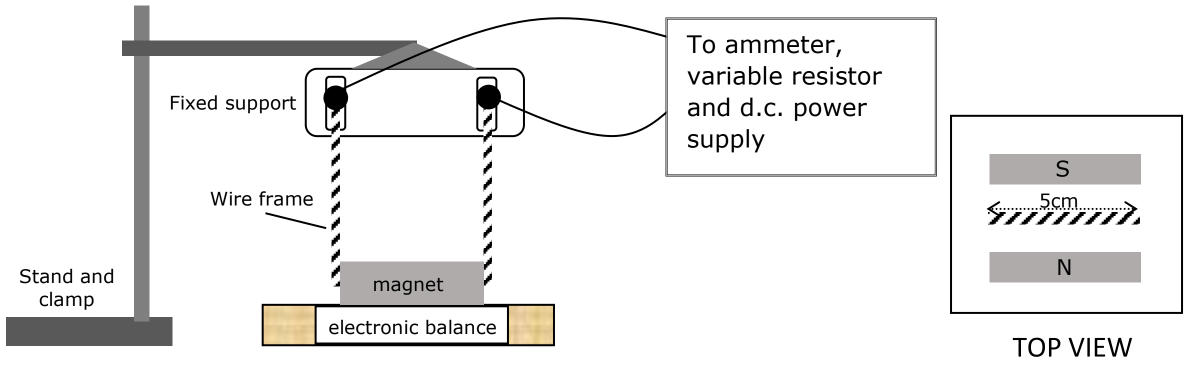

Figure 5

Two bar magnets are placed on an electronic balance, with opposite poles facing each other. The balance is then set to 'zero'. A wire frame is placed between the magnets such that the horizontal part, which is 5 cm long, lies within the magnetic field and is perpendicular to it. The wire frame is fixed and cannot move. It is connected in series to an ammeter, a variable resistor and a d.c. power supply. When the supply is switched ON, a current flows through the wire frame and a magnetic force is created, resulting in a reading on the electronic balance. This reading is a digital display of mass in grams (m/g). For different values of current in Amperes (I/A) through the wire frame, different values of m/g are recorded (see Table 1).

The equation relating the current, I, passing through a conductor to the Force, F, acting on it when placed at right angles to a magnetic field is:

$F = BIL$, where L is the length of the wire and B is the magnetic flux density.

Table 1

Current I/A	**Mass m/g**	**Force F/N**
0.0	0.00	
0.8	0.29	
1.6	0.58	
2.4	0.87	
3.2	1.18	
4.0	1.48	
4.5	1.82	

(a) Copy the part of Figure 5 showing the top view. On it, indicate the direction of the magnetic field, B, and include an arrow on the wire to indicate the direction of the current I for a downward force to be experienced. (1)
(b) Copy Table 1 and complete the missing values. (2)
(c) Plot a graph of F/N on the y-axis against I/A on the x-axis. (4)
(d) Use the graph to determine the value of the magnetic flux density, B. (3)
(e) What can be concluded from the shape of the graph? (1)
(f) Suggest **TWO** precautions that should be implemented in this experiment. (2)
(g) Suggest **ONE** change to this setup so that larger force values would be obtained. (1)

(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) One of the most common stunts performed at a funfair is the motordrome. A biker rides a motorcycle along the boundary of a large rigid wooden cylinder, thereby tracing a circular path.

Figure 6

i) Explain why the biker accelerates when in circular motion along the walls of the motordrome. Your answer should include a free-body diagram showing the forces acting on the motorbike. (3)

ii) The biker maintains his motorcycle at a constant speed of 15 ms^{-1} in a motordrome with a diameter of 12 m. Calculate the centripetal acceleration of the biker. (2)

iii) How long does the biker take to make 20 revolutions in the motordrome? (2)

iv) The same biker now drives the motorbike in another motordrome having a diameter of 9 m. If the biker rides the motorcycle at the same speed as before, how many complete revolutions would he perform in the same time as that calculated in part (iii)? (3)

(b) At the same funfair, a tightrope walker balances herself at point B on a wire rope ABC, as shown in Figure 7. Angle ABC is equal to 140^o (Figure not to scale).

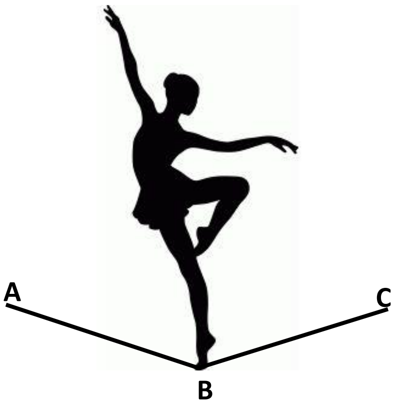

Figure 7

i) Draw a labelled free body diagram for the piece of wire just under the walker's foot. Assume that the walker's foot is exactly bisecting angle ABC. (2)

ii) State the **TWO** conditions required for a system to be in static equilibrium. (2)

iii) If the mass of the tightrope walker is 58 kg, calculate the other forces drawn and labelled in part (b)(i). (2)

iv) What changes would result in the forces experienced by the rope at point B, during this balancing act, if the tightrope walker had a smaller weight? (2)

(Total: 18 marks)

11. (a) Figure 8 shows a material which is experiencing necking.

Figure 8

i) What is necking? (2)

ii) Sketch the stress-strain graph for a metal in the form of a wire, up to the fracture point. (2)

iii) On the same graph, indicate:

- the region in which the metal exhibits plastic behaviour; (1)
- the point at which necking begins. (1)

iv) Copper is a ductile material. Explain. (1)

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(b) The following is the stress-strain graph for glass.

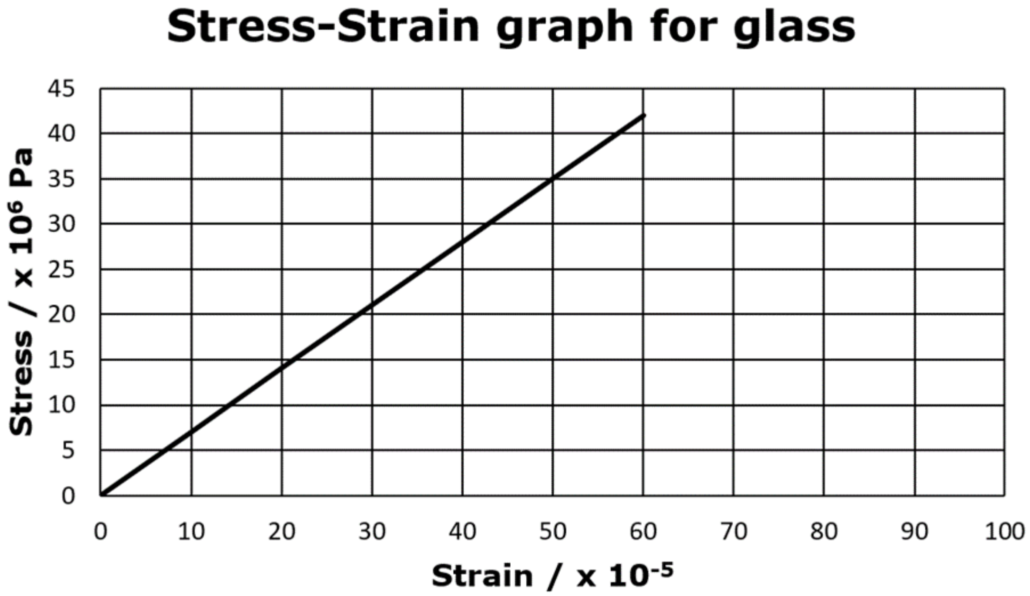

Figure 9

i) Name **ONE** typical elastic property of glass and explain what it means. (1)

ii) Use the graph to find the Young Modulus of glass. (2)

iii) A circular solid glass rod with the same Young modulus as that calculated in part (ii), supports an 85 kg decorative object. The rod is 1.6 m long and has a diameter of 10 cm. Calculate the extension of the glass rod. (3)

(c) Elastic hysteresis is a property of rubber which makes rubber useful in vehicle suspensions.

i) Describe the elastic hysteresis behaviour of rubber. Your answer should include a stress-strain sketch showing the loading/unloading of rubber. (3)

ii) Explain how this behaviour is helpful in vehicle suspensions. (2)

(Total: 18 marks)

12. A physics student was investigating the relationship between current and voltage for various electrical components.

(a) The student was initially supplied with a filament lamp and a thermistor having a negative thermal coefficient of resistance. Any other apparatus that the student needed to use to set up an electric circuit was available in the laboratory.

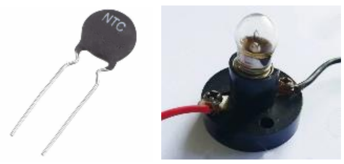

Figure 10

i) Describe an experiment the student may perform to find the relationship between current and voltage for the two components mentioned above. In the description, include:

- a labelled diagram of the circuit used; (2)
- an explanation of how the experiment is carried out; (2)
- sketches of the graphs expected to be obtained from the readings both for the bulb and the thermistor; (2)
- **ONE** precaution that needs to be taken during the experiment, other than taking repeated readings, to make the results more reliable. (1)

ii) State what happens to the temperature and the resistance of each of the two components mentioned above, as the voltage across them is increased. (2)

iii) Thermistors (of a negative thermal coefficient of resistance) are commonly used as voltage controllers in temperature sensor mechanisms. Explain with the aid of a circuit diagram how this is achieved. (3)

b) During the experiment, the student was also given two unknown components, G and H, and was asked to find the I-V relationship for them. The following are the graphs obtained:

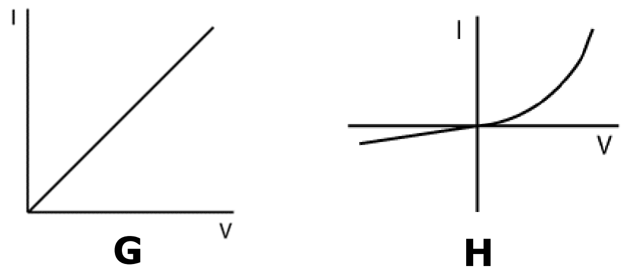

Figure 11

i) State what electrical components G and H represent. Briefly explain your answers. (3)

ii) Mention **ONE** precaution which must have been taken to obtain graph G above. (1)

iii) Explain how the student can use the graph for H to find the resistance of the component H, for a particular value of V. (2)

(Total: 18 marks)

13. (a) The strings on a guitar may be used to produce a stationary wave. Ocean waves are examples of progressive waves.

i) Distinguish between a stationary and a progressive wave in terms of the amplitude of oscillation of neighbouring particles constituting each type of wave. (2)

ii) State **TWO** other differences between a stationary and a progressive wave. (2)

(b) Figure 12 shows a wire AB which is fixed to an oscillator at one end. The wire passes over a pulley and is being held taut by using a mass of 1.250 kg at the other end. The wire is oscillating in the given mode at 150 Hz.

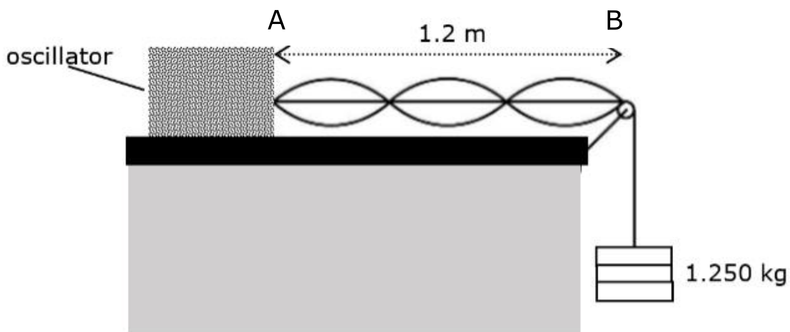

Figure 12

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i) Describe how the standing wave is being formed on the wire. (1)
ii) Calculate the wavelength of the stationary wave formed. (1)
iii) What is an antinode? (1)
iv) Calculate the mass per unit length of the wire. (3)

(c) In Young's double slit experiment, monochromatic light coming from two coherent sources which are close to each other is required for interference fringes to be observed on a screen. A bright or dark fringe is formed depending on the path difference between the waves reaching the screen from the two sources.

i) Explain what are:
- coherent sources; (1)
- monochromatic light; (1)
- path difference. (1)

ii) Explain how the coherent sources of light are obtained during this experiment. (1)

(d) A beam of green light of wavelength 540 nm is directed onto a pair of slits as shown in Figure 13. An interference pattern forms on the screen.

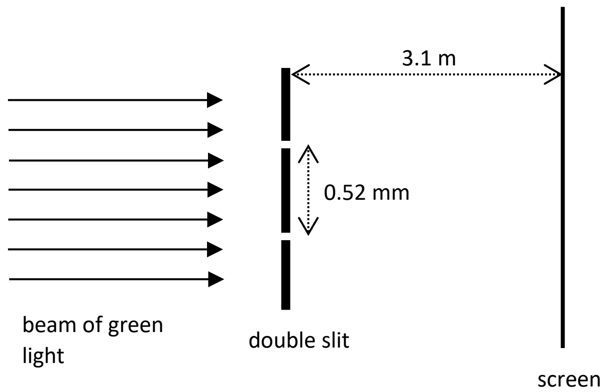

Figure 13

i) Using the data provided in Figure 13, calculate the fringe separation. (2)
ii) State what happens to the fringe separation, giving reasons for your answers, when:
- the distance between the slits is increased; (1)
- the green light is replaced with red light. (1)

(Total: 18 marks)