MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2019 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	27th April 2019
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 to be $9.81\ \mathrm{m\,s^{-2}}$ 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. The speed v of ocean waves, having wavelength λ, in deep waters can be approximated by the expression
   $$v = kg^p\lambda^q$$
   where k, p and q are constants.
      i. Write down the SI base units of v, g and λ. (3)
      ii. If the equation is homogeneously correct and k has no units, determine the values of p and q. (3)

   b. A ship is supposed to be travelling on a course due east with a speed of $20\ \mathrm{m\,s^{-1}}$. Wind and water currents take the ship off-course in a direction that is $10°$ south of east with an increased speed of $22\ \mathrm{m\,s^{-1}}$.
      i. Distinguish between speed and velocity. (2)
      ii. Calculate the combined velocity of the wind and water currents. The angle of the velocity vector should be given relative to the northern direction. (4)

(Total: 12 marks)

2. A child wishes to hit the top end of a goal post which is $2.4\ \mathrm{m}$ high by kicking a rock off the ground. The distance between the post and child is d.

   a. Determine the vertical speed required if the rock is to hit the post when it is at the maximum height of its trajectory. (3)

   b. Determine the time it takes the rock to hit the post. (3)

   c. Show that the angle θ from the ground and the initial speed v of the rock obey the relations $\tan\theta = \frac{4.8}{d}$ and $v^2 = \frac{gd^2}{4.8} + 4.8g$ respectively. (3, 3)

(Total: 12 marks)

3. A ball is released from rest from a height h above the ground. It bounces off the ground.

   a. State the principle of conservation of energy. (2)

   b. Explain the difference between elastic and inelastic collisions in terms of energy. What can you say about the resulting bouncing height of the ball in each type of collision? (2, 2)

   c. Sketch **TWO** energy against time graphs that clearly show how the potential energy and kinetic energy change with time as the ball is released from rest, bounces off the ground and reaches its possible maximum height for the elastic and inelastic collision cases. (3, 3)

   d. Derive an expression for the velocity v of the ball just before it hits the ground. (2)

(Total: 14 marks)

4. Two inextensible strings, each of length L, have one end attached to a slip ring, that can rotate freely on a vertical rod, and the other end attached to a small sphere of mass m, as shown in Figure 1. The distance between the slip rings is d. The sphere is set rotating in circular motion in a horizontal plane with the tension in the upper string being T_1 and the tension in the lower string being T_2.

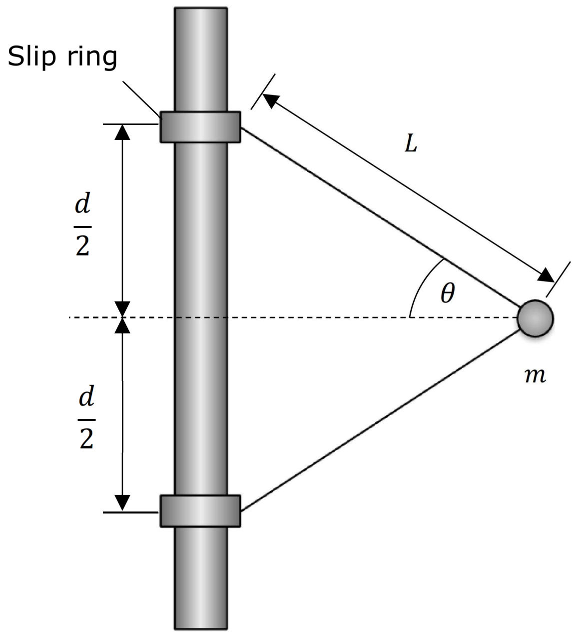

Figure 1

   a. Show that when both strings are taut the relation between the tension in the lower and upper strings is given by

$$T_2 = T_1 - \frac{2mgL}{d}$$

(5)

   b. Hence, show that the angular speed of rotation of the sphere is given by

$$\omega = \sqrt{\left(T_1 - \frac{mgL}{d}\right)\left(\frac{2}{mL}\right)}$$

(5)

   c. During rotation, the lower slip ring slides upwards so that the distance d decreases. Explain the effect that this has on the frequency of rotation of the sphere. (2)

(Total: 12 marks)

5. A shop owner wishes to hang a uniform $20\ \mathrm{kg}$ square sign of length $1\ \mathrm{m}$ just outside the shop by attaching it to a uniform $2\ \mathrm{kg}$ horizontal rod of length $4\ \mathrm{m}$. In order to hold the rod and sign in a horizontal position, a cable is attached from the end of the rod to a point on the wall that is $3\ \mathrm{m}$ above the hinge. The schematic diagram of the layout is shown in Figure 2.

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

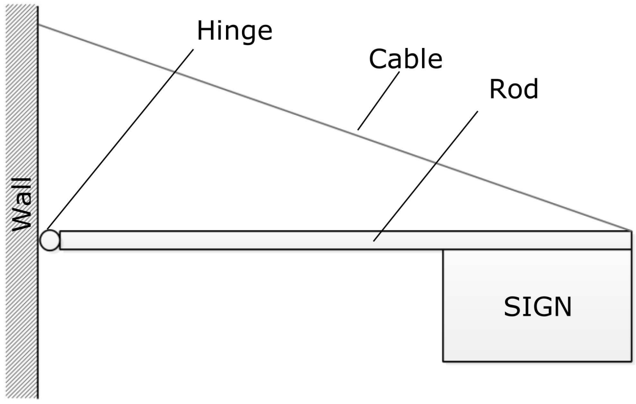

Figure 2

   b. Determine the tension in the cable required to keep the system in equilibrium. (4)

   c. Determine the magnitude and direction of the reaction force at the hinge. (4)

   d. Explain why it is desirable to keep the cable attached to the rod furthest away from the hinge. (2)

(Total: 12 marks)

6. A student is carrying out the photoelectric effect experiment to determine the value of Planck's constant. In the experiment, a stopping voltage V_S is applied to the anode of the photoelectric cell when it is illuminated with light passing through colour filters. The cathode has a work function ϕ. Figure 3 shows the graph obtained when plotting the stopping potential against the wavelength of light shone through colour filters on the cathode.

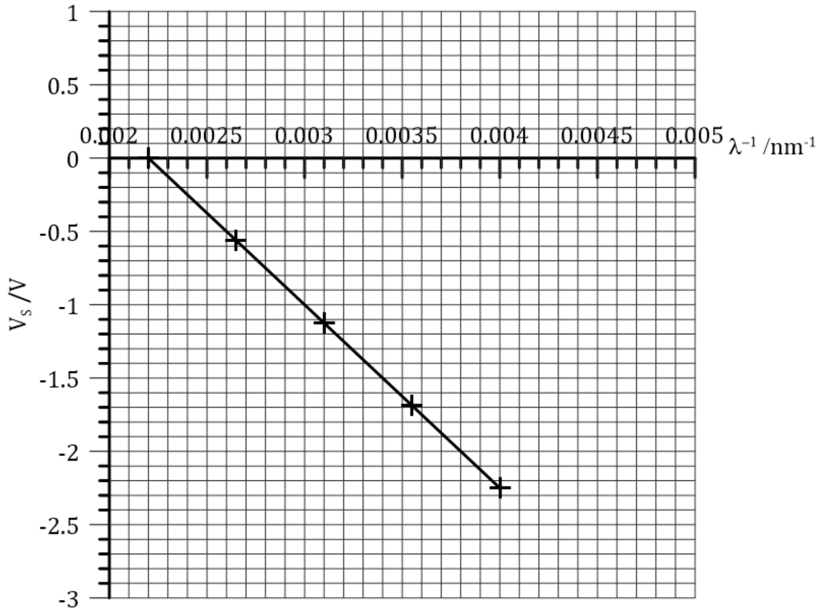

Figure 3

   a. Explain what is meant by work function of a material and the threshold frequency. (2, 1)

   b. Starting from the photoelectric equation, determine how the slope of this graph can be used to obtain the value of Planck's constant. Hence obtain its value. (4, 2)

   c. From the graph, determine the value of the threshold frequency. (2)

   d. For an incident source having a wavelength of $312.5\ \mathrm{nm}$, determine the maximum velocity of the emitted electrons. (3)

(Total: 14 marks)

7. A circuit is set up as shown in Figure 4.

a. State Kirchhoff's laws. (4)

b. State the **TWO** conservation laws that Kirchhoff's laws derive from. (2)

c. Determine the current flowing through the $3\,\Omega$ and $1\,\Omega$ resistors as well as their direction. Furthermore, obtain the value of the unknown emf ε. (2, 2, 1)

d. Determine the amount of charge that passes through the $2\,\Omega$ resistor in $10\,\text{s}$. (1)

(Total: 12 marks)

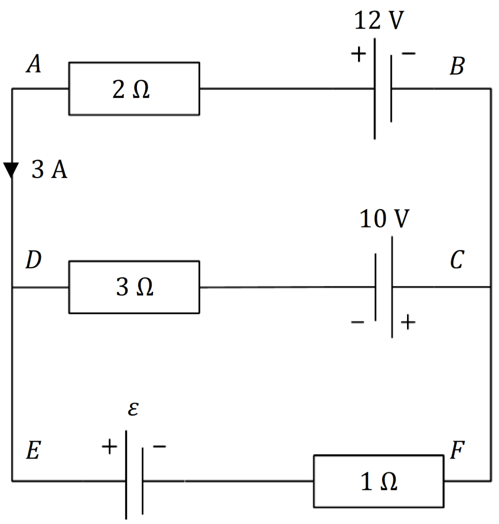

Figure 4

8.

a. Explain briefly how the use of atomic spectra can help distinguish between various elements and also determine the composition of objects like stars. (1, 2)

b. Four energy levels in a mercury atom have energies $-10.4\,\text{eV}$, $-5.5\,\text{eV}$, $-3.7\,\text{eV}$ and $-1.6\,\text{eV}$.

i. Explain the terms ground state, excited state and ionisation energy. (3)

ii. Calculate the frequency of the radiation emitted for a transition from the $-5.5\,\text{eV}$ to the $-10.4\,\text{eV}$ levels. (3)

iii. What is the resulting wavelength of this radiation? (1)

iv. Determine the momentum of the emitted photon. (2)

(Total: 12 marks)

SECTION B

Attempt any FOUR questions from this section. Each question carries 25 marks. This section carries 50% of the total marks for this paper.

9.

a. A cube with sides of length L and density ρ_f is placed gently on the surface of a liquid of density ρ. The cube floats such that the lower part of the cube is submerged, as shown in Figure 5.

i. Explain what is meant by upthrust (buoyant) force. (2)

ii. What is the necessary condition for the cube to float? (1)

iii. If the cube floats, derive an expression for the volume of the cube that is submerged once it reaches equilibrium. (5)

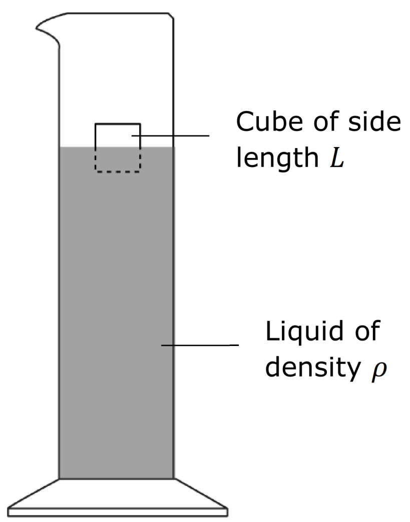

Figure 5

b. A second cube with sides of length L and density ρ_s is placed on the surface of the same liquid. The cube starts to sink with its base facing the sinking direction. As the cube continues to sink, a drag force F_D acts on the cube. Its velocity v is observed to increase until it reaches a constant value.

i. What is the final constant velocity called? (1)

ii. Draw a free-body diagram showing all the forces acting on the cube as it sinks through the liquid. (3)

iii. With reference to the diagram drawn in part (b)(ii), explain in detail how this final constant velocity is achieved, starting from when the cube is at rest on the surface of the liquid until constant velocity is achieved. In your explanation, a reference to Newton's laws must be included. (6)

iv. Sketch a velocity-time graph illustrating the whole process. (3)

v. The drag force F_D is given by $F_D = \frac{1}{2}\rho A v^2 C_D$, where A is the area of the object in the direction of flow, v is the cube velocity and C_D is the drag coefficient (which is a constant). Show that the final velocity is given by $v = \sqrt{\frac{2gL(\rho_S - \rho)}{\rho C_D}}$. (4)

(Total: 25 marks)

10.

a. A battery consists of 3 rows of n cells connected in series. The three rows are connected in parallel. Each cell has an emf of $10\,\text{V}$ and internal resistance $1\,\Omega$. The battery is then connected to an external resistor of resistance $5\,\Omega$.

i. Obtain the current flowing through the external resistor in terms of n. (6)

ii. Determine the voltage across the external resistor and across each internal resistance in terms of n. (4)

b. A circuit is set up as shown in Figure 6. The cell is assumed to be ideal and has an emf ε of $12\,\text{V}$. A voltage-time graph representing the voltage readings of the voltmeter is illustrated in Figure 7.

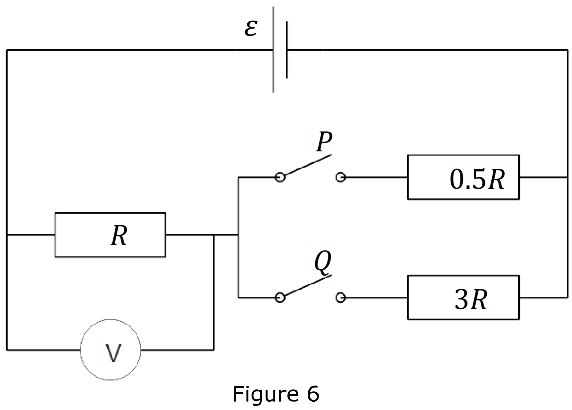

Figure 6

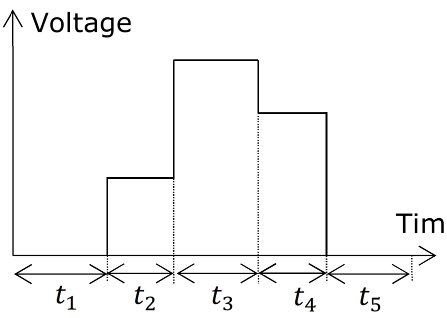

Figure 7

Determine:

i. the voltage read by the voltmeter when both switches P and Q are open; (1)

ii. the voltage read by the voltmeter when switch P is closed and Q is open; (2)

iii. the voltage read by the voltmeter when switch P is open and Q is closed; (2)

iv. the voltage read by the voltmeter when both switches P and Q are closed; (3)

v. from the voltage-time graph and the results obtained above, which switches are open and closed in each time interval (t_1 to t_5); (5)

vi. how the total charge that has passed through the resistor can be obtained from the graph. (2)

(Total: 25 marks)

11.

a. A solid sphere of mass m is attached to a string and is set into a vertical circular motion as shown in Figure 8. As the sphere revolves round, the tension T in the string changes with time as shown in Figure 9.

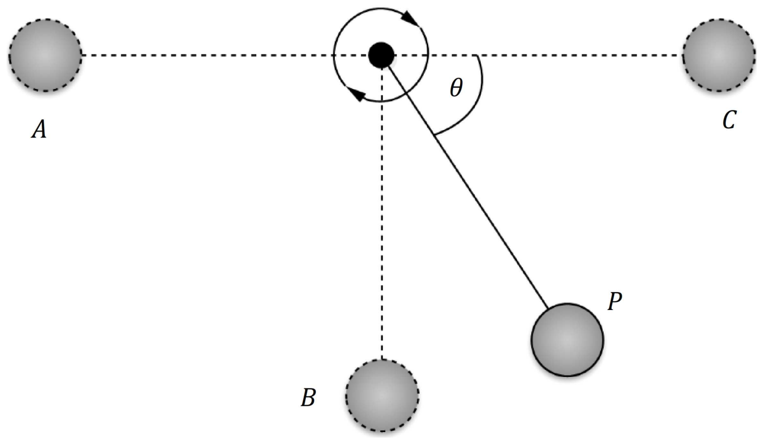

Figure 8

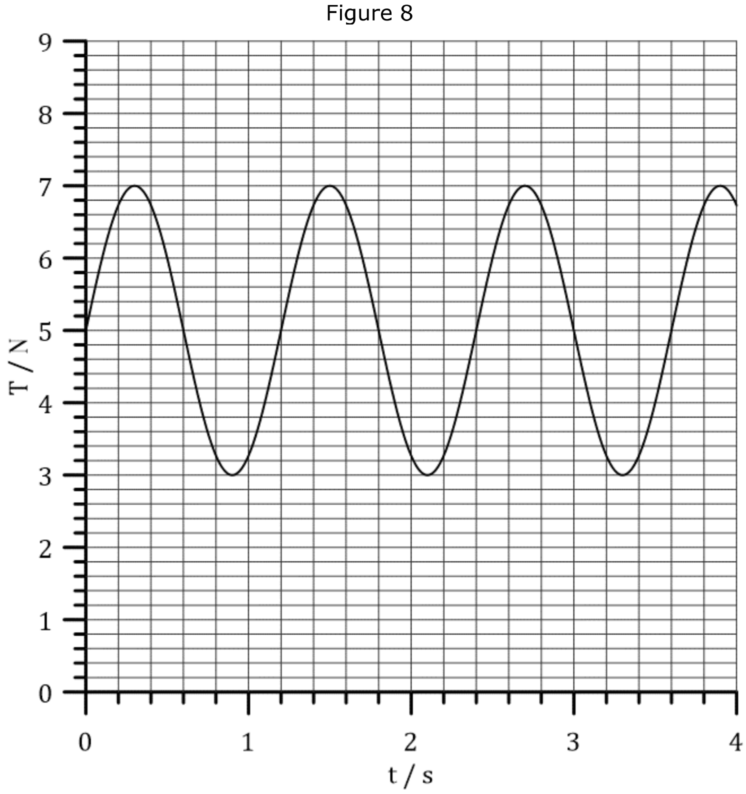

Figure 9

i. What is the initial position and subsequent motion of the sphere (B to A) or (C to B) if the rotation is clockwise? Explain how you arrived at your conclusion. (4)

ii. Show that for the sphere in position P, the tension in the string is given by

$$T = mr\omega^2 + mg\sin\theta$$

where r is the length of the string and ω is the angular velocity. (4)

iii. Using the graph, determine the mass of the sphere. (4)

iv. Determine the frequency of rotation using the graph. (2)

v. Calculate the resulting angular velocity. (2)

vi. Determine the length of the string. (3)

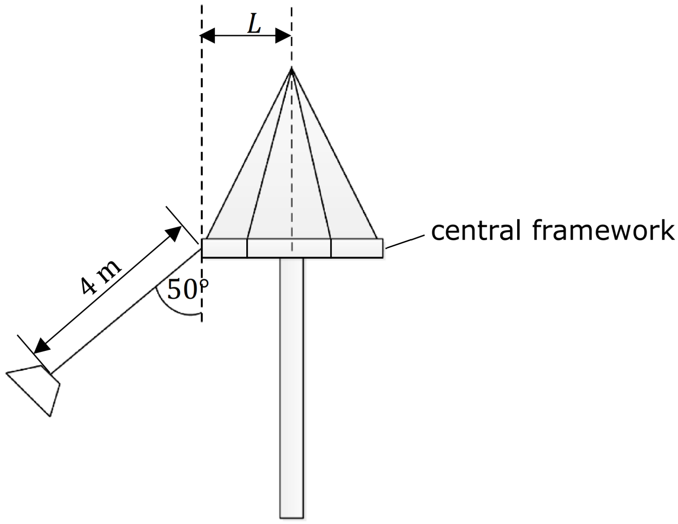

Figure 10

b. In most theme parks, one common ride involves a chair attached to a light chain attached to a central spinning framework. As the central framework spins, the chairs rise until they reach a desired angle, as shown in Figure 10. The maximum angle the chairs can be oriented to be considered safe is $50°$ to the vertical. If the system rotates at an angular speed of $1.5\ \mathrm{rad\ s^{-1}}$, and the chairs are oriented at $50°$, determine the length L. (6)

(Total: 25 marks)

12.

a. A new composite material is under testing to investigate its resistance properties in relation to changes in temperature.

i. Explain what is meant by temperature coefficient of resistance and describe the effects on the material's resistance when this quantity is positive and when it is negative. (3)

ii. Describe an experiment which could be carried out to obtain the temperature coefficient of resistance of this new composite material. Your description should include:

- the list of equipment that is needed; (2)
- a diagram of the circuit to be used; (2)
- the procedure to be followed and a table showing the data that needs to be observed and recorded; (2, 2)
- a sketch of the expected graph; (2)
- an explanation of how the graph is used to obtain a value for this coefficient. (2)

Question continues on next page

b. A circuit is set up as shown in Figure 11, with the switch S kept initially open. The LDR is kept initially uncovered having resistance R_L and the temperature of the thermistor is kept at some constant value T_0 with resistance R_0. The temperature coefficient of resistance of the thermistor is negative. Neglect the resistance of the ammeter.

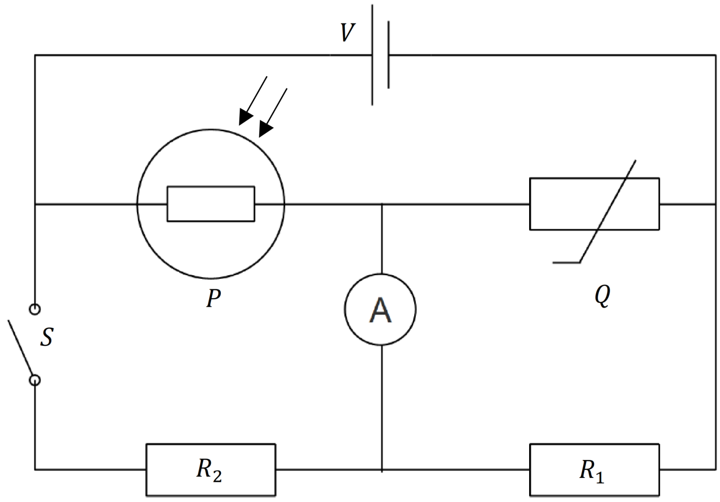

Figure 11

i. Identify the components P and Q. (1)

ii. Determine the ratio of the voltages across the LDR to that across the thermistor in terms of the resistances R_L, R_0 and R_1. (3)

iii. What happens to this ratio if:
- the LDR is covered; (2)
- the temperature of the thermistor is increased? (1)

iv. Switch S is now closed and the ammeter does not read any current. Derive an expression for the resistance of the thermistor in terms of the other resistances. (3)

(Total: 25 marks)

13.

a. Explain what is meant by saying that a substance is elastic. (2)

b. Figure 12 shows the variation of applied force F to two copper wires P and Q and their extension Δl. Both wires have the same length l_0.

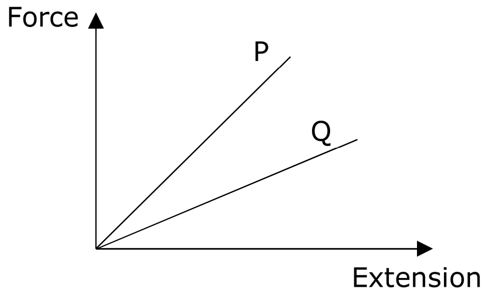

Figure 12

i. Define tensile stress and tensile strain and explain why these two quantities are better suited to describe the elastic properties of a material than force and extension. (4)

ii. Which of the two wires has the smallest cross-sectional area? Explain your answer. (3)

iii. Explain how you would use the graph for wire P to obtain a value for the Young modulus of copper and list any additional measurements that would be needed. (3)

iv. Show how it is possible to use the graph for wire P to determine the work done in stretching the wire. (3)

c. A high-speed lifting mechanism supports an object of mass $750\ \mathrm{kg}$ with a steel cable that is $25.0\ \mathrm{m}$ long and that has a cross-sectional area of $4.00\ \mathrm{cm}^2$. The Young modulus of steel is $20 \times 10^{10}\ \mathrm{Pa}$.
   i. Determine the extension of the steel cable. (3)
   ii. Calculate the additional amount that the cable increases in length if the object is accelerated upward at a rate of $3.0\ \mathrm{m\,s^{-2}}$. (4)
   iii. Determine the value of the greatest mass that can be accelerated upward at $3.0\ \mathrm{m\,s^{-2}}$ if the stress in the cable is **not** to exceed the elastic limit of the cable, which is $2.2 \times 10^8\ \mathrm{Pa}$. (3)

(Total: 25 marks)

14.

a. A radioactive source is emitting γ radiation. A scientist wishes to investigate the properties of this radiation. In order to do so, a Geiger-Müller tube is placed at different distances away from the source and the count rate at each distance is measured.
   i. When the Geiger-Müller tube was switched on but **not** placed incident to the incoming γ radiation, a non-zero count was observed. Explain why this occurs. (2)
   ii. A plot of count rate against the inverse square distance was observed to be linear. What is this property called? Explain this observation. (1, 2)
   iii. If the source were to emit α radiation instead, would this property also hold? Explain your answer. (2)
   iv. Given that the count rate at $0.2\ \mathrm{m}$ is $1500\ \mathrm{s^{-1}}$, determine the count rate when the Geiger-Müller tube is at a distance $0.5\ \mathrm{m}$ away from the source. (3)

b. The scientist then decides to test the absorption capabilities of concrete. With the Geiger-Müller tube in the same position as in part (a)(iv) above, a block of concrete having thickness $4\ \mathrm{mm}$ is now placed between the source and the tube. The count rate is now observed to be $226\ \mathrm{s^{-1}}$.
   i. Determine the absorption coefficient of concrete. (3)
   ii. Define half-value thickness and obtain its value. (3)

c. Carbon dating is a technique to determine the age of certain objects that contain organic material. This can be approached in two distinct ways. The first is to measure the age of the sediment in which an object is found, whilst the second is to measure the carbon count rate of the object itself.
   i. Explain the terms decay constant and half-life. State the relation between the **TWO** quantities. (2, 2)
   ii. The age of a buried, dead tree is to be determined. The carbon activity of the old tree is found to be 6 disintegrations per minute. If a living tree has an activity of 15 disintegrations per minute and the half-life of carbon is 5700 years, estimate the age of the tree in years. (5)

(Total: 25 marks)

Questions continue on next page

15.

a. Define what is meant by moment of inertia of a body. (2)

b. Explain what is meant by principle of conservation of angular momentum. (2)

c. A sphere of radius r and mass m is rolled along the level ground and given a linear velocity v_b. It then continues to travel up an incline and rolls off at the top. It is required that the sphere is projected the distance of $4.00\ \mathrm{m}$ as shown in Figure 13. The moment of inertia of the sphere about its centre of mass is given by $I = \frac{2}{5}mr^2$.

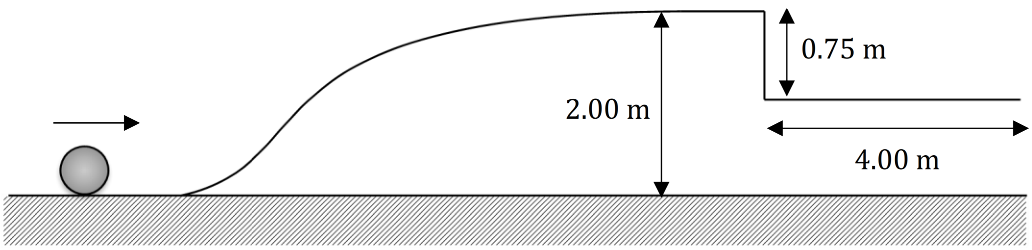

Figure 13

i. Use the principle of conservation of energy to show that the linear velocity of the sphere at the top v_t is related to the linear velocity of the sphere at the bottom v_b by the expression:

$$v_t^2 = v_b^2 - 28$$

(5)

ii. Determine the time taken for the sphere to fall the $0.75\ \mathrm{m}$ height from the top of the track. (2)

iii. Hence obtain the value of the linear velocity at the top of the track. (2)

iv. Determine the required initial velocity for the sphere to be able to complete this trajectory. (2)

d. Two ice skaters, each of mass $60\ \mathrm{kg}$ are travelling at $2\ \mathrm{m\,s^{-1}}$ towards each other. As they get close together, they each stretch out one of their arms of length $0.60\ \mathrm{m}$, grasp each other's hands and start to revolve round their combined centre of mass.

i. Determine the moment of inertia of the skaters around their centre of mass. (2)

ii. Calculate the kinetic energy of the system. (2)

After some time, the two skaters decide to move closer towards each other by $0.4\ \mathrm{m}$ simultaneously.

iii. Determine the new angular velocity of the skaters and the resulting kinetic energy. (2, 2)

iv. Explain the difference in kinetic energies calculated in parts (d)(ii) and (d)(iii). (2)

(Total: 25 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2019 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	27th April 2019
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 to be $9.81\ \mathrm{m\ s^{-2}}$ 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 what is meant by the statement 'After a long enough time, two objects A and B, that are in contact with each other, reach thermal equilibrium'. (2)

   b. Explain how the statement in part (a) is the underlying concept in determining if any two objects that are not in contact have the same temperature. (2)

   c. List **THREE** desirable properties of a thermometric property. (3)

   d. The glass bulb of a constant volume gas thermometer is placed in a liquid at a temperature T. The pressure of the gas at the triple point of water $(273.16\ \mathrm{K})$ is equivalent to $310\ \mathrm{mm}$ of mercury column height.
      i. Determine the pressure of the gas inside the constant volume gas thermometer at the triple point of water. Take the density of mercury to be $13{,}600\ \mathrm{kg\ m^{-3}}$. (2)
      ii. Calculate the temperature T of the liquid in degrees Celsius, if the height of the mercury column when measuring its temperature is $405\ \mathrm{mm}$. (3)
      iii. The temperature reading taken at the same time using a mercury-in-glass thermometer is $82.9\ °\mathrm{C}$. Suggest a reason for the difference between the two readings of temperature. (2)

(Total: 14 marks)

2. A wireless charging pad uses electromagnetic induction to deliver power to charge a mobile phone. The charging pad uses a tightly wound planar copper coil powered by an alternating current. The variation of current with time through the coil is described by the equation

$$I = 0.05\sin(280000\pi t).$$

   a. Explain what is meant by root-mean-square value of an alternating current. (2)

   b. The planar coil with inductance L has a reactance X_L.
      i. What is the peak value of the current through the coil? (1)
      ii. Calculate the root-mean-square value of the current. (2)
      iii. Sketch **TWO** graphs that show how the reactance changes with frequency and with inductance. (2, 2)
      iv. If the inductance is $0.11\ \mathrm{mH}$, calculate the reactance of the coil. (2)
      v. Calculate the peak voltage across the coil. (3)

(Total: 14 marks)

3.

a. Give word definitions for the terms specific heat capacity and specific latent heat of fusion. (2, 2)

b. An aluminium container contains $250\,\mathrm{g}$ of water with a specific heat capacity of $4.186\,\mathrm{kJ\,kg^{-1}K^{-1}}$. The aluminium container itself has a mass of $100\,\mathrm{g}$. The container and water are in thermal equilibrium at $10.0\,°\mathrm{C}$. Two metallic blocks are placed into the water. One is a $50\,\mathrm{g}$ piece of copper at $80.0\,°\mathrm{C}$. Another unknown sample has a mass of $70.0\,\mathrm{g}$ and is originally at a temperature of $100\,°\mathrm{C}$. The entire system stabilises at a final temperature of $20.0\,°\mathrm{C}$.

Table 1 – Table showing the specific heat capacities of a number of materials.

Material	**Specific Heat Capacity / $\mathrm{kJ\,kg^{-1}\,K^{-1}}$**
Aluminium	0.900
Beryllium	1.823
Cadmium	0.230
Copper	0.387
Silver	0.234
Water	4.186

i. Determine the specific heat capacity of the unknown sample. (5)

ii. Can you identify a possible material from the data in Table 1? Explain your answer. (3)

(Total: 12 marks)

4. Figure 1 shows two charges fixed in empty space. Point charge A is a positive charge of $+0.80 \times 10^{-6}\,\mathrm{C}$ and point charge B is a negative charge of $-0.60 \times 10^{-6}\,\mathrm{C}$. Charges A and B are $0.08\,\mathrm{m}$ apart.

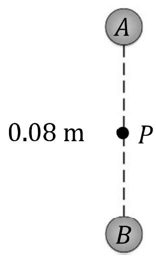

Figure 1

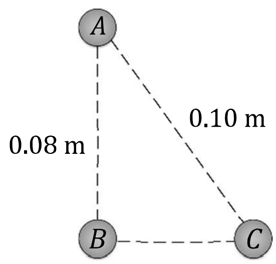

Figure 2

a. Define electric field strength at a point in an electric field. (1)

b. Copy the diagram of Figure 1 and on it include the electric field lines between the two charges. (2)

c. Calculate the electric field strength at point P, which is midway between charges A and B. (3)

d. A third point charge C which is positively charged with a charge of $+1.0 \times 10^{-6}\,\mathrm{C}$ is brought near the first two charges such that all three point charges are now positioned at the vertices of a right angled triangular shape, as shown in Figure 2.

i. Calculate the magnitude of the electric force on charge B due to the other two charges. (4)

ii. Determine the direction with respect to the horizontal in which this electric force acts. (2)

(Total: 12 marks)

5.

a. Define Simple Harmonic Motion. (2)

b. A small sphere of mass m is attached to one end of a light spring having spring constant k. The other end of the spring is attached to a fixed support so that the sphere can perform vertical oscillations. The sphere is pulled downwards and released so that it starts oscillating. Show that these oscillations are simple harmonic and derive an expression for the periodic time T. (5)

c. The vertical displacement y in metres of the sphere about its equilibrium position can be described by $y = 0.04\sin(0.7t)$.

i. What is the value of the amplitude of the oscillation? (1)

ii. Calculate the periodic time T of oscillations. (2)

iii. Write down a second equation that describes the motion of a second identical sphere in an identical setup which is oscillating out of phase and leading the first one by $\frac{T}{4}$. (2)

(Total: 12 marks)

6.

a. State Snell's law of refraction for incident light going through two transparent media with refractive indices η_1 and η_2. (2)

b. Light incident on a boundary between two transparent media can be totally reflected back at the boundary. State **TWO** conditions required for this happen. (2)

c. A horizontal monochromatic light ray of wavelength $590\,\text{nm}$ in air enters an isosceles crown glass prism. The crown glass prism has a refractive index η equal to 1.5.

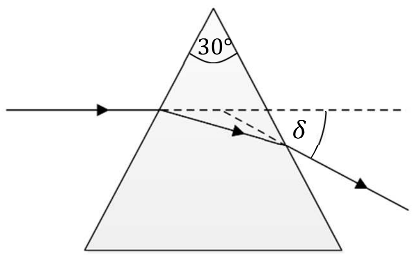

Figure 3

i. Calculate the wavelength of the monochromatic light in glass. (2)

ii. Calculate the angle δ that the emerging light ray makes with the horizontal. (6)

(Total: 12 marks)

Questions continue on next page

7. In 1929, Edwin Hubble discovered that the velocity v with which nearby galaxies recede away from our galaxy is related to the distance D between the two. Doppler shift of light emanating from stars in a galaxy usually determines whether the galaxy is receding or not and with what velocity it is doing so.

   a. State Hubble's law and write down its mathematical representation. (2, 1)

   b. Hubble estimated the Hubble's constant to be $16 \times 10^{-18}\ \mathrm{s}^{-1}$. However, in July 2018 the Planck Mission published its calculated value of the Hubble constant to be $H_0 = 2.184 \times 10^{-18}\ \mathrm{s}^{-1}$.
      i. Why is there such an uncertainty in the Hubble constant? (2)
      ii. Determine the age of the Universe, in billions of years, using both values of Hubble's constant. (2, 2)

   c. Receding galaxies are one evidence of the Big Bang Theory.
      i. Explain the term Doppler shift and describe briefly how this is used to determine the velocity of recession of a galaxy. (2)
      ii. State **ONE** other piece of evidence that backs the Big Bang theory. (1)

(Total: 12 marks)

8. A video clip on the Internet markets a self-expanding polyurethane foam that is sprayed on the inside of wooden walls to decrease heat losses from a house. The inside temperature is $20\ ^\circ\mathrm{C}$, the outside temperature is $0\ ^\circ\mathrm{C}$ and the wooden wall and insulating foam have equal thicknesses with conductivities of $0.13\ \mathrm{W\,m^{-1}\,K^{-1}}$ and $0.022\ \mathrm{W\,m^{-1}\,K^{-1}}$ respectively.

   a. State **ONE** condition that is necessary for heat to flow in **all** modes of heat transfer. (1)

   b. Explain why it is more likely that an insulating substance in the form of a foam usually acts as a good insulator. (2)

   c. Calculate the temperature at the interface between the insulating foam and the wooden wall. (4)

   d. Calculate the temperature at the interface if the wood is on the inside and the foam is sprayed on the outside. (4)

   e. Does it matter whether the foam is sprayed on the inside or the outside of the wooden wall? Explain. (1)

(Total: 12 marks)

SECTION B

Attempt any FOUR questions from this section. Each question carries 25 marks. This section carries 50% of the total marks for this paper.

9.

   a. A vacuum flask full of hot coffee is shaken. Explain the changes, if any, that take place in:
      i. its internal energy; (2)
      ii. temperature of the coffee. (1)

   b. State the law with which you derived your conclusions to part (a) and write its mathematical representation explaining any symbols used. (1, 3)

c. An ideal gas enclosed in a container with a tightly fit moveable piston is in contact with a heat reservoir so that it remains at a constant temperature of $300.0\ \mathrm{K}$. The gas, initially at a pressure 3 times atmospheric pressure, is compressed from a volume of $0.024\ \mathrm{m^3}$ to a volume of $0.014\ \mathrm{m^3}$. During the process, the mechanical device pushing the piston to compress the gas is found to expend $5.00\ \mathrm{kJ}$ of energy. Take atmospheric pressure to be $1.01 \times 10^5\ \mathrm{Pa}$.

i. Draw a PV diagram that shows the process undergone by the gas and indicate clearly the initial and final states of the gas. (4)

ii. On the same PV diagram shade the area that represents the work done on the gas. (2)

iii. Determine the amount of heat that flows between the heat reservoir and the gas and state the direction in which the heat flow occurs. (3)

iv. Calculate the number of moles of gas present in the container. (2)

v. Calculate the final pressure reached by the gas after compression. (2)

d. A heat pump water heater is being marketed as being more efficient than the traditional element water heater. The heat pump water heater absorbs heat from the ambient air and delivers it to the water. Describe, through the use of a schematic diagram, how a heat pump operates. (2)

e. In a certain steam engine, the boiler temperature is $127\ ^\circ\mathrm{C}$ and the cold reservoir temperature is $27\ ^\circ\mathrm{C}$. While this engine does $6.2\ \mathrm{kJ}$ of work, calculate the minimum amount of heat that must be discharged into the cold reservoir. (3)

(Total: 25 marks)

10.

a. A student sets up the experiment to observe, what the British botanist Robert Brown did in 1828, the phenomenon known as Brownian motion.

i. Describe briefly what the student will observe. (2)

ii. List the main deductions from the observations of Brownian motion. (3)

b. A container in the form of a cube of side length L contains N molecules of an ideal gas each of mass m. A single molecule is travelling with a velocity u_x in the positive x-direction towards one of the surfaces of the cube and normal to it. Let u_y and u_z be the velocity components of the molecule in the other perpendicular directions.

i. Derive an expression for the change in momentum Δp_x of the single molecule as it hits the surface when moving in the positive x-direction. (3)

ii. Hence, derive an expression for the average force F_{av} in the x-direction that a single molecule exerts on the surface of the container. (3)

iii. Show that the total force F exerted by the N molecules on this surface is given by

$$F = \frac{Nm < u_x^2 >}{L}$$

(1)

iv. Also, show that the pressure by the N molecules inside the container is given by

$$P = \frac{1}{3}\rho < u^2 >$$

where ρ is the density of the gas and $u^2 = u_x^2 + u_y^2 + u_z^2$. (4)

c. Show that the root mean square speed of a molecule in an ideal gas at an absolute temperature T is given by $u_{rms} = \sqrt{\left(\frac{3kT}{m}\right)}$ where k is Boltzmann's constant. (4)

d. A cylinder contains $0.002\ \mathrm{m}^3$ of oxygen gas (O_2) at a pressure $0.9 \times 10^4\ \mathrm{Pa}$ and a temperature of $27°\mathrm{C}$. Molar mass of oxygen gas (O_2) is $32\ \mathrm{g}$. Calculate:
   i. the number of moles of oxygen in the cylinder; (2)
   ii. the number of molecules; (1)
   iii. the root mean square speed of the molecules in the container. (2)

(Total: 25 marks)

11.

a. Our planet Earth of mass M_E rotates in an orbit of radius R around the Sun of mass M_S. Assume the Earth to have a perfect spherical shape of radius R_E and an average density given by ρ.
   i. What is the nature of the force that keeps the Earth revolving round the Sun? (1)
   ii. Write down an equation for this force acting on planet Earth due to the Sun. (2)
   iii. State what is meant by gravitational field strength at a point in a gravitational field. (2)
   iv. Show that the gravitational field strength g at the surface of the Earth is given by $g = \frac{4}{3}\pi\rho R_E G$. (4)
   v. Derive an expression that relates the periodic time T of rotation of the Earth around the Sun in terms of G, M_S and R. (4)
   vi. Taking the periodic time T for the Earth to go around the Sun to be approximately 365 days, and R to be $1.50 \times 10^{11}\ \mathrm{m}$, calculate the mass of the Sun. (3)

b. The escape speed from the surface of the Earth is $11.2\ \mathrm{km\,s^{-1}}$.
   i. Explain what is meant by gravitational potential at a point in a gravitational field. (2)
   ii. Derive an expression for the escape speed. (3)
   iii. Determine the escape speed from another planet that has the same density as Earth but twice the radius of Earth. (4)

(Total: 25 marks)

12.

a. A parallel plate capacitor consists of two conducting metal plates positioned parallel to each other and separated by a dielectric.
   i. Define the capacitance of a capacitor. (2)
   ii. Sketch **TWO** graphs to show how the capacitance C of a parallel plate capacitor varies with the area of the plates and their separation. (2)
   iii. State **TWO** important characteristics of a dielectric. (2)

b. A condenser microphone consists of a parallel plate air capacitor, a resistor and a power source as shown in Figure 4. Changes in voltage across the resistor are then fed to an audio amplifier. One of the round plates is fixed while the other moves to and fro with the incoming sound waves. The plates have a radius of $3\ \mathrm{mm}$ and when no sound waves are incoming the plates are separated by $1\ \mathrm{mm}$ of air.

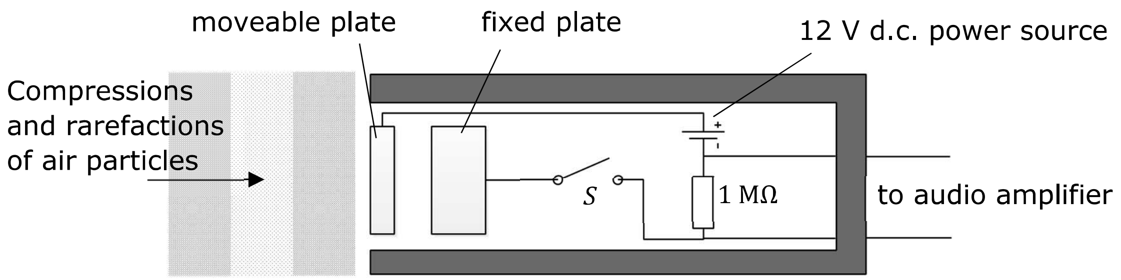

Figure 4

i. Explain why the only dielectric suitable for the capacitor in this microphone is air. (2)

ii. Calculate the capacitance of the capacitor when no sound is being captured by the microphone. (2)

iii. The switch S is turned on. Calculate the time it takes the capacitor to charge up to 90%. (3)

iv. Calculate the total charge that can be stored on the capacitor. (2)

The capacitor is now fully charged. A sound pressure wave reaches the microphone and in the first instant pushes the moveable capacitor plate inwards, increasing the capacitance of the capacitor by 50%.

v. Calculate the temporary voltage on the capacitor at the instant when this increase in capacitance first occurs. (3)

vi. In which direction, clockwise or counter-clockwise, will current flow through the circuit? (1)

vii. Sketch a graph that shows how the voltage on the capacitor changes with time before and after the sound pressure wave hits the microphone. (3)

viii. In a second instant the sound pressure wave pulls the moveable plate away from the fixed plate. Explain the changes, if any, in the direction of the current through the circuit. (3)

(Total: 25 marks)

13.

a. Distinguish between stationary waves and progressive waves by mentioning at least **THREE** differences between the two types of waves. (3)

b. Explain the principle of superposition of waves. (2)

c. A microwave source is place at a distance of $1\ \mathrm{m}$ from a vertical metal sheet. The metal sheet acts as a reflector of microwaves. A detector is placed between the microwave source and reflector, along the normal line joining the source and reflector. As the reflector is moved further away from the source, the detector detects a minimum microwave radiation at $2.5\ \mathrm{cm}$ intervals.

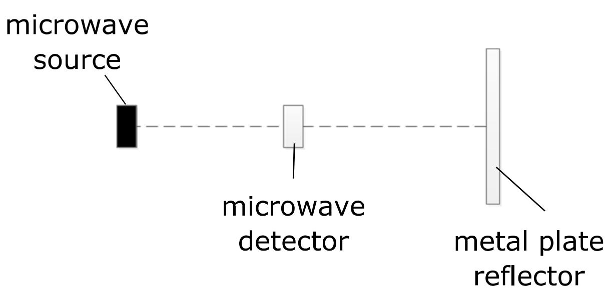

Figure 5

i. Draw a diagram to illustrate how the stationary waves are set up between the source, detector and reflector. (2)

ii. Calculate the frequency of microwave radiation emanating from the source. (2)

Question continues on next page

d. A paper inkjet printer ejects tiny dots of ink on the page. The distance between the dots of ink should be small enough so that a human eye can't resolve the individual dots and a smooth picture or text is seen on the page. Assume that text is printed in violet colour (wavelength of violet light is $400\ \text{nm}$), the pupil in the eye is a circular aperture with a diameter of $2.5\ \text{mm}$ and that the approximate viewing distance of the page is $40\ \text{cm}$.

i. Calculate the maximum distance apart that the dots can be, such that the individual dots **cannot** be resolved. (4)

ii. Explain why this maximum distance calculated for violet light holds for other colours in the visible electromagnetic spectrum. (1)

e. The wave nature of light can be demonstrated by Young's double slit experiment. This experiment can also be used to determine the wavelength of a monochromatic light source. Describe this experiment. In your description include:

i. a list of the apparatus that is needed; (2)

ii. a diagram of how the apparatus should be set up, including relative distances between each component of the apparatus; (2)

iii. a description of the method used to carry out the experiment, including a table of the data to be recorded from the experiment; (3)

iv. a labelled graph; (2)

v. the calculations that are required to obtain the wavelength of the monochromatic light source. (2)

(Total: 25 marks)

14. Figure 6 shows a source of charged particles being accelerated through a potential difference of ΔV volts applied across two metal plates. The particles then enter a magnetic field with magnetic flux density B pointing out of plane of paper. The charged particles end up on a detector.

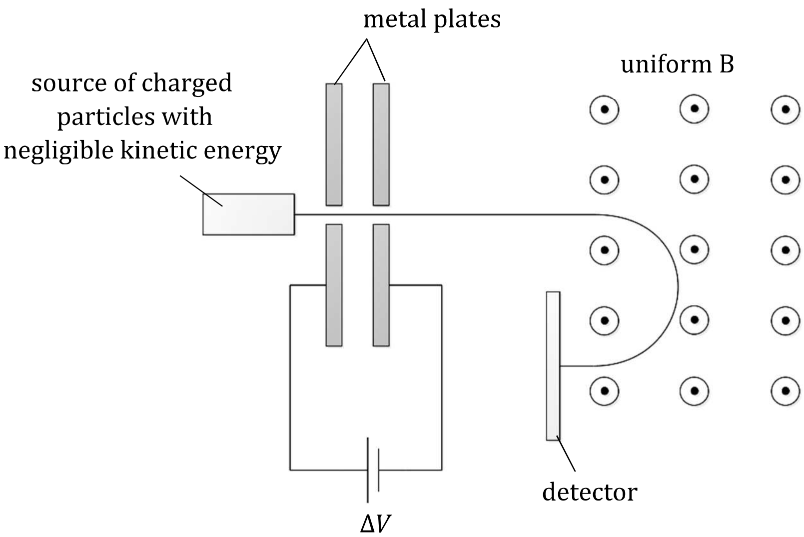

Figure 6

a. What is the polarity of the charges that are accelerated through the metal plates? Explain. (2)

b. Define the term magnetic flux density and write down its mathematical representation. Explain any symbols used. (3)

c. The particles from the source have negligible kinetic energy.
   i. Explain why the charged particles exiting from between the metal plates all have the same kinetic energy. (2)
   ii. For a charged particle having mass m, derive an expression for the velocity v with which the particle leaves the metal plates. (3)

d. As the charges enter the magnetic field, they experience a force at right angles to their direction of travel.
   i. Explain why this is so and state any rule that is used to determine the direction of the force. (3)
   ii. Starting with $F = BIL$, the force on a current carrying conductor of length L carrying current I in a magnetic field B, show that the force exerted on a charged particle carrying charge q entering the magnetic field with speed v is given by $F = Bqv$. (4)
   iii. The particles execute a circular path. Show that the radius of the path is given by $r = \frac{mv}{Bq}$. (2)

e. Two equally charged particles q_1 and q_2 of mass $6.015\ \mathrm{u}$ and $7.016\ \mathrm{u}$ respectively enter the magnetic field. The radius of the path taken by q_1 in the magnetic field is $8.4\ \mathrm{cm}$. Calculate the radius of the path taken by q_2. (3)

f. The fact that a charged particle in a magnetic field undergoes circular motion is the principle behind the operation of ring accelerators. Show that the supply frequency f of one such ring accelerator is given by $f = \frac{Bq}{2m\pi}$. (3)

(Total: 25 marks)

15.

a. Explain the meaning of magnetic flux linkage. (1)

b. State Faraday's and Lenz's laws of electromagnetic induction. (2, 2)

c. In the following diagram (Figure 7), the primary coil of negligible resistance is connected to a $12\ \mathrm{V}$ supply and a switch S which is initially open. The secondary coil is close to the primary coil. The switch S is closed, and then opened again a few seconds later.

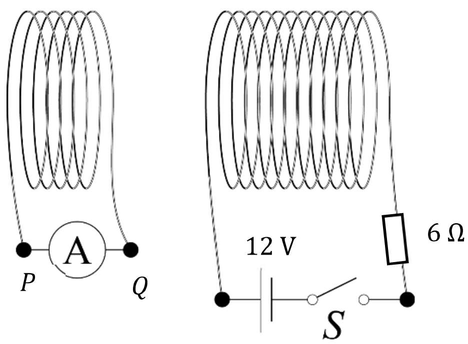

Figure 7

   i. Draw a graph that shows how the current through the primary coil changes with time from the moment switch S is closed. (3)
   ii. The initial rate of change of current is $0.5\ \mathrm{A\,s^{-1}}$. Calculate the self-inductance L of the coil. (2)
   iii. Calculate the energy stored in the primary coil. (1)

iv. In what direction does current flow through the ammeter connected to the secondary coil when switch S is closed (P to Q or Q to P)? (2)

d. The power source of the primary coil is replaced by an alternating current source and the ammeter in the secondary coil is replaced by a p-n junction diode and a load resistance R, as shown in Figure 8.

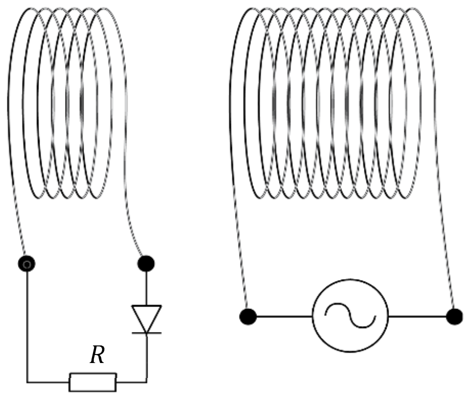

Figure 8

i. Explain briefly what is meant by potential barrier and depletion layer of a p-n junction diode. (2, 2)
ii. Describe what happens to the majority and minority charge carries in both types of semiconductor when the current is flowing with the p-n junction diode in forward bias mode. (3)
iii. The single p-n junction diode provides half-wave rectification. Sketch a graph to show how the emf across the resistance R varies with time. (2)
iv. Full-wave rectification and smoothing can be obtained by connecting four p-n junction diodes and a capacitor. Draw a circuit diagram that shows a full-wave rectification circuit with smoothing. (3)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

L-Università ta' Malta

ADVANCED MATRICULATION LEVEL
2019 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III – *Practical*
DATE:	4th June 2019
TIME:	2 hours 5 minutes

Experiment: Experiments with Lenses

Apparatus: light bulb, cardboard box enclosure with metal grid, convex lens, concave lens, metre ruler and screen.

Diagram:

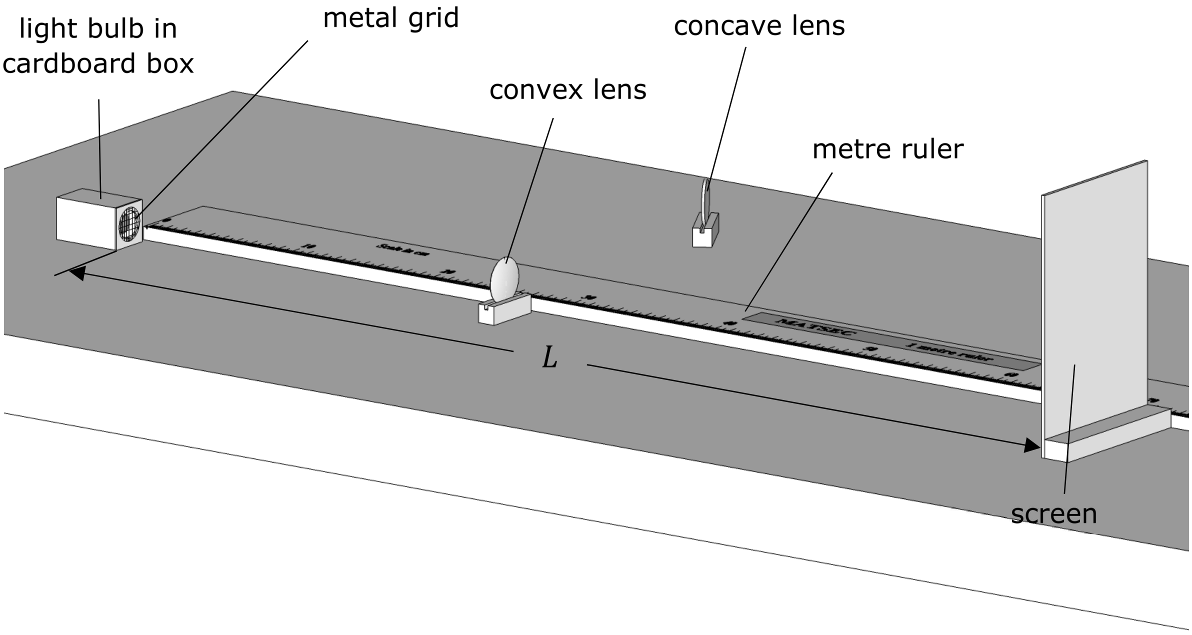

Figure 1 The experimental setup

Method – Part A:

1. Set up the optical system in the order shown in Figure 1 above.
2. The metal grid on the front of the cardboard box containing the bulb will act as the object for this first part of the experiment. Make sure that the metal grid on the front face of the cardboard box is aligned next to the $0\ \text{cm}$ mark on the metre ruler.
3. Place the screen such that it is at a distance L of $70\ \text{cm}$ from the object.

4. For a fixed object to screen distance, the convex lens can produce a sharp real image at two positions along the optical axis. Write down the thin lens equation and refer to it to explain this statement.

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(4)

5. Place the convex lens nearer to the light bulb than the screen and find the first position where a sharp image of the object is formed on the screen.
6. With the lens in this position, use the metre ruler to determine the distance d_1 between the lens and the screen. Write this down in Table 1. (2)
7. Move the convex lens to a position that is nearer to the screen than it is to the object until a second sharp image of the object is obtained on the screen.
8. Using the metre ruler, determine the distance d_2 between the lens and the screen. (2)
9. Change the distance L between the object and the screen according to the values shown in Table 1 and repeat steps 5 to 8. Each time you change the value of L, a pair of readings of d_1 and d_2 should be recorded. (16)

Table 1

L / cm	d_1 /cm	d_2 /cm	$D = d_1 - d_2$ /cm	$L^2 - D^2$ /cm^2
70				
75				
80				
85				
90				

10. Work out the values of D /cm and the values of $L^2 - D^2$/cm^2 in Table 1 above. Note that the distance D is the distance moved by the lens from position 1 to position 2. (10)
11. The focal length f of the lens is related to the distance L and the distance D by the expression:

$$L^2 - D^2 = 4fL$$

12. Plot a graph of $L^2 - D^2$ /cm^2 on the y-axis against L /cm on the x-axis. (10)

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13. Use the graph to determine the focal length f of the convex lens.

(5)

14. The equation in Step 11 indicates that there is a minimum value of distance L within which a real image can be formed. Derive in terms of f this minimum value of the distance L and calculate its value.

(4)

Method – Part B:

15. In this part of the experiment, the image produced by the convex lens will serve as a virtual object for a concave lens such that the latter can produce a real image on screen.
16. Place the convex lens at about $30\ \mathrm{cm}$ from the light bulb along the optical axis.
17. Move the screen until a sharp image is obtained, as in Figure 2.

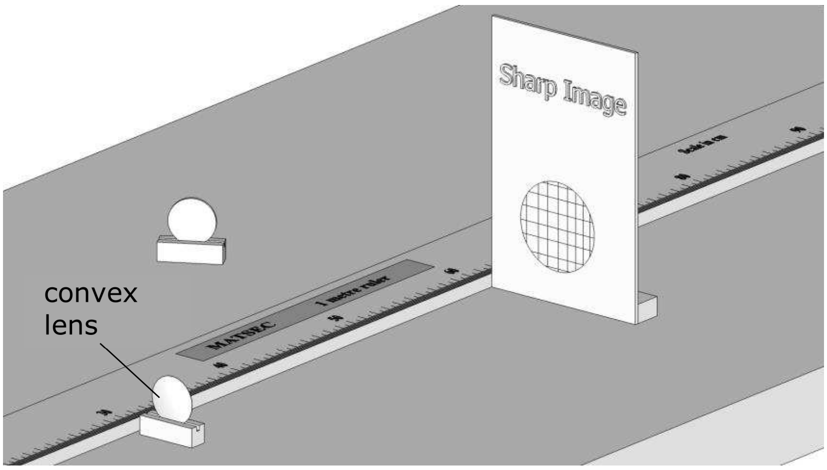

Figure 2

18. Place the concave lens between the convex lens and the screen and adjust their separation P to be $24.0\ \mathrm{cm}$ which is the first value of P shown in Table 2. The image on the screen should become blurred (see Figure 3).
19. Use the metre ruler to measure the distance between the concave lens and the screen u'. This distance is the (virtual) object distance for the concave lens. Record this in the column for u' in Table 2. The recorded values should be negative due to the virtual nature of the object. (2)

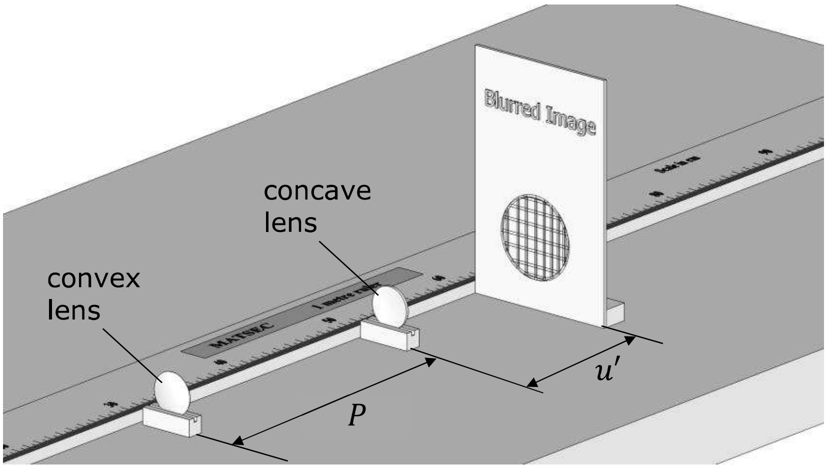

Figure 3

20. Move the screen away from the lenses and light bulb to restore a sharp and clear image. In this second position of the screen, use the metre ruler to measure the (real) image distance v' between the concave lens and the screen (see Figure 4). (2)

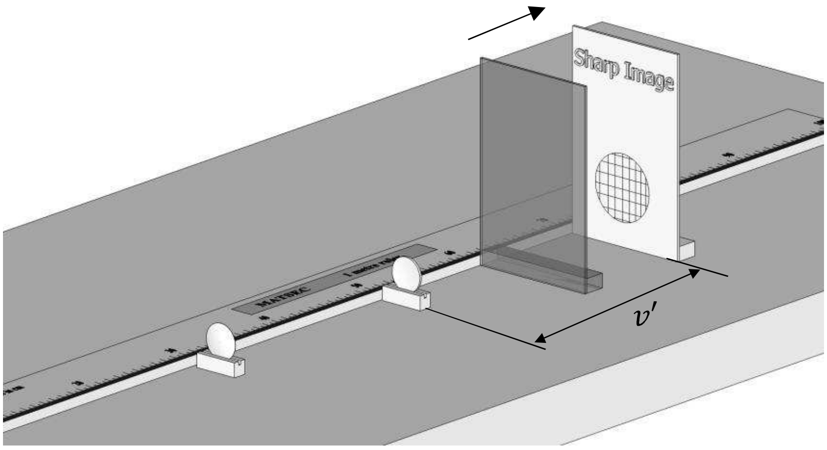

Figure 4

21. For the distances P between the convex lens and the concave lens given in Table 2, repeat steps 19 to 20, each time recording the values for u' and v'.

Table 2

P / cm	u'/ cm	v'/ cm	$\frac{v'}{u'}$
24.0			
25.0			
26.0			
27.0			
28.0			
29.0			

(20)

22. Complete Table 2 by working out the missing values. (6)

23. Plot a graph of $\frac{v'}{u'}$ on the y-axis against v' on the x-axis. The graph is a straight line with a negative gradient and intercept.

(10)

24. The image height, object height, image distance and focal length f' of the concave lens are related by the equation:

$$\frac{v'}{u'} = \frac{v'}{f'} - 1$$

25. Use the graph to obtain a value for the focal length f' of the concave lens.

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(5)

Questions continue on page 8

26. State **ONE** source of error and **ONE** corresponding precaution undertaken during the experiment of part B.

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(2)