L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2021 FIRST SESSION

SUBJECT:	**Physics**
DATE:	26th June 2021
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. A projectile is launched horizontally from the top of a cliff, of height *h*, equal to 280 m. The projectile lands at a horizontal distance *d*, equal to 52 m, away from the bottom of the cliff (see Figure 1).
   a. Calculate the time of the flight. (2)
   b. Determine the horizontal velocity, *v*, with which the projectile was launched. (3)

   (Total: 5 marks)

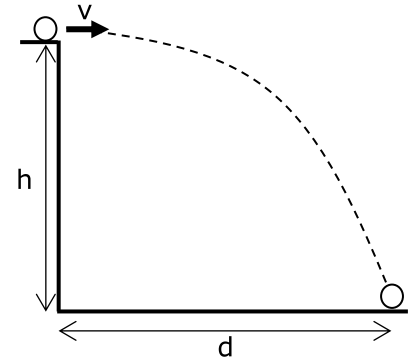

Figure 1

2. A shipping company uses crumpled newspaper to protect fragile objects during transportation. Two graphs are shown in Figure 2. These show how the force of impact acting on the same object changes, with and without the use of crumpled newspaper.

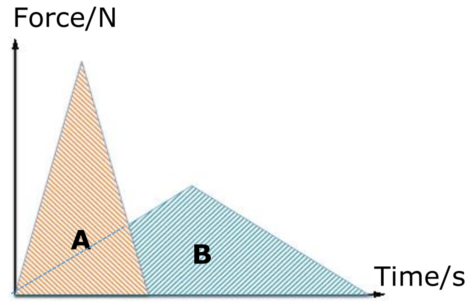

Figure 2

   a. State Newton's second law of motion in terms of the rate of change of momentum. (2)
   b. Identify, with explanation, the graph which corresponds to the object with the crumpled newspaper. (1)
   c. By referring to the graph, explain the role of crumpled newspaper in keeping the fragile object safe. (2)
   d. Explain why the area under both graphs must be the same. (1)

   (Total: 6 marks)

3. A beaker contains 700 g of water at 86 °C.
   a. Calculate the amount of heat energy required to bring the water to its boiling point? (2)
   b. How much energy is required to completely convert the water from its initial state at 86°C to steam at 100 °C? (2)
   c. Calculate the difference between the answers obtained in parts (a) and (b). Explain what this indicates. (1)
   d. Briefly describe an experiment to find the latent heat of vaporisation of water, using an electrical heater. (3)

   (specific heat capacity of water: 4200 J kg^{-1} K^{-1};
   specific latent heat of vaporisation of water: 2.26 x 10^6 J kg^{-1})

(Total: 8 marks)

4. The first law of thermodynamics is described by the following equation:

$$\Delta U = \Delta Q + \Delta W$$

   a. Explain what is meant by the internal energy of a gas, indicating the term in the equation which represents the change in internal energy. (1)
   b. Apply the first law of thermodynamics to explain the following situations in detail, providing relevant equations:
      i. a rubber band which is released after being stretched; (2)
      ii. a battery driving a current through a bulb. (2)

(Total: 5 marks)

5. Two copper wires, X and Y, have the same length. Wire Y has twice the diameter of wire X. An experiment is conducted using wire X only.
   Figure 3 shows an approximate stress-strain graph resulting from the experiment with the copper wire X.

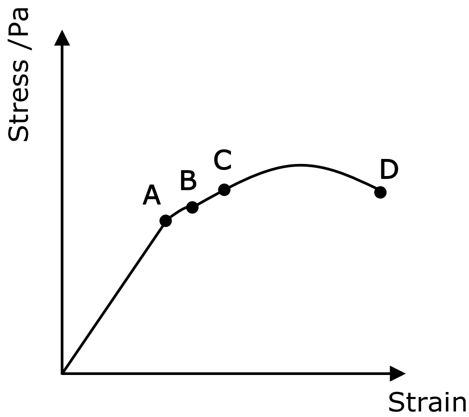

Figure 3

   a. Name the points on the graph marked A, B, C and D. (2)
   b. State whether the following statement is true or false, explaining your reasoning:
      If the same load is applied on both wires X and Y, the strain on X is four times the strain on Y. (3)

(Total: 5 marks)

6. A bulb is connected to a battery. A current of 0.8 A flows through the bulb for 54 s. The connecting wires have a cross-sectional area of 1 mm^2 and carry 10^{29} free electrons per m^3.
   a. Calculate the amount of charge flowing through the bulb during the time indicated. (2)
   b. How many electrons flow through the bulb during this time? (1)
   c. Draw the circuit showing the bulb and battery and on it indicate the direction of flow of charge in terms of electrons. (1)
   d. Explain how a complete circuit helps electrons to acquire a drift speed. Calculate the drift speed of the electrons described in part (b). (3)

(Total: 7 marks)

7. In a school laboratory, a student is supplied with a battery, a 10 Ω resistor, an ammeter, and connecting wires.
   a. Draw a circuit diagram showing how the apparatus must be connected for current to flow through the resistor. (1)
   b. Explain why an ideal ammeter has no resistance. (1)
   c. Calculate the voltage across the resistor when the ammeter reads 1.12 A. (1)
   d. If the battery has an e.m.f. of 12 V, why is the voltage across the resistor not equal to 12 V? What is this difference called? (1)
   e. The student now uses a different battery and connects it to a variable resistance. He also uses a voltmeter, to read the potential difference (p.d.) across the resistance, and an ammeter to read the current flowing through the resistance. He records corresponding values of current and p.d. and plots a graph with the results obtained. The graph is shown in Figure 4.
      i. Use the graph to determine the internal resistance of the battery. (2)
      ii. Determine the e.m.f. of the battery. (1)

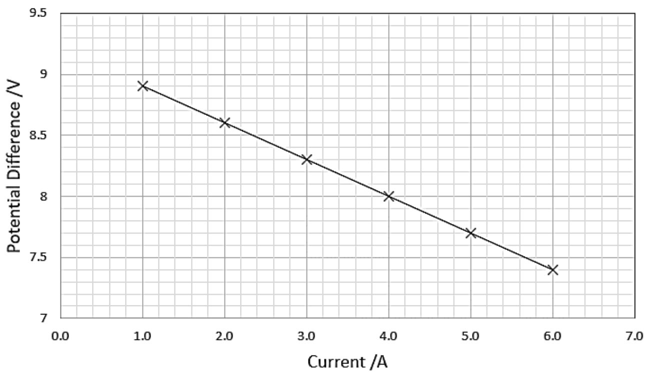

Figure 4

(Total: 7 marks)

8. A 450 μF capacitor is first charged by connecting it to a battery of e.m.f. V_0 equal to 12 V. The capacitor is then discharged through an 80 kΩ resistor.
   a. Calculate the total charge stored by the capacitor after this is connected to the battery. (1)
   b. Find the time constant of the discharging circuit. (1)
   c. Using the answer in part (b), or otherwise, calculate the charge on the capacitor plates, after discharging the capacitor for 144 s. (1)
   d. On the same set of axes, sketch graphs of voltage against time showing how the voltage across the capacitor changes during the charging and the discharging process. Label the charging graph, X. (2)
   e. Similarly, sketch a graph of current against time to show the variation during the charging and discharging process of the capacitor. Label the charging graph, Y. (2)

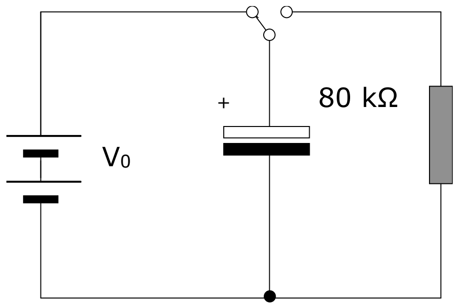

Figure 5

(Total: 7 marks)

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

9. A student engineer is reading about how aerospace engineers test different aluminium alloys for the production of aircraft components, by applying varying stresses to them. Aluminium alloys are known for their corrosion resistance, ductility, conductivity, appearance, strength, and most of all their light weight.

The student decides to test the elastic properties of one such aluminium alloy in the form of a wire, in a laboratory, using the apparatus shown in Figure 6. The test wire used has an original length of 2 m and a cross-sectional area of 1.98×10^{-6} m^2.

Results obtained by the student are shown in Table 1, below:

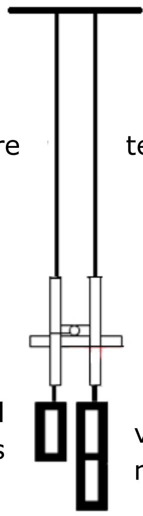

Figure 6

Table 1

Force / 10^2 N	Stress / MPa	Extension / 10^{-3} m	Strain
1.0		1.26	
2.0		2.80	
3.0		4.20	
4.0		5.20	
4.5		6.00	

a. Copy Table 1 and fill in the missing values. (2)
b. Plot a graph of Stress /MPa on the y-axis against Strain on the x-axis. (5)
c. The general equation of a straight line is y = mx + c. Explain **each** term in this equation, with reference to your graph. Use your graph to determine the Young Modulus of the aluminium alloy, stating the units of the Young Modulus. (4)
d. State **ONE** precaution that would have helped the student to improve the results obtained during the experiment. (1)
e. Explain the importance of using the control wire in this experiment. (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. A car of mass 1200 kg travels with constant speed of 20 ms^{-1} along a horizontal road where the frictional force is 200 N. Calculate the power developed by the engine. (2)

b. The same car now travels with a different constant speed up an inclined plane. It takes 25 s to cover a distance of 240 m. The plane is inclined at an angle of 12 ° to the horizontal, as shown in Figure 7.

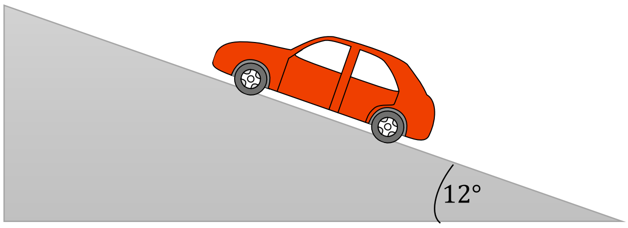

Figure 7

i. State the component of the weight of the car which is:
   - parallel to the inclined plane;
   - perpendicular to the inclined plane. (2)

ii. Assuming the frictional force is still 200 N, calculate the work done by the car in moving 240 m up the incline. (3)

iii. Calculate the new power developed by the car engine. (2)

iv. In practice, a car engine is said to be 30% efficient. Explain this statement. (1)

c. A toy of mass 0.8 kg is made to swing along a curved surface as shown in Figure 8. The initial vertical height of the centre of mass of the toy at A is 2.2 m.

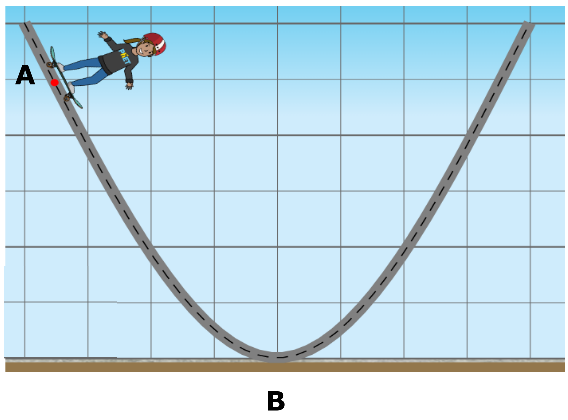

Figure 8

i. Describe the energy changes of the toy that occur as the toy moves from A to B and then up on the other side of the curved surface. (3)

ii. Calculate the maximum speed of the toy on reaching point B, assuming **all** energy is conserved. (2)

iii. If in moving up on the other side of the curved surface, the toy does **not** reach the same level as A, what does this imply? (1)

iv. After a number of swings, the toy eventually stops at B. Discuss **TWO** ways of increasing this number. (2)

(Total: 18 marks)

11. a. The diagrams in Figure 9 show a magnet being dropped through the centre of a narrow coil of wire and the resulting changes in e.m.f. induced in the coil, as monitored on an oscilloscope.

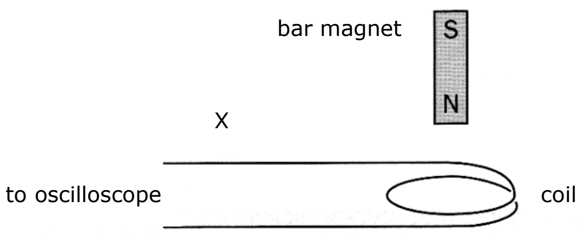

Figure 9 (a)

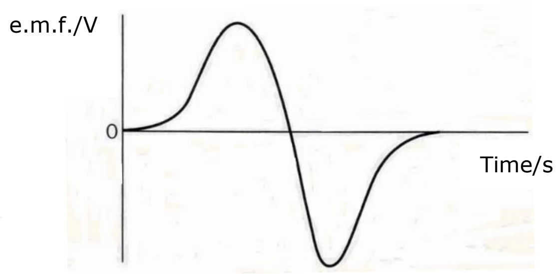

Figure 9 (b)

i. What is the induced magnetic polarity on the top side of the coil, as the magnet falls towards the coil? Explain your answer by making reference to any applicable electromagnetic induction principles. (2)

ii. Copy Figure 9(a). Assuming the coil of wire forms part of a closed circuit, indicate the direction of the current flow at position X, as the magnet falls towards the coil. Explain your answer. (2)

iii. With reference to Figure 9(b), explain the shape of the curve. (3)

iv. Copy Figure 9(b) and using a dotted line, include another graph showing changes in what would be observed on the oscilloscope screen had the magnet been dropped from a greater height. Explain your answer. (2)

b. An electric guitar has small bar magnets placed under the steel strings of the guitar. Each magnet is surrounded by a coil. The magnet magnetises the steel guitar string immediately above it. When the string vibrates, it creates a changing magnetic field of its own which affects the coil.

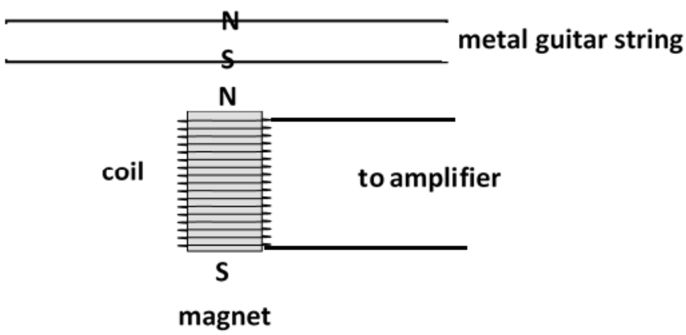

Figure 10

i. What is the result of a changing magnetic flux within the coil? (1)

ii. What happens if a coil with a larger number of turns is used? (1)

iii. Someone suggested that the steel string above the magnet could be replaced by a plastic one. Explain why this would not work. (1)

c. A current of 2 A flows through a rectangular coil (see Figure 11 on the next page) in the direction ABCD. AB is 10 cm while BC is 8 cm long. The coil has 4 turns and the magnetic flux density is 0.5 Tesla.

i. Define the Tesla. (1)

ii. State the direction of the force, if any, acting on the sides AB and BC, mentioning a valid rule that helped in reaching your conclusions. (3)

iii. Calculate the value of the force acting on **each** of the sides mentioned in part c (ii). (2)

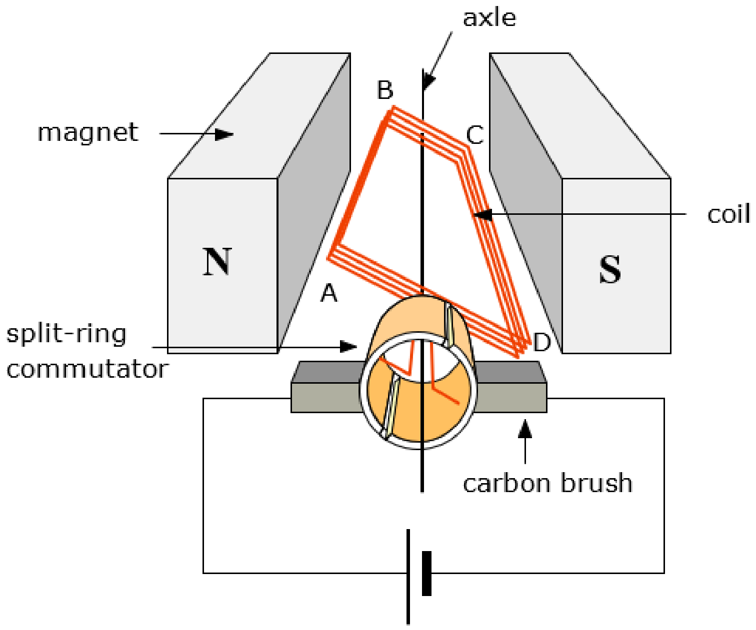

Figure 11

(Total: 18 marks)

12. a. A student decides to conduct a number of experiments.

   i. The student starts by attaching a sphere to a spring. The spring is then stretched a small vertical distance and then released. What name is given to the subsequent oscillatory motion of the spring? (2)

   ii. Sketch graphs that show the variation of the following quantities related to the motion of the sphere, after it is released to perform the oscillatory motion:
   - displacement versus time;
   - velocity versus time (drawn in relation to the previous sketch);
   - acceleration versus displacement from mean position.

   Clearly distinguish between the graphs. (3)

b. The student now experiments with a guitar string. At one moment, the guitar string is stretched between supports which are 0.75 m apart. The student makes the string vibrate at its first harmonic, as shown in Figure 12 below. The speed of the wave generated in the string is 500 m/s.

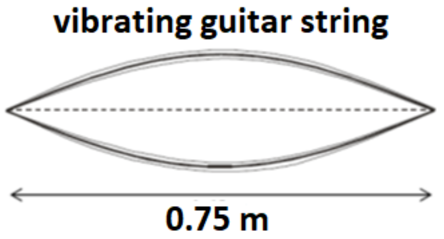

Figure 12

   i. Calculate the frequency of vibration of the string. (2)

   ii. The student now slowly increases the frequency of vibration of the string until the string vibrates at its second harmonic. Draw a diagram to show the vibrating string in this situation. (1)

   iii. What is the expected frequency of vibration of the string at the second harmonic? (2)

c. The student further experiments using a laser beam. He shines light through a pair of narrow slits (see Figure 13).

   i. A fringe pattern results on the screen. Describe the pattern formed giving a physical explanation for what causes it. (3)

   ii. What is the effect, if any, on the observed pattern when:
      - the wavelength of the light source is increased;
      - the distance between the slits is increased. (2)

   iii. The separation of the slits is 0.12 mm and the distance between the slits and the screen is 0.9 m. Given the light has a wavelength of 4.4×10^{-7} m, calculate the fringe spacing. (3)

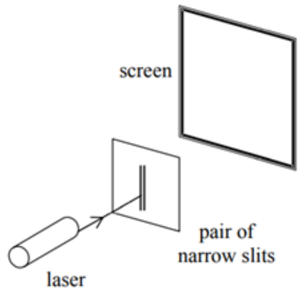

Figure 13

(Total: 18 marks)

13. a. Figure 14 shows a typical energy level diagram.

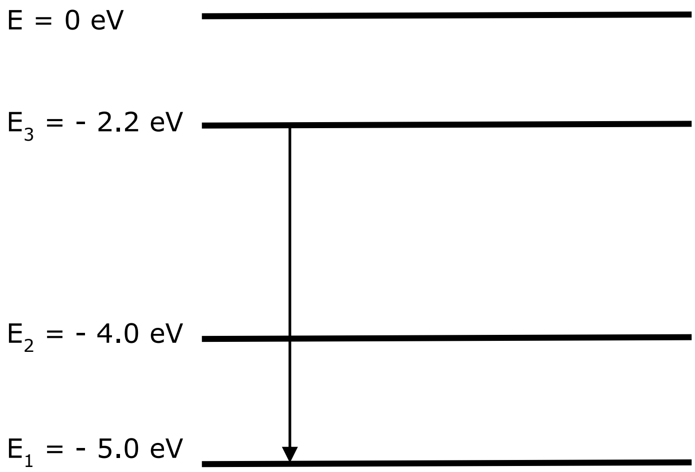

Figure 14

   i. What does the line E = 0 eV represent? (2)

   ii. What does the arrow from level E_3 to level E_1 represent? (2)

   iii. Explain why energy levels are assigned negative values. (2)

   iv. Define the electronvolt. (1)

   v. Convert the energy change represented by the arrow into Joules. (2)

   vi. Calculate the wavelength of the electromagnetic energy associated with the energy change within the atom as represented by the arrow shown in Figure 14. (2)

b. Figure 15 shows some energy levels for the hydrogen atom. A free electron with kinetic energy equal to 12 eV collides with an atom of hydrogen in its ground state, causing the electron within the atom to reach its first excited state. The electron within the atom eventually returns to its ground state, emitting a photon.

   i. What is meant by 'excited state' and 'ground state'? (2)

   ii. Calculate the frequency of the photon emitted when the electron within the hydrogen atom returns to its ground state. (2)

   iii. Calculate the velocity of the **free** electron, **after** the collision. (3)

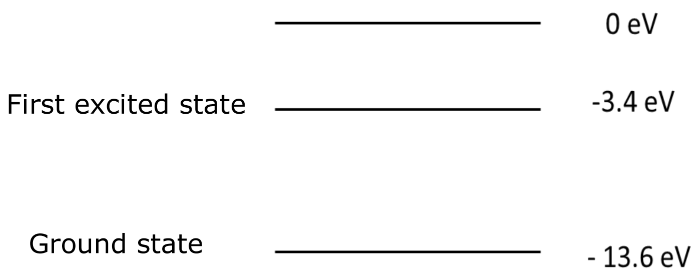

Figure 15

(Total: 18 marks)