MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	30th August 2023
TIME:	9:00 a.m. to 12:05 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 EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1.
a. Explain whether an equation which is homogeneous must be correct. Support your argument with an example. (3)

b. Distinguish between vectors and scalars. Show that the product of two vectors can be either a scalar or a vector by providing an example for each case. (3)

c. A boat was pulled forward at constant velocity by two equal forces of 400 N acting at an angle of 50° to each other. The forces are applied symmetrically to the front of the boat. Calculate:
i. the resultant forward force on the boat; (2)
ii. the drag force on the boat. Explain how you arrived at your answer. (2)

(Total: 10 marks)

2.
a. Define Power and derive an equation for power in terms of force and velocity. (3)

b. An electric kettle consumes 200 kJ in 2 minutes in order to boil some water.
i. Calculate the power rating of the kettle. (1)
ii. If the kettle has an efficiency of 80%, calculate the energy supplied to the water in these 2 minutes. (1)
iii. Why is the kettle not 100% efficient? (1)

c. A ball rolls down a 30 cm long inclined plane from rest as shown in Figure 1. Calculate the velocity of the ball when it has travelled 20 cm along the slope. State any assumptions used. (4)

(Total: 10 marks)

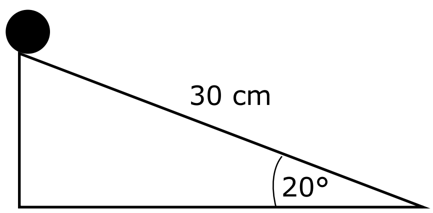

Figure 1

3.

A gymnast performs a backflip by swinging off a bar. The gymnast rotates in the air before landing as shown in Figure 2.

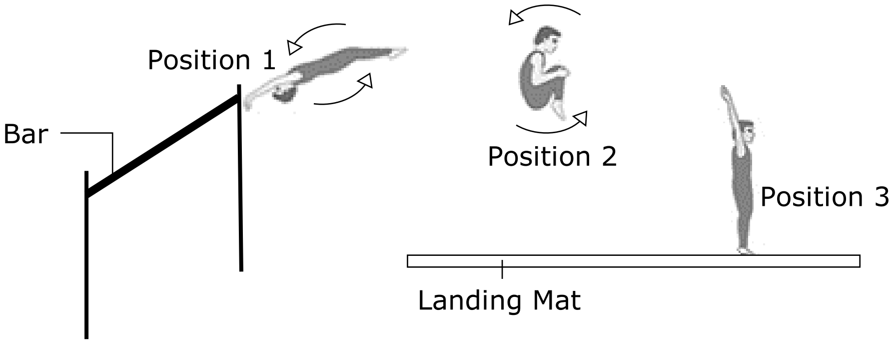

Figure 2

a. Explain how the moment of inertia and the angular speed of the gymnast change when he tucks in his knees as shown in position 2. Use an equation to justify your answer. (3)

b. The gymnast leaves the pole with an angular momentum of 48 kg m^2 s^{-1}. He completes 2.3 rotations in 1.1 s whilst in position 2. Find his moment of inertia when he is rotating in position 2. (3)

c. State and explain **TWO** actions the gymnast can take to complete more rotations. (4)

(Total: 10 marks)

4.

a. A simplified diagram of a mass balance is shown in Figure 3. The spring system of the balance consists of five identical springs connected in parallel, each with a spring constant of 35 N m^{-1}.

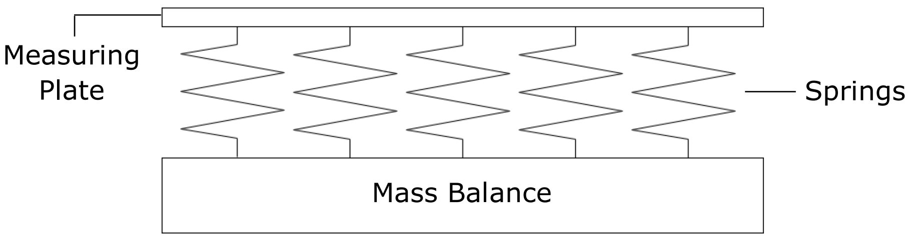

Figure 3

i. Does the measuring plate change the proportionality of the mass balance? Explain your answer by referring to Hooke's law and sketch a suitable graph. (4)

ii. When 80 g are loaded on the plate, the springs are compressed by 14 mm in total. Calculate the mass of the plate. (2)

b. A copper plate with equal sides of 5 cm and a thickness of 1 cm is compressed with a force of 55×10^6 N. The thickness is reduced to 0.8 cm. Assume that the other dimensions do not change as shown in Figure 4.

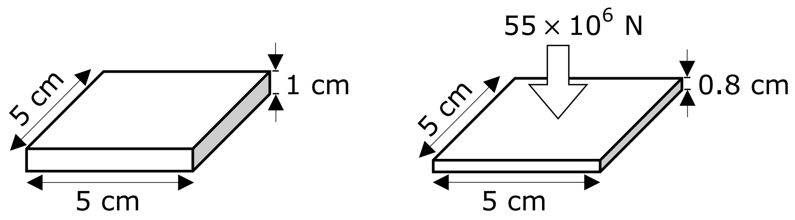

Figure 4

i. Calculate the Young's Modulus of copper. (3)

ii. The assumption involved is incorrect. Explain how a realistic scenario would affect the value calculated in part b.i. (1)

(Total: 10 marks)

5.

a. Derive an equation for the current flowing through a conductor of uniform cross-sectional area, in terms of electrons per unit volume. Explain all symbols used. Draw a diagram to aid your explanation. On your diagram label clearly, the direction of motion of the electrons and that of the current. (5)

b. A conductor and an insulator have identical dimensions, and carry the same current. Using the equation derived in part a., explain the difference between the two in terms of electron behaviour. (3)

c. A copper wire carries a steady current of 2 A. Calculate how many electrons flow through the wire in 5 minutes. (2)

(Total: 10 marks)

6.

a. Sketch and discuss (on separate graphs) the I-V characteristics of:

i. an ohmic conductor at constant temperature; (2)

ii. a filament lamp; (2)

iii. a negative temperature coefficient thermistor; (2)

iv. a semiconductor diode (including reverse bias). (4)

(Total: 10 marks)

7.

Describe a simple experimental setup and procedure required to determine the temperature coefficient of resistance of a wire. Your description should include:

i. a list of apparatus to be used; (3)

ii. a labelled diagram of the setup; (2)

iii. a brief description of the method and data collected; (2)

iv. a sketch of the expected graph and the associated calculations to find the temperature coefficient of resistance. (3)

(Total: 10 marks)

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8.

a. A simple setup of Rutherford's scattering experiment is shown in Figure 5.

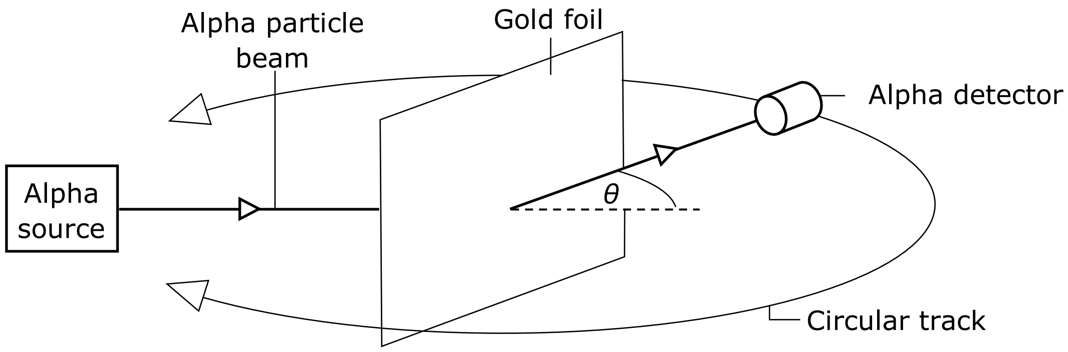

Figure 5

i. Describe **THREE** main observations made as the alpha particles pass through the gold foil. (3)

ii. For **each** observation mentioned in part i., identify the associated implications about the nature of atoms. (3)

b. The two protons inside a helium nucleus are separated by approximately 1 x 10^{-6} nm.

i. Calculate the electrostatic repulsion between the two protons. (1)

ii. Which is the main force that keeps the two protons from getting separated? Sketch a well labelled plot of the variation of this force against the distance, *r*, between the helium protons. (3)

(Total: 10 marks)

SECTION B

Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9.

a. Two identical javelins A and B are thrown from the same position at ground level with identical initial speeds, but at different angles θ_A and θ_B respectively, with respect to the horizontal. Assume that $\theta_A < \theta_B < 90°$.

i. State whether both javelins can travel the same horizontal distance. Illustrate your answer by sketching a well labelled diagram of the javelins' trajectories. (4)

ii. Derive an expression for the time taken for one of the javelins to reach its maximum height. Write your answer in terms of the initial speed, v_0, the initial angle θ and the acceleration due to gravity, g. (2)

iii. Given that they land on the same spot, show that the ratio of their time of flight is given by $\frac{t_A}{t_B} = \frac{\cos\theta_B}{\cos\theta_A}$. (3)

iv. Derive an expression for the maximum height reached by one of the javelins. (3)

v. Show that the horizontal range is given by $\frac{2v_0^2\cos\theta\sin\theta}{g}$. (3)

b. A tow truck of mass 4500 kg pulls a car of 2000 kg. The truck accelerates at 0.7 m s^{-2}. If the truck experiences a frictional force of 400 N and the car a frictional force of 150 N:

i. Calculate the forward force exerted by the truck's engine. (3)

ii. Draw separate and labelled force diagrams for the truck and the car. Identify a pair of forces satisfying Newton's third law of motion. (2)

(Total: 20 marks)

10.

a. A planet orbits a star in three Earth years at a distance of 2.5 x 10^8 km.

i. Draw a free body diagram of the planet to show the forces acting on it. Include the velocity and acceleration of the planet relative to the star. (2)

ii. Calculate the angular and linear velocities of the planet. (4)

b. A Formula 1 driver is driving a racing car. Part of the racing track includes a turn with a radius of 80 m and banked at angle θ. Assume that air resistance is negligible.

i. Draw a free body diagram of the forces acting on the car as it enters the banked turn with its wheels straight. Identify the component responsible for turning the car. (4)

ii. Derive an equation for the speed at which the banked turn is designed. (4)

iii. If the designed speed of the banked turn is 150 km hr^{-1}, calculate the required angle of banking θ. (2)

iv. Explain what happens to the car if its speed is either below or greater than the speed at which the banked curve is designed. (4)

(Total: 20 marks)

Please turn the page.

11.

a. State **THREE** conditions for static equilibrium. (3)

b. A uniform metal beam AB, of length 1 m and mass 10 kg, is hinged to a vertical wall at A. The beam is held in equilibrium in a horizontal position by a supporting rod CD as shown in Figure 6.

i. Find the supporting force produced at D. (3)

ii. Find the magnitude and direction of the force exerted on the rod AB at A. Draw the direction of the force and its component using arrows. (5)

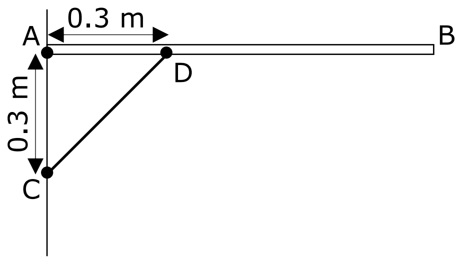

Figure 6

c. A uniform plank AB has mass m and length 5a. The end A of the plank lies on rough horizontal ground. A rock of mass $^{m}/_{6}$ is stuck to the plank at B. The plank is resting on a smooth thin horizontal bar C that is attached to the ground. The plank is in equilibrium, making an angle θ with the horizontal such that $\sin\theta = \frac{3}{5}$. The coefficient of friction between the plank and the ground is μ. The plank is lying in a vertical plane perpendicular to the bar as shown in Figure 7.

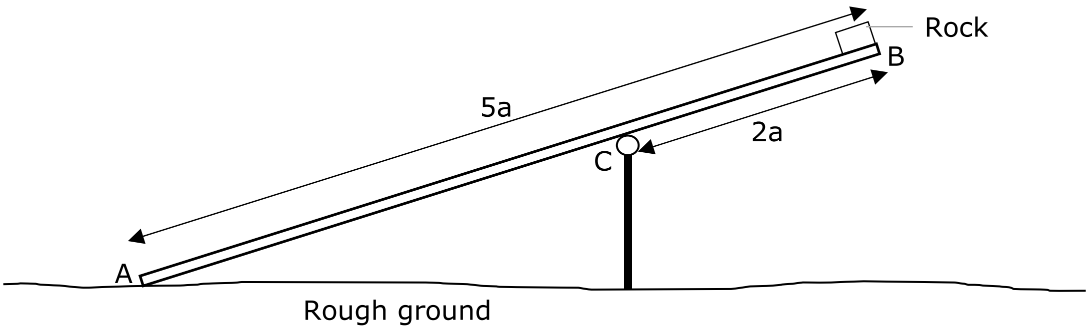

Figure 7

i. Show that the reaction of the bar on the plank has magnitude $\frac{8}{9}$ mg. (4)

ii. Show that $\mu \geq \frac{48}{41}$. (Slipping occurs when the horizontal force exceeds the product of the vertical force and the coefficient of friction). (4)

iii. Why is it important for the calculation that the bar is smooth? (1)

(Total: 20 marks)

12.

a. A physicist wishes to investigate the elastic properties of a rubber cord. Describe an experiment that could be carried out to investigate such properties. Your description should include:

   i. a list of apparatus used; (2)
   ii. a well labelled diagram of the setup; (2)
   iii. a detailed method to be followed; (3)
   iv. data tabulation; (2)
   v. a suitable graph to be plotted; (3)
   vi. conclusions about the elastic properties of the rubber band with reference to the plotted graph. Name the phenomenon associated with the graph plotted. (3)

b. A tug boat pulls a small 1000 kg boat by using a steel cable with a diameter of 10 cm. When the small boat is accelerating at 3 m s^{-2}, a tensile strain of 2 x 10^{-6} is produced within the steel wire. Calculate the total frictional force experienced by the small boat. (Take Young's modulus of steel to be 200 GPa) (5)

(Total: 20 marks)

13.

a. A semiconductor is a material which has an electrical conductivity value falling between that of a conductor, such as copper, and an insulator, such as glass.

   i. Describe the basic bonding structure of a pure silicon lattice. Include a simple diagram in your explanation. (4)
   ii. With reference to the bonding structure of a pure silicon lattice, describe how impurities within this structure increase the conduction of the lattice. (5)
   iii. Give an example of each type of impurity. Identify the impurity atom and the type of semiconductor for each example. (2)

b. Draw a detailed and well labelled diagram to distinguish between conductors, different types of semiconductors and insulators in terms of simple band theory. (6)

c. Briefly describe how a potential barrier is formed at a junction between the two different types of extrinsic semiconductors. (3)

(Total: 20 marks)

Please turn the page.

14.

a. An electrician wants to charge a capacitor and then discharge it through a filament lamp. A voltmeter and an ammeter are used to read the voltage across the capacitor and the current through the lamp respectively. The only power source available provides alternating voltage. Moreover, if the power source is connected directly to the capacitor, it will cause dielectric breakdown because its voltage is too high. Draw a circuit that enables the electrician to safely charge the capacitor and then discharge it through the lamp. Indicate the direction of current flowing through the lamp and the polarity of the charged capacitor's plates. (6)

b. Use Kirchhoff's laws to find the resistance R, and the currents flowing through the other resistors in the circuit shown in Figure 8. (7)

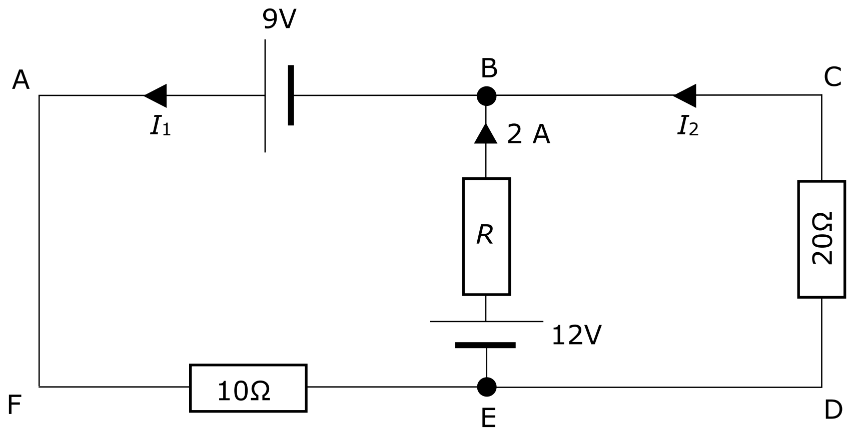

Figure 8

c. An electric motor rotates 35000 times per minute. 5 J of electrical energy are converted to 3 J of useful kinetic energy per rotation.

i. Define the term 'electrical power'. (1)

ii. Calculate the power consumption of the motor. (1)

iii. Calculate the efficiency of the motor. (2)

iv. Calculate the energy consumed by the motor over three hours. Give your answer in kilowatt-hours. (2)

v. Where are kilowatt-hours most commonly used? (1)

(Total: 20 marks)

15.

a. Five energy levels in a Hydrogen atom have energies as shown in Table 1. An electron undergoes two transitions. Transition A occurs from level 4 to level 2, and transition B from level 2 to level 3.

Table 1

Energy level	Energy / eV
1	-13.60
2	-3.40
3	-1.51
4	-0.85
5	-0.54

i. Explain the terms 'ground state', 'excited state' and 'ionization energy'. (2)

ii. Explain why the energy levels have negative energy values. (2)

iii. Draw a simple diagram to illustrate the five energy levels of the Hydrogen atom and the electron transitions A and B. Identify whether energy is being absorbed or emitted during the transitions. (4)

iv. Calculate the wavelengths of the light which is either absorbed or emitted during transitions A and B. (4)

b. An astrophysicist is trying to understand what physical and chemical processes are occurring on a distant star.

i. Describe the emission spectrum of an atom and explain how it is produced. (3)

ii. Describe the absorption spectrum with reference to the emission spectrum. (2)

iii. How can these spectra provide information about distant celestial objects? (2)

iv. Name the instrument that is used to study these spectra. (1)

(Total: 20 marks)

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SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	31st August 2023
TIME:	9:00 a.m. to 12:05 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 EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1.

a. State the zeroth law of thermodynamics. (1)

b. Describe briefly an experiment to determine the value of the specific heat capacity of a metal block using an electric method. Your answer should include a labelled diagram of the apparatus used, an indication of what measurements need to be made and how the final value is calculated. (5)

c. A 50 g ice block at -8 °C is placed in 0.5 kg of water at 18 °C. After all the ice melts, what is the final temperature of the mixture? Assume that the specific heat capacity of ice is 2.108 KJ kg^{-1} K^{-1}, that of water is 4.2 KJ kg^{-1} K^{-1}, the specific latent heat of fusion of water is 334 kJ Kg^{-1} and the density of water is 1000 kg m^{-3}. (Assume that energy losses of the container are negligible). (4)

(Total: 10 marks)

2.

a. Define gravitational field strength. (1)

b. Show that for a satellite, T^2 is proportional to R^3, where T is the satellite's period of orbit and R is the orbital radius. (4)

c. A rocket is launched from Earth for deep space exploration purposes.

i. Derive an equation for the minimum initial velocity of the rocket such that it escapes the gravitational pull of Earth. Give your answer in terms of the gravitational constant G, mass of the Earth M and the distance from the centre of the Earth r. (3)

ii. Calculate the escape velocity for a rocket escaping Earth. Assume that Earth's radius is 6.38×10^3 km and Earth's mass is 5.98×10^{24} kg. (2)

(Total: 10 marks)

3.

a. Draw the magnetic field lines for Earth. On your diagram, indicate the polarity of the magnetic poles and include the geographic poles as well. (2)

b. State Fleming's Left-hand rule. Hence determine the direction of the force on the current-carrying conductor in the following diagram. (3)

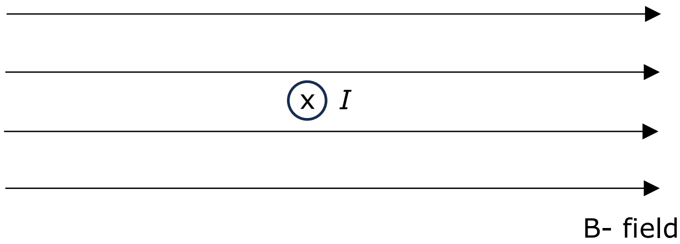

Figure 1

c. A 0.5 m long straight copper wire carrying a current of 0.8 A is placed in a uniform magnetic field of 0.2 T. A force of 3.5×10^{-2} N is exerted on the wire.

i. Calculate the angle the wire makes with the magnetic field. (2)

ii. Consider an electron within the wire drifting at a drift velocity of 8 mm s^{-1}. Calculate the number of electrons within the wire. (3)

(Total: 10 marks)

4.

a. A rectangular coil of area 10 cm^2 and 180 turns is rotated at a constant angular velocity ω=50 rad s^{-1} in a magnetic flux density of 0.5 T. Initially, at time t=0 s the normal to the coil is parallel to the magnetic field.

i. Write an expression for the flux linkage in terms of the angle that the normal to the coil makes with the magnetic field. (1)

ii. Find the time at which the flux linkage is 0.03 Wb for the first time after rotating from its initial position. (3)

iii. Calculate the peak e.m.f. generated at this frequency. (2)

iv. What is the angle between the coil's normal and the magnetic field when the peak e.m.f. is generated? (1)

v. Explain how the direction of the induced e.m.f. in the coil is determined with reference to the laws of electromagnetic induction. State the relevant conservation law. (3)

(Total: 10 marks)

5.

a. An alternating current supply with a frequency of 250 Hz is connected across a parallel plate capacitor of capacitance 8.0 μF in series with an ammeter. The root mean square voltage across the capacitor is 9 V.

i. Explain the term 'root mean square voltage'. (2)

ii. Calculate the peak current inside the circuit. (3)

iii. The circuit is incomplete due to the capacitor's dielectric between the plates. Explain whether it is possible for current to flow though the ammeter. (3)

iv. If the frequency is increased, explain how the current through the ammeter changes with reference to the voltage across the plates. (2)

(Total: 10 marks)

6.

a. A narrow beam of blue light is directed onto a diffraction grating of 300 line per mm.

i. Draw a diagram to show the diffraction of the beam. Include an intensity diagram up to the second order fringe. (4)

ii. The beam of light consists of two blue wavelengths of 450 nm and 490 nm. Calculate the angular separation between the second order maxima of the two beams. (4)

iii. If the beam consisted of white light, briefly explain what would be observed at the different fringes. (2)

(Total: 10 marks)

7.

a. An optical fibre has a core of refractive index 1.525 which is surrounded by a cladding of refractive index 1.465. A ray of monochromatic light enters one end of the core at an angle of incidence θ, as shown in Figure 2.

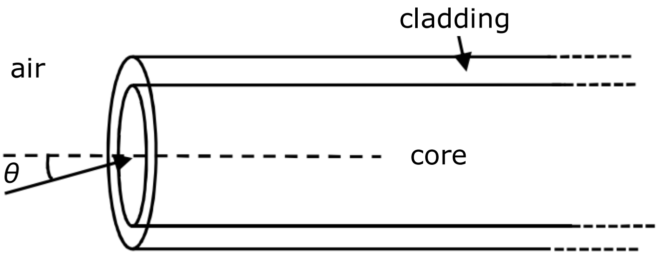

Figure 2

i. State the main application of an optical fibre and the optical phenomenon used to accomplish this. (2)

ii. Calculate the maximum angle θ at which the incident light must enter the core in order for the optical fibre to function properly. (5)

b. Consider an optical setup as shown in Figure 3.

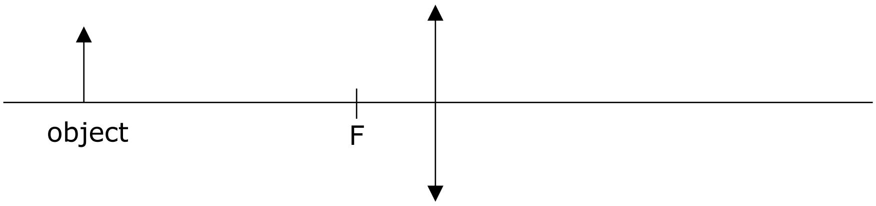

Figure 3

i. Copy Figure 3 and draw the image formed. (1)

ii. State **all** the properties of the image formed. What is the type of lens used? (2)

(Total: 10 marks)

8.

a. An ambulance drives past an athlete running in the street in the opposite direction. The ambulance is driving at 100 km hr^{-1} and its siren is emitting a sound at 700 Hz. The athlete is running at 6 m s^{-1}. The speed of sound in air is 300 m s^{-1}.

i. The athlete observes that the sound of the siren changes as the ambulance drives by him/her. State and define the phenomenon that gives rise to the athlete's observation.(2)

ii. Explain how the sound heard by the athlete changes as the athlete is running towards and away from the ambulance. (2)

iii. Calculate the frequency observed by the athlete as the ambulance is driving towards him/her. (4)

iv. Calculate the frequency observed by the athlete as the ambulance is driving away from him/her. (2)

(Total: 10 marks)

SECTION B

Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9.

a. A car piston is filled with an ideal gas. It is expanded isothermally from state A to state B, and then compressed to its original volume adiabatically to state C.

i. State an equation for the first law of thermodynamics and explain the sign convention used. (2)

ii. Explain the terms 'isothermal process' and 'adiabatic process'. For each process, identify the values which are equal to zero (if any) in the equation stated in part (a)(i). (3)

iii. Identify the process required for the gas to return to its original state A. (1)

iv. Sketch and label the complete cycle on a p-V graph. Indicate the temperatures of state A and state C with T_A and T_C and indicate which is higher. (3)

v. What does the area enclosed inside the cycle represent? (1)

b. An ideal gas at an initial pressure of 150 kPa undergoes isochoric heating such that its temperature is tripled. Determine its final pressure. (2)

c. Briefly describe the difference between a heat engine and a heat pump. Include a flow diagram for each object in your description. Name an everyday application for each type of system. (8)

(Total: 20 marks)

10.

a. Identify and describe the main evidence for the random motion of molecules in a gas.(2)

b. Using the kinetic theory for gases, pressure may be expressed as $pV=\frac{1}{3}Nm\overline{c^2}$.

i. List **FOUR** assumptions used in the kinetic theory of gases. (4)

ii. Derive $pV=\frac{1}{3}Nm\overline{c^2}$ using kinetic theory. (8)

iii. Given four molecules with respective speeds 2 m s^{-1}, 4 m s^{-1}, 2.5 m s^{-1} and 3 m s^{-1}, calculate the root mean square speed for these molecules. (2)

c. An ideal gas is trapped inside a container with a volume of 0.02 m^3 at a pressure of 175 kPa and a temperature of 300 K.

i. Calculate the number of moles and the number of molecules inside the container.(2)

ii. Find the average kinetic energy of each particle. (2)

(Total: 20 marks)

11.

a. Identify and explain the main mode of heat transfer when heating a fluid in the presence of a gravitational field. (3)

b. A well-insulated metal structure is made of three rods as shown in Figure 4. Rod 1 is made of aluminium with a thermal conductivity of 235 W m^{-1} K^{-1}. Rod 2 is made of brass and rod 3 is made of copper with a thermal conductivity of 398 W m^{-1} K^{-1}. Rod 1 is heated from its outer end at a temperature of 650 K, such that heat is transferred in one direction to the other end. Eventually, steady conditions are established throughout the metal structure such that the temperature at the other end is 460K.

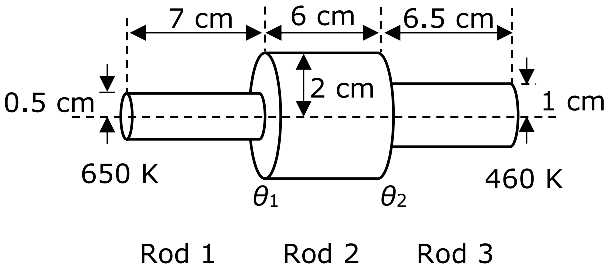

Figure 4

i. State an observation which indicates that steady conditions are established. (1)
ii. Explain how the steady conditions are reached. (3)
iii. Given that the rate of heat transfer within rod 1 is 40 W, calculate θ_1. (3)
iv. Hence, find the thermal conductivity of brass. (7)
v. Name a similarity on the atomic scale between thermal and electrical conductors. (1)
vi. Briefly distinguish between heat flow and electrical current on the atomic scale. (2)

(Total: 20 marks)

12.

a. Two identical hot air balloons, A and B, are tied by two strings each 1.5 m long to a 12 g mass and float in equilibrium. The balloons can be assumed to be spherical in shape and their centres are 0.7 m apart, as shown in Figure 5 below. As the balloons ascend through the air, they are constantly rubbing with water droplets until the equilibrium state is reached. A charge Q (which may be positive or negative) is accumulated on each balloon. The relative permittivity of humid air between the balloons is 1.3.

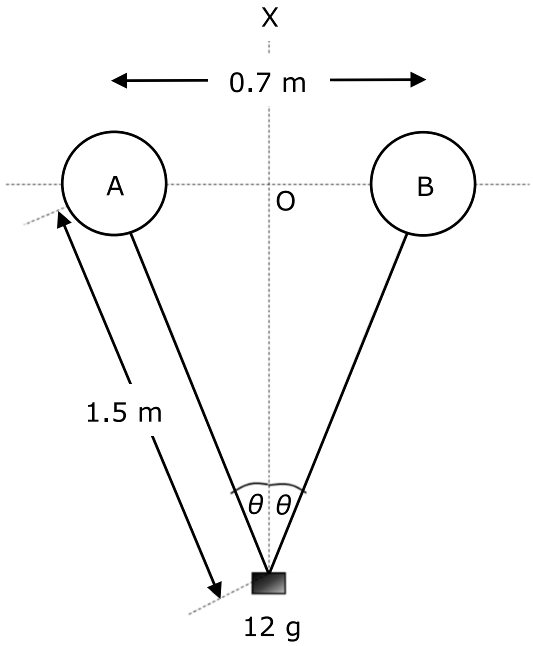

Figure 5

i. Will the charge accumulated on the balloons have the same polarity? Explain. (3)

ii. Sketch the electric field lines around the two charged balloons. (2)

iii. Define the term 'equipotential'. In your diagram from part ii. include **TWO** equipotential lines, one close to both balloons and one further away. (3)

iv. Write down an equation for the charge Q accumulated on each balloon in terms of the tension in each string, T, their separation, r, and θ. (4)

v. Find the charge Q on each balloon. (6)

vi. If the charge accumulated on balloon A is equal to 2Q instead, will the strings still make equal angles with the vertical through the hanging mass? Explain. (2)

(Total: 20 marks)

13.

a. A square parallel plate capacitor, of side L, is filled with a liquid of dielectric constant $\varepsilon_r = 3.5$. The plates are a distance of $L/50$ apart and the voltage across them is kept constant. The liquid leaks out such that its top surface decreases with velocity v as shown in Figure 6.

i. How is the capacitance affected as the liquid leaks out? Explain. (2)

ii. When the capacitor is completely filled with liquid, its capacitance is 100 pF. Calculate L. (3)

iii. Calculate its capacitance when all the liquid has leaked out. (2)

iv. Show that the total capacitance as a function of time is $C(t) = 25\varepsilon_0(7L - 5vt)$. (8)

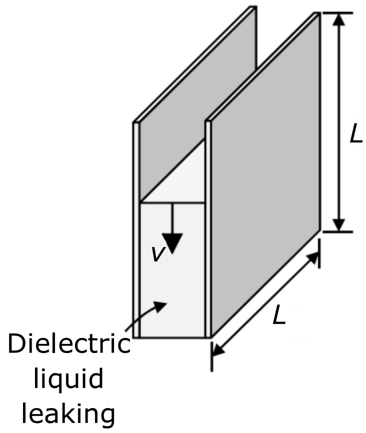

Figure 6

b. A 30 μF capacitor is fully charged from a 20 V power supply. It is then disconnected from the power supply and connected across an uncharged 50 μF capacitor. Calculate the final charge across the 50 μF capacitor. (5)

(Total: 20 marks)

14.

a. Describe a simple experiment to verify the laws of electromagnetic induction. Your description should include:

i. a list of equipment to be used; (2)

ii. a description of the method used; (2)

iii. a diagram of the setup; (2)

iv. all the observations made during the experiment which are associated with reference to one of the laws of electromagnetic induction. (3)

b. A coil of 15 turns and a radius of 10 cm is placed in a uniform magnetic field such that the flux links the coil normally. If the coil is removed completely from the field in 0.8 s, the average induced e.m.f. in the coil is 0.3 V. Calculate the magnetic field strength. (3)

c. A conducting rod of length l moves up an inclined plane with a constant velocity v in a uniform magnetic field directed vertically down as shown in Figure 7.

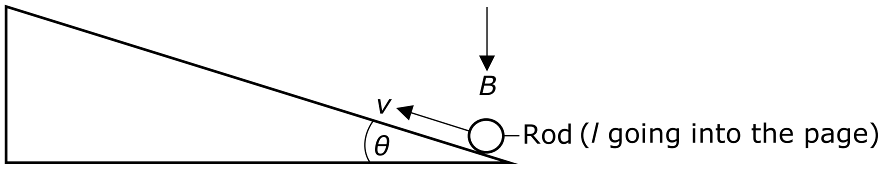

Figure 7

i. Derive an expression for the induced e.m.f. inside the rod. (4)

ii. The magnetic field strength is 5×10^{-4} T and the length of the rod is 1.2 m. When the rod is moved at a velocity of 3 m s^{-1}, an e.m.f. of 1.6×10^{-3} V is induced. Calculate the angle of inclination θ. (3)

iii. State the direction of the induced current (into or out of the page). (1)

(Total: 20 marks)

15.

a. Define simple harmonic motion. (2)

b. A spring rests on a large frictionless horizontal surface. One end of the spring is fixed to the surface and the other end is fixed to a mass, *m*, of 2 kg as shown in Figure 8. The mass is displaced a distance of 2 cm in the positive *x* direction from its equilibrium position, O. It is released to vibrate in simple harmonic motion such that it completes one whole oscillation in 3 s.

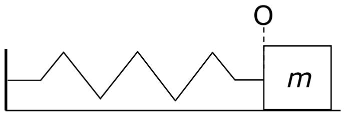

Figure 8

Calculate:

i. the stiffness constant of the spring; (3)
ii. the acceleration of the mass when it is 1 cm away from O; (2)
iii. the velocity of the mass when it is -0.5 cm away from O; (2)
iv. the shortest time the mass takes to travel from maximum distance on one side to a distance of 0.8 cm on the other side; (4)
v. the maximum kinetic energy. (1)

c. On the same axes sketch **THREE** curves showing how the kinetic, potential and total energy change with displacement from O. (3)

d. Explain briefly what is meant by mechanical resonance in vibrating systems and sketch a curve of amplitude against frequency for forced oscillations. (3)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III
DATE:	29th August 2023
TIME:	10:00 a.m. to 12:05 p.m.

Experiment: Investigating electrical circuits

Apparatus: Printed Circuit Board (PCB) with onboard electronic components, a chain of resistors, a multi-meter, battery and a stopwatch.

Diagram:

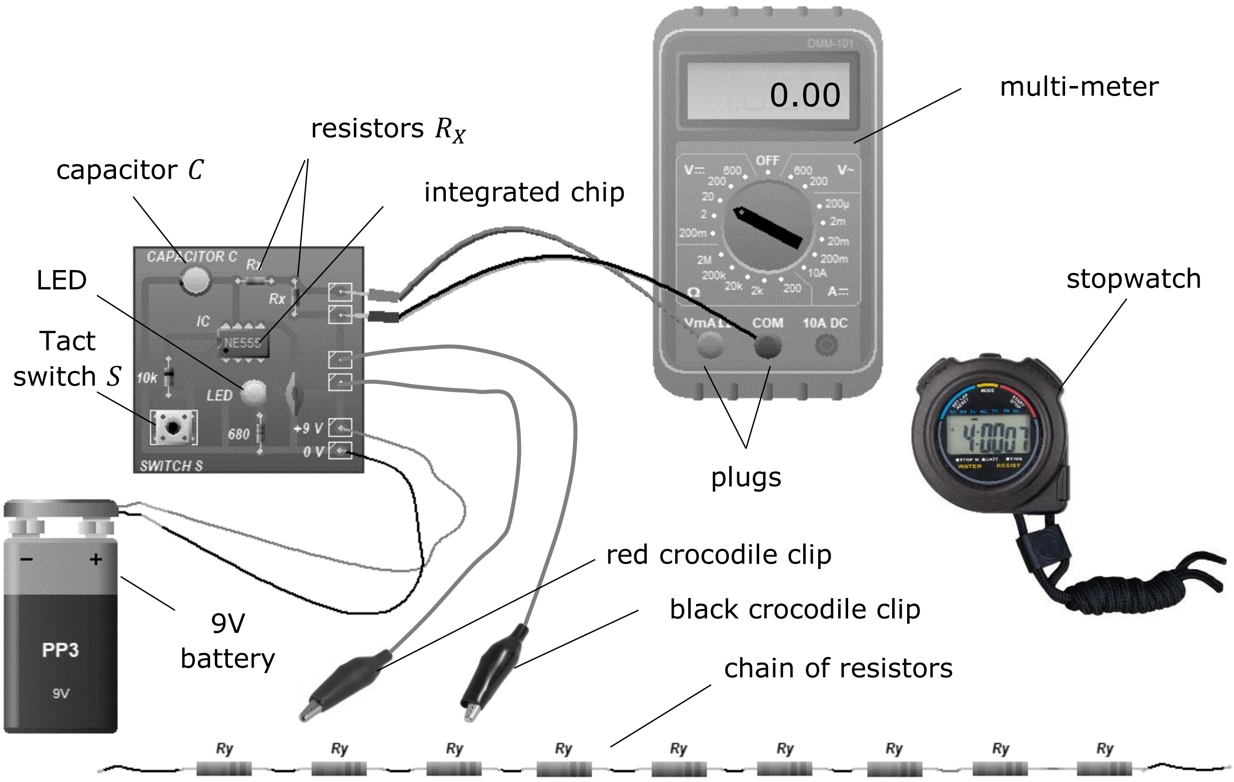

Figure 1: The experimental setup

Method – Part A:

1. The circuit board includes a number of resistors R_X, a tact switch S, a capacitor C, a LED and an integrated chip (IC) used as a timer. There is also a chain of identical resistors R_Y connected together.

2. The $9\ \mathrm{V}$ battery is already connected to the battery clip. If it is not, kindly ask for assistance as connecting it the wrong way round may damage the circuit.

3. Turn on the multi-meter and set it to read voltage up to $20\ \mathrm{V}$ d.c. The multi-meter should read $0\ \mathrm{V}$ for the time being.

Please turn the page.

4. State whether resistors R_Y are connected in series or in parallel.

____ (1)

5. Connect the red crocodile clip to one end of the chain of resistors and the black crocodile clip to wire joining the first and second resistor. The multi-meter should now show a voltage reading.

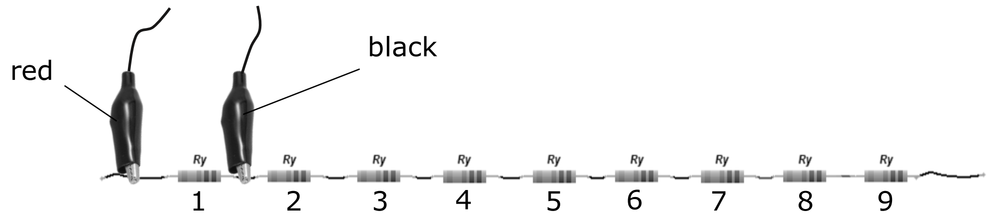

Figure 2

6. Record the voltage on the voltmeter in the row for $n = 1$ in Table 1, where n stands for the number of resistors connected between the two crocodile clips. (1)

7. Disconnect the black crocodile clip and connect it to the wire joining the second and third resistor. The red crocodile clip should be left connected to the end of the chain of resistors. Record the voltage in Table 1 in the row for $n = 2$. Repeat this procedure for all the resistors in the set. For $n = 9$, you should end up with the red crocodile clip connected to one end and the black crocodile clip connected to the other end. (8)

Table 1

Number of resistors	Voltage	
n	V/V	$\frac{1}{V}$ /V^{-1}
1		
2		
3		
4		
5		
6		
7		
8		
9		

8. Complete Table 1 by working out $\frac{1}{V}$ to two decimal places. (3)

9. It is known that the relation between the number of resistors and the voltage is given by

$$V = \frac{Q}{nR_Y + 2R_X}$$

where Q is a constant.

10. Show that the expression in step 9 can be written as $\frac{1}{V} = \frac{nR_Y}{Q} + \frac{2R_X}{Q}$.

____

____

____

____ (2)

11. Plot a graph of $\frac{1}{V}$ on the y-axis against n on the x-axis and draw the best straight-line graph through the plotted points. (8)

12. Use the graph to determine the value of Q and R_X. Each of resistors R_Y has a value of $22000\ \Omega$. Express R_X in $\mathrm{k\Omega}$.

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____

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____ (6)

13. The constant Q is given by $Q = V_T R_X$, where V_T is the terminal voltage of the battery.

14. Determine the terminal voltage V_T in Volts of the battery and state how it compares to the value of the one printed on the battery itself.

____

____

____ (2)

Method – Part B:

15. In this part of the experiment, you will need to disconnect the multi-meter by carefully removing the plugs.

16. The integrated chip uses the combination of resistors R_X and capacitor C to turn on a LED for a period of time. Once the tact switch S is pressed, the capacitor C starts charging and the LED is turned on. As soon as the voltage on the capacitor reaches $2/3$ the terminal voltage of the battery, the LED is turned off.

17. As soon as the switch S is pressed the capacitor, with capacitance C, will start charging through the two resistors R_X.

18. Briefly state how you would expect the voltage on either of the resistors R_X to change as the capacitor is charging.

    ____ (2)

19. The equation that relates the voltage V on the charging capacitor with time t is given by $V = V_T\left(1 - e^{-\frac{t}{2R_XC}}\right)$. Given that the LED remains turned on for the time it takes the voltage V on the capacitor to reach $\frac{2}{3}V_T$, show that this time is given $t = 2R_XC \times ln\, 3$.

    ____

    ____

    ____

    ____ (3)

20. Similar to what was done in Step 5, connect the red crocodile clip to one end of the chain of resistors and the black crocodile clip to wire joining the first and second resistor.

21. You will now use the stopwatch to measure the time the LED stays ON when only one resistor is connected between the crocodile clips. Press the switch and start the stopwatch. Ensure that the stopwatch is started at the same time that the switch is pressed.

22. Record the time in the column for T_1 in Table 2 in the row for $n = 1$. (1)

23. Repeat another two times to have three repeated readings. Record these two repeated time measurements in the columns for T_2 and T_3 in the row for $n = 1$ of Table 2. (2)

24. Disconnect the black crocodile clip and connect it to the wire joining the second and third resistor. The red crocodile clip should be left connected to the end of the chain of resistors.

25. For these two resistors, record three repeated time measurements T_1, T_2 and T_3 in Table 2 in the row for $n = 2$. (3)

26. Repeat this procedure for all the resistors in the set and each time take three repeated readings for the time. (21)

Table 2

n	T_1/s	T_2/s	T_3/s	$\bar{T}/s$
1				
2				
3				
4				
5				
6				
7				
8				
9				

27. Complete Table 2 by working out the average value for $\bar{T}$. (3)

28. The relationship between the time T that the LED stays on and the number of resistors n is given by $T = 1.1nR_YC + 2.2R_XC$.

29. Plot a graph of $T\ /s$ on the y-axis against n on the x-axis. (8)

30. Use the value of R_Y provided in step 12 and the graph plotted in step 29 to determine the capacitance C of the capacitor, clearly stating its unit.

____

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____ (3)

DO NOT WRITE ABOVE THIS LINE

31. Briefly state how the value of the capacitance obtained through the experiment compares with the printed value of the capacitance on the capacitor itself.

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____ (1)

32. State **ONE** possible source of error and **ONE** corresponding precaution that could be taken to improve the setup or the procedure.

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____ (2)