MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2017

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	29th April 2017
TIME:	9.00 a.m. to 12.05 p.m.

A list of useful formulae and equations is provided.

This paper carries 40% of the marks for the examination.
It is expected that answers be accompanied by the proper units.

SECTION A

Attempt all EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1. a. The energy stored in a parallel plate capacitor depends on the capacitance of the capacitor C and the voltage V across its plates. The energy, E, stored by the capacitor is given by

$$E = \frac{1}{2}CV^2$$

i. The voltage V can be expressed in terms of the work done in moving a unit charge. Show that another unit for V is the J C^{-1}. (2)

ii. Given that the above equation is homogeneously correct in respect of base units, show that the compound unit for capacitance can be $kg^{-1}\ m^{-2}\ s^2\ C^2$. (3)

b. A man is pushing a chest of drawers at constant speed, as shown in Figure 1. The chest of drawers weighs 750 N and needs a horizontal push of 450 N to move in this way.

i. What is the resultant force acting on the chest of drawers? (1)

ii. Draw a free body diagram showing **THREE** forces acting on the chest of drawers. (3)

iii. Calculate the magnitude and direction of the contact force that the floor exerts on the chest of drawers. (5)

(Total: 14 marks)

Figure 1

2. a. Distinguish between distance travelled and displacement. Hence explain whether the displacement magnitude is always equal to the distance travelled. (4)

b. The graph in Figure 2 shows the displacement along a line of a moving object as it changes with time.

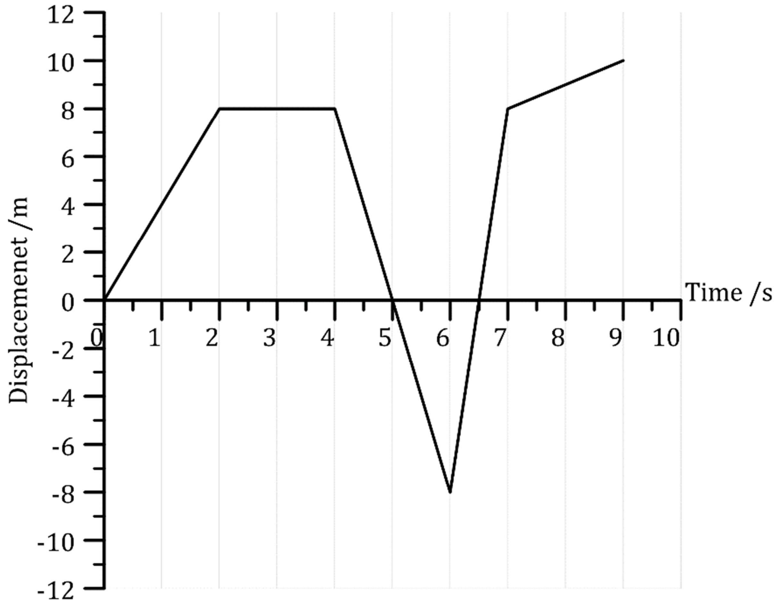


Figure 2

i. From the graph, determine the magnitude of the displacement of the object at the end of the 9 second time interval. (1)

ii. At what times did the object return to its starting position? (2)

iii. Draw a velocity time graph that shows how the velocity of the object changed during the 9 second time interval. (7)

(Total: 14 marks)

3. a. Explain what is meant by energy and distinguish between potential energy and kinetic energy. (3)

b. A lift is designed to carry a maximum load of 1500 kg, which includes the mass of the cabin. The lift has a counterweight of 800 kg (as shown in Figure 3) that always moves with the same speed as the cabin but in the opposite direction.

i. Explain the energy conversions taking place as the lift is moving upwards. (3)

ii. Calculate the average power that the motor operating the lift must deliver to carry the maximum load through a height of 45.0 m in 1 minute. (3)

iii. Calculate the percentage increase in the power that must be delivered by the motor if there were no counterweight. (3)

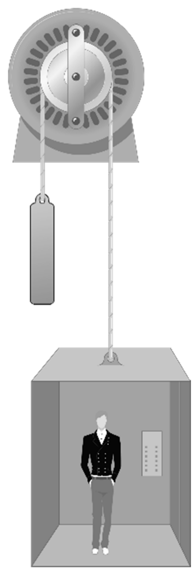


Figure 3

(Total: 12 marks)

4. a. Explain what is meant by a couple. (2)

b. Show that the torque of a couple is independent of the points of application of the forces constituting the couple relative to the axis of rotation, if the magnitude of the forces F and their separation r remain constant, as shown in Figure 4.

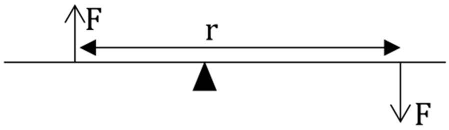


Figure 4

(3)

c. Two children are playing with the revolving door in the lobby of a hotel. They exert forces on the door as shown in Figure 5. Assume that there are no other mechanical forces acting on the revolving door and that it is free to rotate.

i. Calculate the torque exerted by boy B on the door. (2)

ii. Calculate the net torque on the revolving door and state the direction of rotation of the revolving door. (3)

iii. State **ONE** way with which either of the boys can bring the revolving door to a halt. (2)

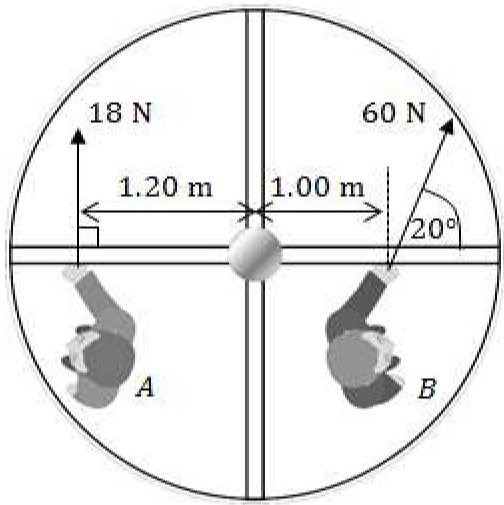


Figure 5

(Total: 12 marks)

5. a. Explain why a particle of mass m moving at a constant speed v along a circular path experiences a centripetal acceleration. (1)

b. Show that the acceleration of an object moving in a circular path of radius r with uniform speed v is $\frac{v^2}{r}$. (7)

c. An electric model aeroplane of mass 0.45 kg flies in a horizontal circle with its wings horizontal as shown in Figure 6. A light string of length 15 m keeps the model aeroplane flying along the horizontal circular path of radius r. The string makes an angle of 50° to the vertical and it takes 2 s for the aeroplane to fly once round its circular path.

i. Calculate the radius r of the circular path. (1)

ii. Determine the magnitude of the tension T in the string. (2)

iii. Calculate the magnitude of the lift produced by the wings of the aeroplane. (1)

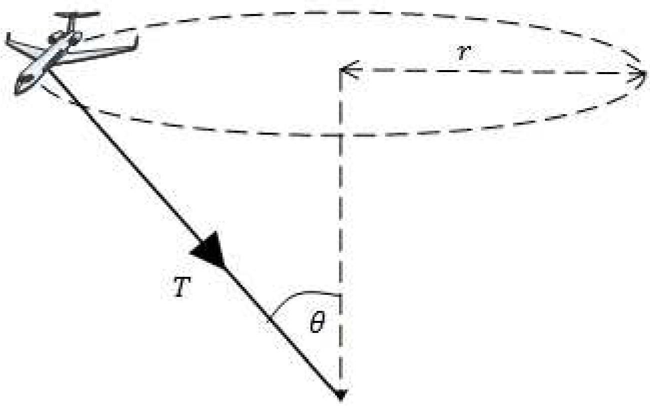


Figure 6

(Total: 12 marks)

6. a. Define electric current. (2)

b. A potential difference is applied across the ends of a copper wire of diameter of 2.053 mm. There are 8.00×10^{28} conduction electrons per cubic meter in copper.
   i. Describe the motion of the electrons in the wire before and after a potential difference is applied across its ends. (3)
   ii. Calculate the cross-sectional area of the wire in square metres. (2)
   iii. Determine the drift speed of the electrons in the wire when a direct current of 5.0 A flows through it. (3)
   iv. Determine the time it takes for a single electron to move 1 m along the wire. (2)

(Total: 12 marks)

7. a. In 1861, Georg Simon Ohm investigated how the current I through a given metal varied with the potential difference across it.
   i. State Ohm's law. (2)
   ii. Is the magnitude of the current affected when the potential difference applied across a metal is reversed? Explain. (2)

b. Sketch **TWO** graphs that show the I-V characteristics of a resistor and a diode. Use the same axes for both graphs and label clearly both graphs. (2,1)

c. An extension cable of length 25 m is composed of two insulated copper wires. The wires carry currents of equal magnitude in opposite directions. The conductivity of copper is $5.988 \times 10^{7}\ \Omega^{-1}\ \mathrm{m}^{-1}$.
   i. Calculate the resistance of each wire given that the wire diameter is 0.912 mm. (2)
   ii. The copper wire is replaced by an aluminium wire of the same length. Determine the minimum diameter of the aluminium wire if its resistance is not to exceed that of copper. The resistivity of aluminium is $2.650 \times 10^{-8}\ \Omega$ m. (3)

(Total: 12 marks)

8. a. With the help of diagrams, where necessary, explain briefly **THREE** major results of Rutherford's alpha scattering experiment. (3)

b. Give **THREE** conclusions about the atom that were derived from these three results. (3)

c. An alpha particle having charge q is fired directly to a gold nucleus having charge Q and it rebounds back along the same line. The closest approach occurs when it is at a distance d_0 from the gold nucleus.
   i. Write down an equation for the potential energy of the alpha particle at d_0. (2)
   ii. If the initial kinetic energy of the alpha particle was E_α, show that $d_0 = \frac{qQ}{4\pi\varepsilon_0 E_\alpha}$ (2)
   iii. Calculate the distance of closest approach between an alpha particle of energy 5.5 MeV if the charge on the gold nucleus is $+79e$ and the charge on the alpha particle is $+2e$. (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 student is holding a bicycle wheel at P with its axle along the horizontal as shown in Figure 7. He pulls on a thread wound on an axle of diameter 0.05 m attached to the wheel. The wheel is at rest and the length of the string is 0.75 m. He applies a constant force of 5 N to the string.

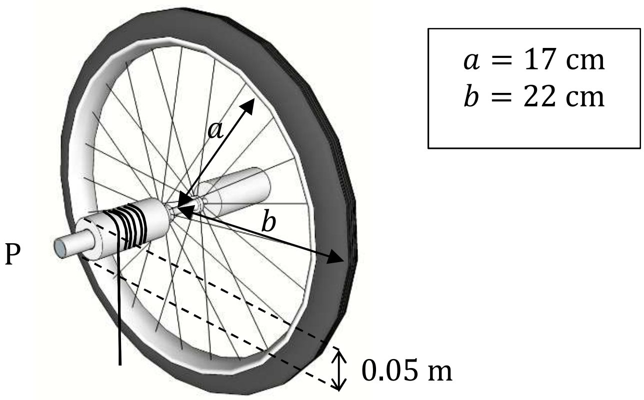


Figure 7

The bicycle wheel has a mass of 2.7 kg. Assume that the axle and shaft have negligible mass when compared to the mass of the wheel. The moment of inertia of the wheel can be approximated to that of a hollow cylindrical shell and is given by $I = M(a^2 + b^2)$.

i. Explain what is meant by moment of inertia. (3)
ii. Calculate the moment of inertia of the wheel. (2)
iii. Determine the angular acceleration of the wheel as the string is being pulled. (2)
iv. Calculate the angular speed of the wheel when all the string has been unwound. (3)
v. Calculate the number of turns that the wheel makes while the string is being pulled. (2)
vi. Calculate the rotational kinetic energy of the rotating wheel when all the string has been unwound. (2)

b. While the wheel is rotating, the student steps on a platform which can rotate in the horizontal plane. He then rotates the axis of rotation of the wheel as shown Figure 8. The student and platform begin to rotate in the opposite direction to that of the wheel. Student and platform have a combined moment of inertia I_s of $0.637\ \text{kg m}^2$.

i. Explain why the student and platform begin to rotate in the opposite direction to that of the wheel. (4)
ii. Show that the final angular speed of the student and platform ω_s is given by

$$\omega_s = \frac{I_w}{I_s} \times \omega_w,$$

where I_w is moment of interia of the wheel and ω_w is the angular speed of wheel. (3)
iii. Calculate the angular velocity of the student and platform. (2)
iv. State what happens to the student and platform as the bicycle wheel is positioned again with its rotating axis in the horizontal direction. (2)

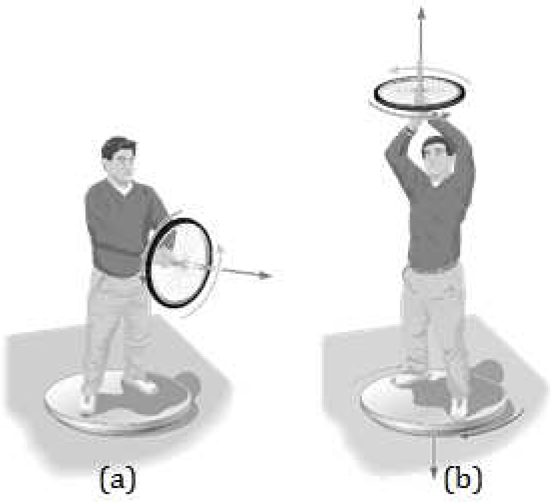


Figure 8

(Total: 25 marks)

10. a. Two identical stones A and B are projected from ground level with identical initial speeds v, but at two different angles θ_A and θ_B respectively above the horizontal. Assume that $\theta_A < \theta_B < 90^\circ$.

i. Explain how both stones can land on the same spot on the ground and include sketches of their trajectories. (3)

ii. Show that the time stone A takes to reach maximum height is given by $t_A = \frac{v \sin\theta_A}{g}$. (2)

iii. Given that they land on the same spot, show that the ratio of their time of flight is given by $\frac{t_A}{t_B} = \frac{\cos\theta_B}{\cos\theta_A}$. (4)

iv. Derive an expression for the maximum height reached by stone A. (3)

v. Hence show that the horizontal range s_B of stone B is given by $s_B = \frac{2v^2 \sin\theta_B \cos\theta_B}{g}$. (3)

b. A Youtuber posted a video online that showed him kicking a ball into the trunk of a moving truck. The ball is kicked at an angle θ of 45° and it lands in the back of the moving truck which has a trunk of length L of 2.5 m. The initial horizontal distance from the back of the truck to the ball, at the instant of the kick, is d_o = 5 m, and the truck moves directly away from the ball at velocity V, as shown in Figure 9.

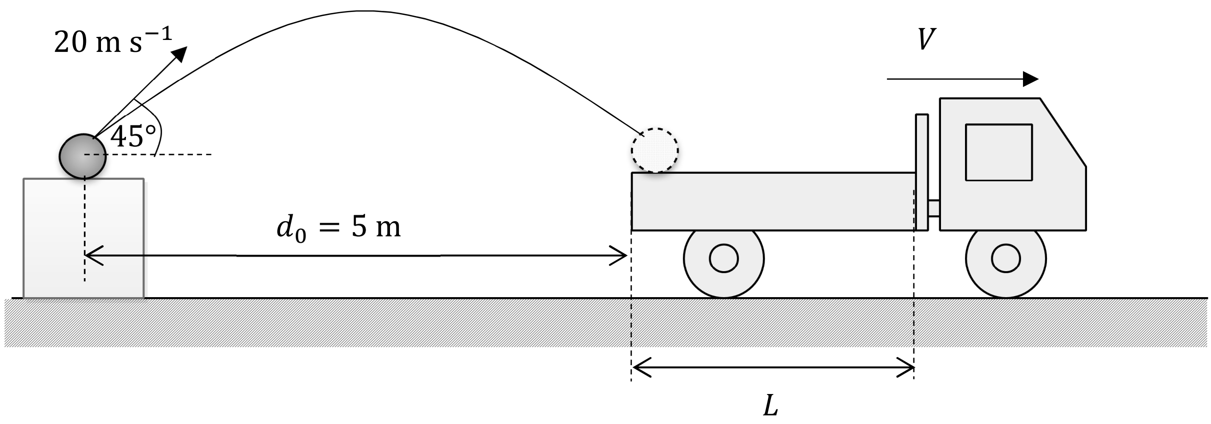


Figure 9

i. Use the equation derived in part (a)(v) to show that the horizontal distance travelled by the ball is given by $s_X = \frac{v^2}{g}$. (2)

ii. Given that the time of flight is t, write down an expression for the minimum distance that the ball has to travel to land in the trunk, in terms of d_0, V and t. (2)

iii. Given that the maximum velocity with which the ball can be projected is 20 m s^{-1}, calculate the time of flight for the ball to land in the trunk. (2)

iv. Calculate the maximum velocity that the truck can move with if the ball is to just land in its trunk. (4)

(Total: 25 marks)

11. a. A student built a device to measure the acceleration of a moving car. The device consists of a simple pendulum attached to the car window as shown in Figure 10.
   i. State Newton's first law of motion. (2)
   ii. Use Newton's first law of motion to describe:
   - the movement of the bob when the car is moving with constant velocity;
   - the movement of the bob when the car is accelerating;
   - the movement of the bob when the car decelerates. (1, 1, 1)

b. At one point during the trip, the student measures an angle of 15° with the vertical.
   i. Draw a free body diagram showing the forces on the bob at this point in time. (2)
   ii. Determine the acceleration of the car at this point in time. (4)

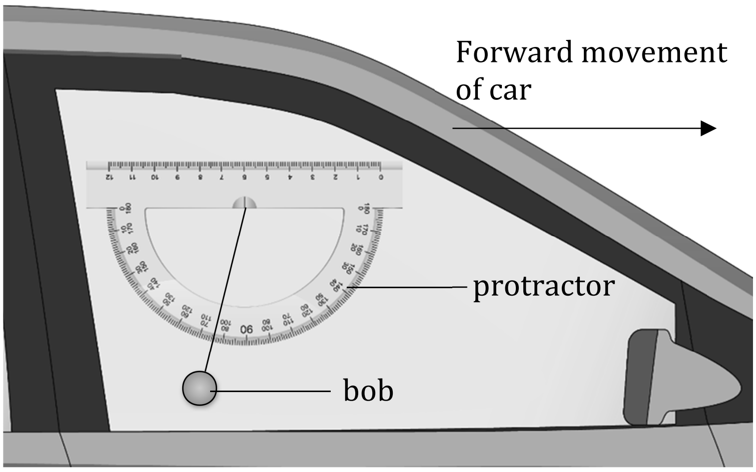


Figure 10

c. Define linear momentum and state the law of conservation of linear momentum. (2, 2)

d. Two trolleys P and Q of masses 0.7 kg and 0.3 kg respectively are held together on a horizontal track against a spring which is in a state of compression, as shown in Figure 11. When the spring is released the trolleys separate freely and P moves to the left with an initial velocity of 2 m s^{-1}.

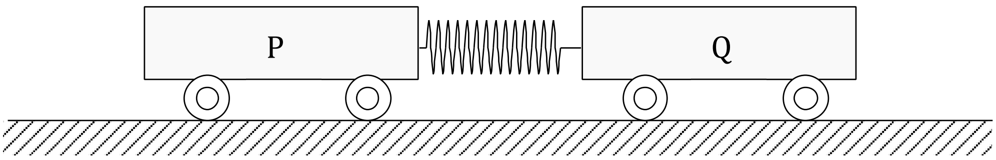


Figure 11

   i. Calculate the initial velocity of Q. (4)
   ii. What is the initial total kinetic energy of the system as the spring is released? (3)
   iii. Suppose trolley P is held still when the spring is released. Calculate the initial velocity of Q in this case. (3)

(Total: 25 marks)

Please turn the page

12. a. State Hooke's law for a thin long metal wire and hence define the term elastic limit. (4)

b. Sketch stress-strain graphs up to the breaking point for a stretched metal wire and use these graphs to explain the terms elastic behaviour and plastic behaviour. (4)

c. Draw another graph that shows the behaviour of a brittle material. Label clearly this curve and give **ONE** example of this type of material. (2)

d. A student has a 1.5 m long thin copper wire. He needs to determine the energy stored in the wire as it is stretched within the elastic range. Describe an experimental investigation that can be used to determine the energy stored. Your description shall include:
   i. a labelled diagram of the apparatus used; (2)
   ii. a description of the method used to carry out the experiment, including a table of the data to be recorded from the experiment; (2, 1)
   iii. any **ONE** source of error and **ONE** corresponding precaution; (1, 1)
   iv. a labelled graph; (2)
   v. the calculations that are required to determine the energy stored in the wire for a particular extension. (2)

e. If the Young modulus for steel is 2.00×10^{11} N m^{-2}, calculate the work done in stretching a steel wire of cross-sectional area $0.025\ \text{cm}^2$ when a load of 135 N is slowly applied without the elastic limit being reached. (4)

(Total: 25 marks)

13. a. A wire of cross-sectional area A and number of free electrons per unit volume n, each carrying a charge e is connected across a potential difference of V volts. When the p.d. is applied, the electrons move with a drift velocity v. Show that the drift velocity v of electrons crossing a plane perpendicular to the wire $v = \frac{Q}{nAe\,\Delta t}$, where Q is the total charge of the electrons flowing through the perpendicular plane in time Δt. (3)

b. Use the simple band theory to explain briefly the differences between conductors, intrinsic and extrinsic semiconductors and insulators. The use of diagrams to illustrate your explanation is expected. (8)

c. State Kirchhoff's two laws that govern flow of electric currents in a closed circuit and show how each law is essentially a conservation law. (6)

d. A student set up the circuit, as shown in Figure 12. Work out the current read by the three ammeters A, B, C. (8)

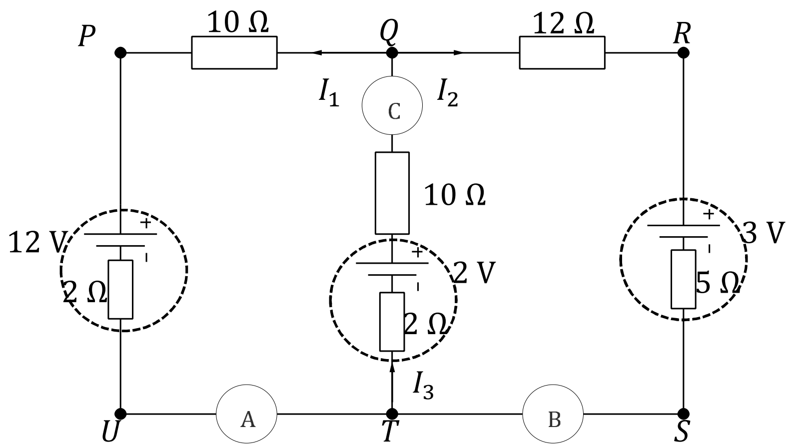


Figure 12

(Total: 25 marks)

14. a. The circuit shown in Figure 13 consists of a 12 V battery and five resistors connected in series and parallel.

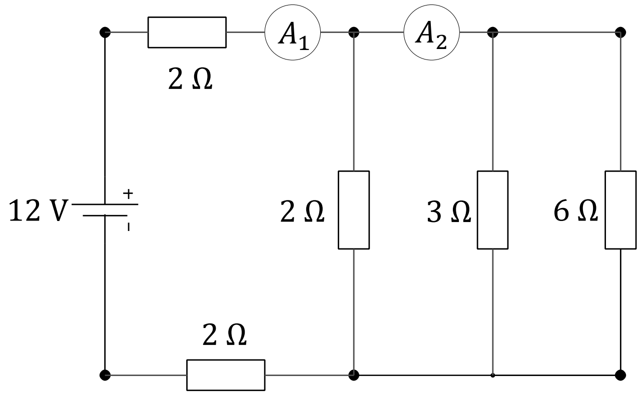


Figure 13

i. Determine the total resistance of the circuit shown in Figure 13. (2)
ii. Determine the values of the currents in A_1 and A_2. (5)
iii. Calculate the total power consumed by the circuit. (2)
iv. How is this electrical power used up in the resistors? (2)

b. Figure 14 shows a circuit consisting of a battery with internal resistance of 2 Ω connected to four resistors A, B, C and D, a centre-zero galvanometer G and a switch S.

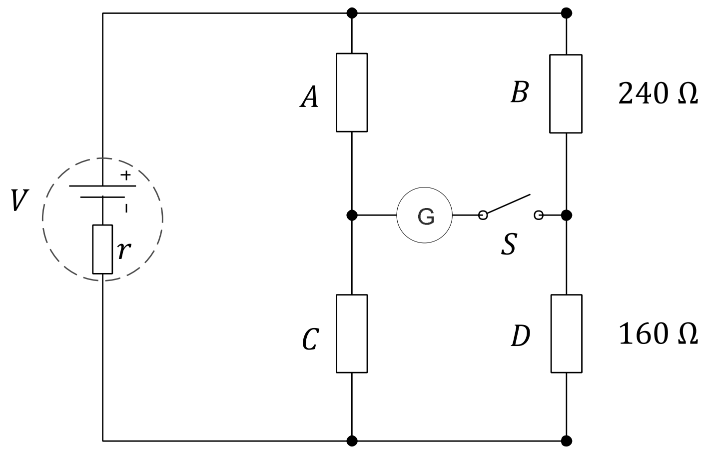


Figure 14

i. Explain the difference between e.m.f and electric potential difference. (4)
ii. What limits the maximum current that can be drawn from the 12 V battery? (1)
iii. Calculate the maximum current that can be drawn from the 12 V battery. (2)
iv. Given that the terminal potential difference is 11.82 V, calculate the potential difference across resistor B when the switch S is in the open position. (3)
v. Given that no current flows through the galvanometer when switch S is closed, calculate the potential difference across resistor C. (2)
vi. If the current flowing through resistor C is 0.059 A, calculate its resistance. (2)

(Total: 25 marks)

Please turn the page

15. a. Describe the photoelectric effect and state **FOUR** aspects of the experimental results that could not be explained through classical physics. How does the photon model of light explain the experimental results in each case? (10)

b. Einstein's equation for the photoelectric effect is given by:

$$hf = \frac{1}{2}mv^2 + \varphi$$

Explain the meaning of each term in the equation. (3)

c. In a photoelectric effect experiment, two different metals A and B are exposed to electromagnetic radiation. Photoelectrons are ejected from metal A when it is exposed to both red and blue light. Metal B only ejects photoelectrons when exposed to blue light but not when subjected to red light.

i. Which metal or metals produce photoelectrons when exposed to ultraviolet radiation? Explain. (3)

ii. Which metal or metals might produce photoelectrons for infrared radiation? (2)

d. A potassium surface which has a work function of 2.0 eV is situated in a vacuum in front of a collecting electrode and an electromagnetic radiation source.

i. Calculate the potential difference that has to be applied between the surface and the collecting electrode to prevent the collection of electrons when the wavelength of the radiation source is set at 350 nm. (3)

ii. What would be the kinetic energy and the speed of the most energetic electrons emitted? (4)

(Total: 25 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2017

SUBJECT:	PHYSICS
PAPER NUMBER:	II
DATE:	29th April 2017
TIME:	4.00 p.m. to 7.05 p.m.

A list of useful formulae and equations is provided.

This paper carries 40% of the marks for the examination.
It is expected that answers be accompanied by the proper units.

SECTION A

Attempt all EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1. In order to measure the power of an immersion heater, a student immerses the heater in a copper container filled with water. The temperature of the water is initially below room temperature. The heater is switched ON and the temperature is recorded every 30 s.

   a. Sketch a graph to show how the temperature increases with time. (3)

   b. Describe how the student may use the graph to measure the rate of increase in temperature at room temperature. Illustrate on the graph sketched in part (a) how this could be done. (4)

   c. Write down an equation by which the student can calculate the power of the heater. (2)

   d. What is the advantage of measuring the rate of increase in temperature at room temperature rather than at another temperature? (2)

   e. What should the student do before taking each temperature reading? (2)

(Total: 13 marks)

2. From the kinetic theory of gases, the internal energy, U, of one mole of an ideal gas is,

$$U = \frac{3}{2}RT$$

   where R is the gas constant
   T is the temperature

   a. One mole of an ideal gas is heated at constant volume so that its temperature increases by 100K.
   Using the first law of thermodynamics, calculate:
   i. the heat transfer to the gas; (5)
   ii. the specific heat capacity of the gas at constant volume if the molar mass of the gas is 4.00×10^{-3} kg. (3)

   b. Explain why the heat transfer required is greater when the temperature of the gas is increased at constant pressure rather than at constant volume. (2)

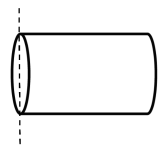
(Total: 10 marks)

3. The rate of flow of heat by conduction through a thin conducting sheet is given by

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta \theta}{\Delta x}$$

where $\frac{\Delta Q}{\Delta t}$ is the rate of heat flow
k is the coefficient of thermal conductivity
A represents the surface area
$\Delta\theta$ represents the change in temperature
Δx represents the change in distance

A well lagged copper bar, shown in Figure 1, is used to measure the thermal conductivity of copper.



hot end at $x = 0$

Figure 1

a. Explain why, under steady conditions, the rate of heat flow through the bar is constant. (2)

b. Sketch a graph of temperature, θ, against distance, x, from the hot end for the lagged copper bar. Label your graph A. (2)

c. Use the equation above to explain the shape of your graph in part (b). (4)

d. On the same axes as in part (b), draw a temperature – distance graph for the same bar after the lagging has been removed and steady conditions have again been reached. Label your graph B. (2)

e. Use the equation above to explain the shape of your graph B. (4)

(Total: 14 marks)

4. *"By 1929 Edwin Hubble had measured enough galaxy redshifts to find whether a galaxy redshift depends upon its distance from us"*

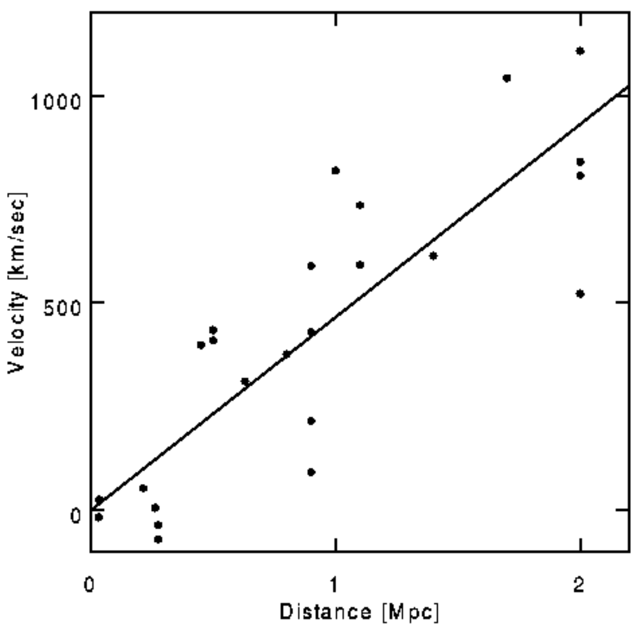


Figure 2

Figure 2 shows the result of Hubble's observations. The vertical axis represents the velocity of a galaxy in kms^{-1} while the horizontal axis is distance in megaparsecs, Mpc. The megaparsec is a distance unit used by astronomers, where 1 Mpc is equal to 3.1×10^{22} m.

a. What observations can you make from Hubble's diagram [Figure 2]? (2)

b. From the diagram, obtain an approximate value for Hubble's constant in SI units. (3)

c. What is the main source of uncertainty in Hubble's constant? How does the graph show this uncertainty? (2)

d. A more accurate value for Hubble's constant is $2.23 \times 10^{-18}\ s^{-1}$. Use this value of Hubble's constant to estimate the age of the Universe in billions of years. (3)

e. Estimate the distance between two particles in deep space which move apart a distance of 1 m in one year. (4)

(Total: 14 marks)

5. An a.c. signal generator is connected across a coil connected in series with a filament lamp, as shown in Figure 3. The output sinusoidal voltage of the generator is kept constant.

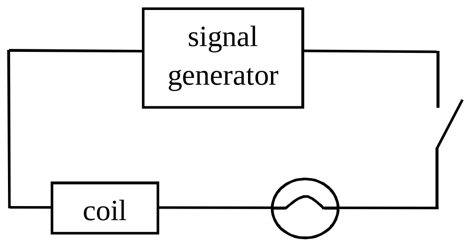


Figure 3

Explain the following observations:

a. The brightness of the lamp appears uniform even though the current through the filament is changing continuously; (2)

b. The brightness of the lamp decreases as the frequency is increased; (5)

c. When an iron rod is gradually inserted into the coil, the brightness of the lamp decreases while the temperature of the rod rises. (6)

(Total: 13 marks)

Please turn the page

6. An alternating voltage is applied across the hollow tubes shown in Figure 4 such that charged particles are accelerated as they cross the gap between the tubes while moving with constant velocity within the tubes. The time spent inside each tube is exactly half the period, P, of the applied alternating voltage.

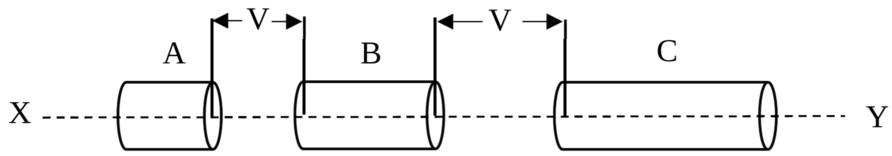


Figure 4

a. Explain why the accelerated particles must be moving from X towards Y. (2)

b. In one such accelerator, the particles are electrons each with charge, e, and mass, m. If the period of the supply is P, and the speed of the electrons in tube A is v_A, derive an equation to determine the length of tube A. (2)

c. If a linear accelerator has n gaps each of voltage difference V, what is the final kinetic energy of an electron which has travelled through n gaps? (2)

d. Calculate the speed of an electron which has been accelerated through one gap having a potential difference of 1.0×10^6 V. Comment on your answer. (4)

(Total: 10 marks)

7. A very long thin horizontal conductor AB carrying a current of 25 A is supported by two threads of negligible mass, as shown in Figure 5. The tension in each supporting thread is T.

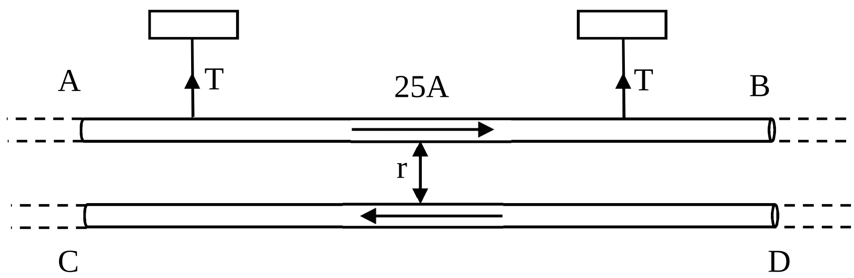


Figure 5

a. Calculate the magnetic flux density at a point P, 6.0 mm directly below the conductor AB. (2)

b. A second conductor CD carrying a current, I, is now fixed in a position directly below AB, as shown in Figure 5, so that it cannot move.

i. Draw a diagram to show the pattern of the magnetic flux between the two conductors, and hence explain why there is a force of repulsion between the conductors AB and CD. (5)

ii. Show that the force per unit length acting on each conductor can be written as $\frac{F}{L} = \frac{5\times10^{-6}}{r} I$. (3)

iii. The mass per unit length of the conductor AB is 4.6×10^{-3} kgm^{-1}. When the conductors are 5.0 mm apart, what current, I, flowing through CD will reduce the tension in the threads to zero? (2)

(Total: 12 marks)

8. An optical fibre has a core of refractive index 1.475 which is surrounded by a cladding of refractive index 1.455. A ray of monochromatic light enters one end of the core at an angle of incidence of 10^o, as shown in Figure 6.

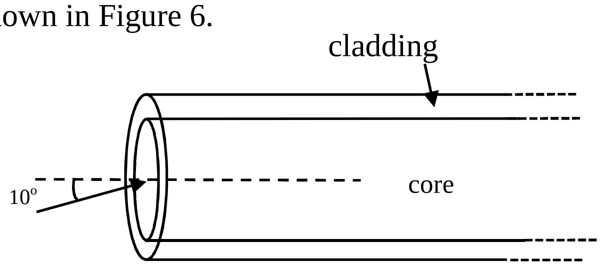


Figure 6

a. By calculating the subsequent path of the ray, explain whether the ray can propagate along the fibre. (9)

b. How long does it take for a light pulse to travel a distance of 2 km along the axis of the fiber shown above? (3)

c. Ordinary light is described as a superposition of plane waves having a broad range of wavelengths. Explain why a pulse of such light does not retain its shape as it travels along an optical fibre. (2)

(Total: 14 marks)

Please turn the page

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 gas in a cylinder fitted with a piston is made to contract reversibly by the application of a pressure, P. Show that for a small decrease in volume, ΔV, the work done on the gas, ΔW, is given by the equation $\Delta W = P\Delta V$. (4)

b. What are the properties of a reversible change in this context? (3)

c. In a certain heat engine, one mole of a monatomic ideal gas is taken around the cycle ABCDA shown in the P-V diagram below (Figure 7):

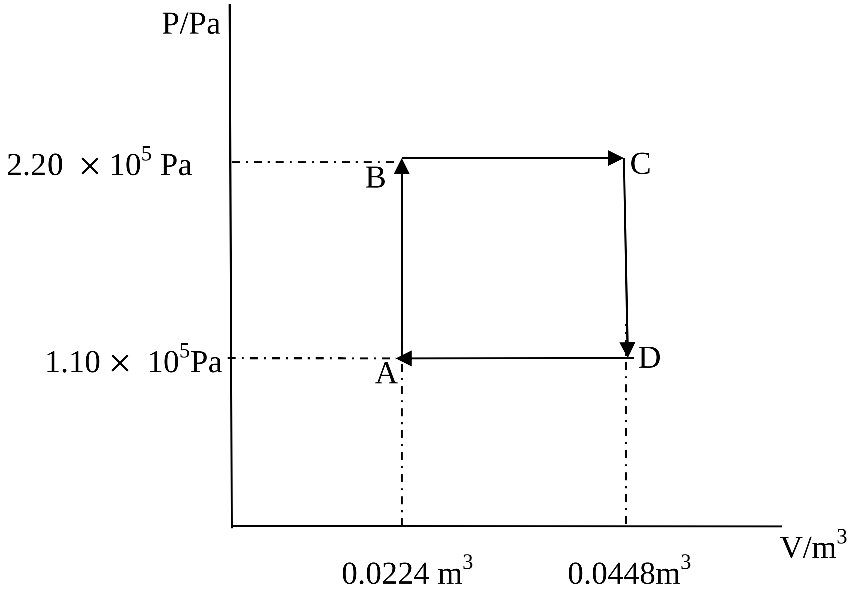


Figure 7

i. Calculate the temperatures, T_A, T_B, and T_C of the gas under the conditions represented by points A, B and C, respectively. (6)

ii. Find the net work done during the cycle ABCDA. (3)

iii. If the molar heat capacity at constant volume of an ideal gas is given by the equation $C_V = \frac{3}{2}R$, where R is the gas constant. Write down the equation for the molar heat capacity at constant pressure, C_P. (2)

iv. During which parts of the cycle is heat absorbed by the gas? Calculate the heat transferred to the gas during these processes. (5)

v. Calculate the efficiency of the cycle. (2)

(Total: 25 marks)

10. a. A polythene rod is rubbed with a cloth. The rod is then scraped across the metal cap of a digital coulomb meter, shown in Figure 8. (A coulomb meter is an instrument which measures charge.)

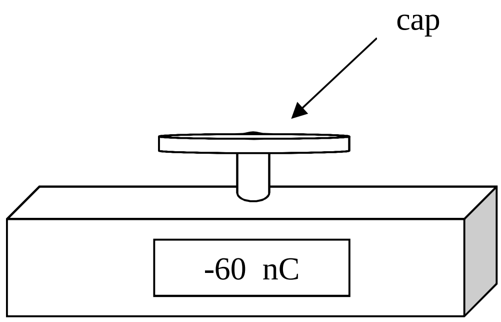


Figure 8

i. Explain why the charge on the coulomb meter is negative. (2)
ii. What is the sign of the charge on the cloth? Explain your answer. (2)
iii. The coulomb meter shows a charge of 60 nC. What is the number of charged particles which travel to earth when the cap of the instrument is earthed? (2)
iv. If the mean current in the earthing conductor is 3 μA, what times does it take the charge to pass through a section of the earthing conductor? (2)

b. A do-it yourself coulomb meter may be constructed by connecting a voltmeter across a capacitor as shown in Figure 9:

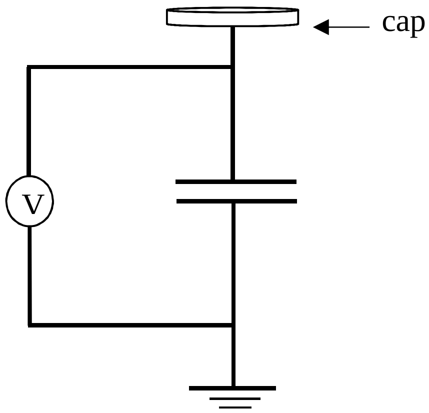


Figure 9

i. Explain why the voltmeter shows a reading when a charged rod scrapes the cap. (2)
ii. Write down the relationship between the charge supplied and the reading on the voltmeter. (2)
iii. Explain why the voltmeter should have a very high resistance, while the capacitor should have a small capacitance. (5)

c. In one such coloumb meter, the resistance of the voltmeter was 1×10^{11} Ω and the capacitance of the capacitor was 4 nF.
i. Calculate the time constant of the coulomb meter. (2)
ii. Calculate how long it takes for the reading on the voltmeter to fall by 10% of its initial value? (4)
iii. Explain how this time will be affected if another 4 nF capacitor is connected across the 4 nF capacitor already in the circuit. (2)

(Total: 25 marks)

11. a. A body of mass 0.3 kg hangs on the free end of a light helical spring. The load is pulled downwards and released. The amplitude of the motion is 0.1 m. The graph shown in Figure 10 shows how the restoring force acting on the load changes with displacement from the centre of oscillation.

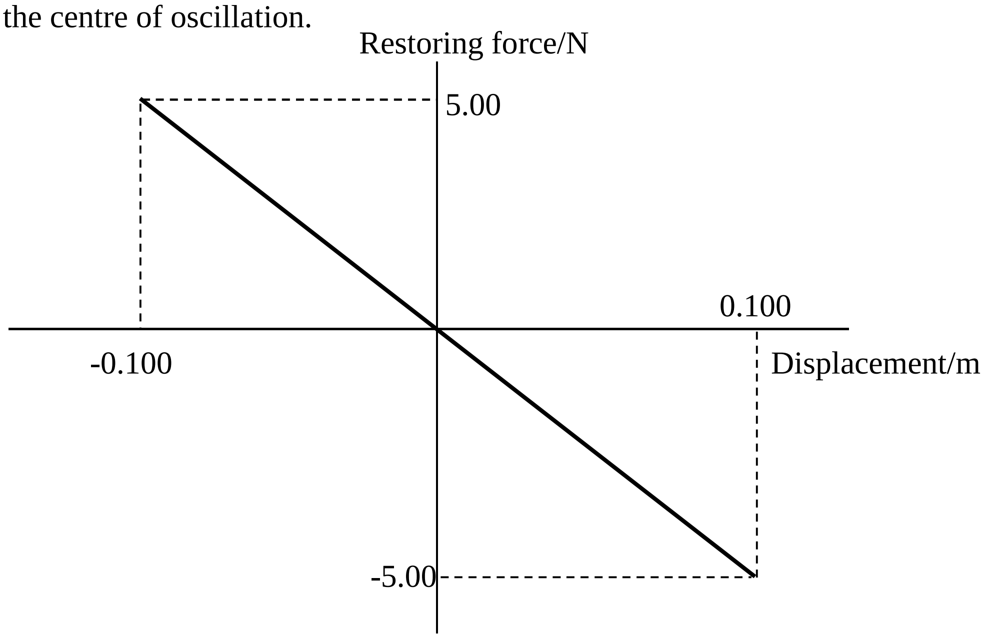


Figure 10

i. Define simple harmonic motion, and write down the equation relating acceleration to displacement. Hence explain how the graph shows that the body performs such motion. (4)

Use the graph to calculate:

ii. the period of motion; (4)

iii. the maximum potential energy of the oscillating mass; (4)

iv. the velocity of the mass when its displacement from the centre of oscillation is 0.05 m; (6)

v. Sketch a graph of potential, kinetic and total energy against displacement. (3)

b. The same mass now hangs from two helical springs in parallel as shown in Figure 11, each spring being identical to the spring mentioned above.

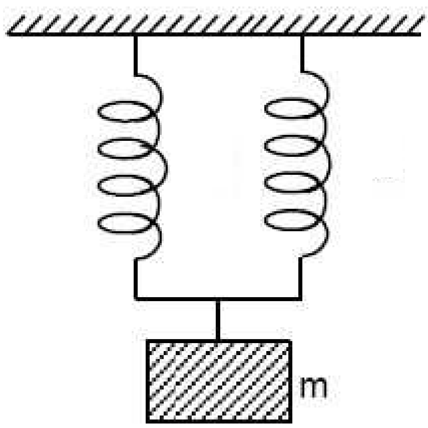


Figure 11

i. Sketch a force-displacement graph for this system, and state how the new graph differs from the one given in part (a). (4)

(Total: 25 marks)

12. a. Define electric field strength. (2)

b. Figure 12 shows a conductor moving with constant velocity, *v*, across a uniform magnetic field of flux density, B directed into the paper.

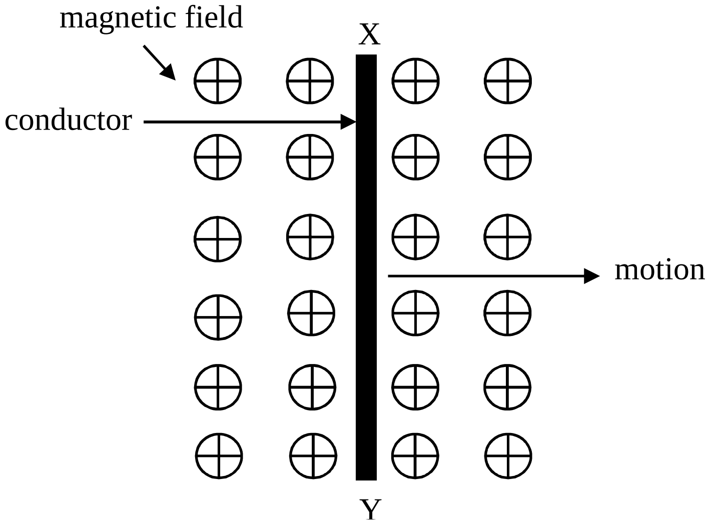


Figure 12

i. In which direction, XY or YX, will the free electrons inside the conductor move? (2)

ii. What forces act on an electron inside the conductor while it is moving across the magnetic field? (2)

iii. Derive an equation for the electric field strength, *E*, in terms of *v* and *B*. (3)

c. The conductor now moves across the magnetic field along a pair of frictionless, horizontal rails, as shown in Figure 13.

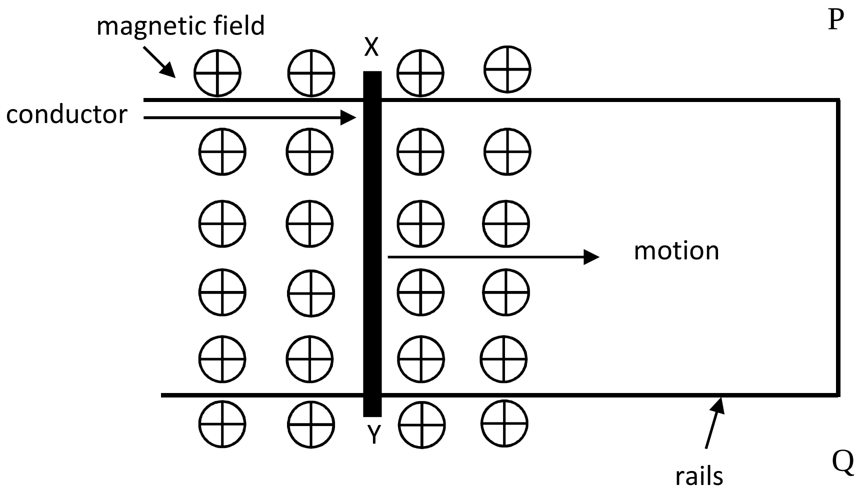


Figure 13

i. Explain why a force has to be applied to move the conductor across the field. (4)

ii. A new magnetic field is produced as the conductor moves. What is the direction of this new magnetic field in the loop XPQY? (2)

iii. If the induced e.m.f. is *e* and the current in the circuit is *I*, what is the work done in 1 second, in terms of *e* and *I*, in moving the conductor? (2)

iv. If *F* is the force applied, what is the work done in 1 second in terms of *F* and *v*? (2)

v. Hence show that the induced emf, $e = BLv$, where *L* is the length of conductor between the rails. (4)

vi. What is the rate of change of flux in the loop XPQY as the conductor moves across the field? (2)

(Total: 25 marks)

13. A student carries out a Young's double slit experiment in order to determine the wavelength of monochromatic red light. The student uses the apparatus shown in Figure 14 to produce an interference pattern on the screen.

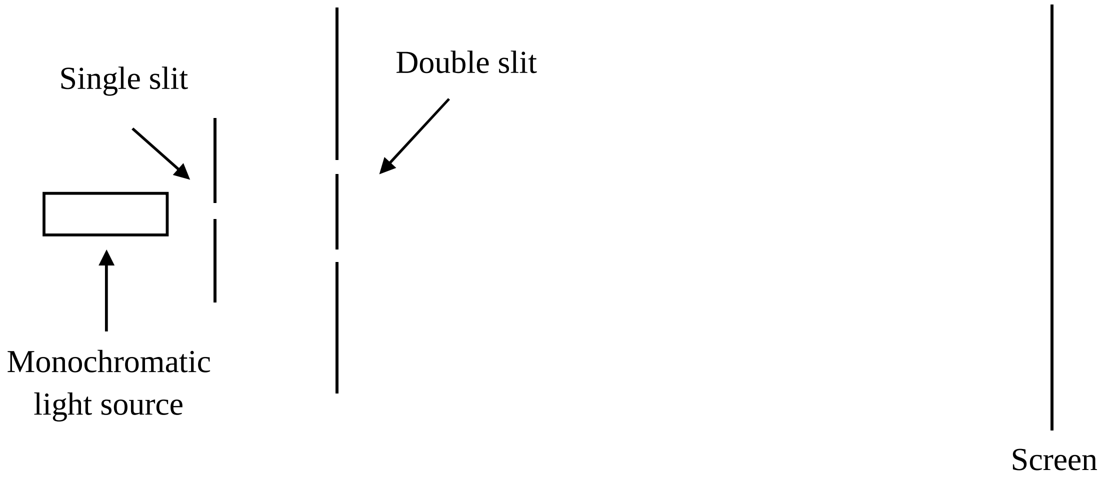


Figure 14

a. Name **TWO** conditions that must be satisfied in order to demonstrate the interference of light. (2)

b. Explain how these conditions are met in the above set up of Young's double slit experiment on interference. (4)

c. Describe what the student observes on the screen and how the image is formed on the screen. (4)

d. List the measurements which the student must take to obtain a value for the wavelength of red light and the instrument used to obtain each measurement. (6)

e. Which measurement may the student change before repeating the experiment? (2)

f. Give estimates for the width of each slit, distance between slits, and distance between slits and screen. (3)

g. The student replaces the laser by a straight filament lamp and a red-light filter. The apparatus shown in Figure 14 is now placed inside a dark room and the distance between the slits and the screen is less than 1 m. Explain carefully why the observed number of fringes is smaller compared to when the red-light laser was used. (4)

(Total: 25 marks)

14. In Figure 15, two small microphones, M_1 and M_2, are placed some distance away from a loudspeaker, L. The loudspeaker is connected to a signal generator. M_1 and M_2 are connected to the Y-inputs of a double beam oscilloscope.

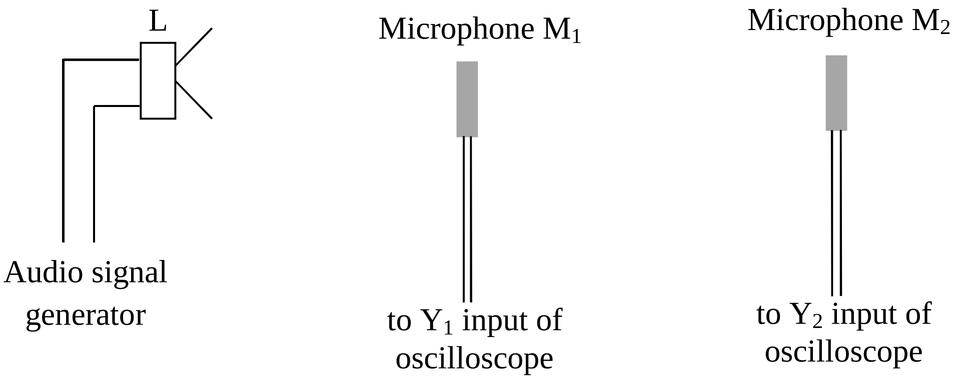


Figure 15

a. With the Y-gain at a convenient value, and the time base speed set at 0.20 ms/cm, four complete oscillations of both Y_1 and Y_2 inputs are observed on a wide screen set at a distance of 10 cm. What is the frequency of the sound wave? (3)

b. Draw a line 10 cm long to represent the time axis on the oscilloscope screen. Then draw the two traces you would expect to observe. Explain any important features of your traces. (4)

c. Microphone M_1 is kept fixed while microphone M_2 is moved slowly away from M_1 along a metre ruler. The two traces on the oscilloscope screen are observed to coincide when microphone M_2 is at the following positions along the metre rule:

2.3cm; 18.7cm; 35.4cm; 51.9cm; 68.7cm; 85.1cm

Calculate the speed of sound in air. (4)

d. The speed of sound, v, in air is given by the equation,

$$v = \sqrt{\frac{1.41P}{\rho}}$$

where P is the pressure of air, and ρ is its density. By assuming that air is an ideal gas, use the ideal gas equation to show that the speed of sound in air is given by

$$v = \sqrt{\frac{1.41RT}{M}}$$

where M is the mass of 1 mole of air. (2)

e. Write down the proportionality relationship between speed of sound and air temperature. (2)

f. The experiment described above was carried out at a temperature of 290 K. Calculate the speed and the wavelength of sound at 300 K using your value for the speed at 290 K. (4)

g. Use the readings given in part (c) above to discuss whether the experiment is capable of measuring the difference in wavelength corresponding to a 10 K increase in air temperature. (6)

(Total: 25 marks)

15. a. Explain what is meant by gravitational field strength and gravitational potential difference. What is the relationship between these two quantities? (5)

b. The mean gravitational field strength on the surface of the planet Mars is 3.70 Nkg^{-1}.

i. If the radius of the planet is 3400 km, what is its density? (Assume that the planet is a sphere of uniform density). (5)

ii. Calculate the value of free-fall acceleration at the planet's surface. (4)

c. Mars rotates on its axis once every 24.7 hours.

i. Explain why the gravitational field strength at the Martian pole is greater than the gravitational field strength at its equator, if it is assumed that the planet is a sphere of uniform density. (3)

ii. Calculate the difference between these values of the gravitational field strength. (3)

d. Mars has two moons, one of which is Phobos. The radius of Phobos' orbit around Mars is 9380 km and it takes 2.77×10^4 s to complete one orbital revolution. Use this information to obtain a value for the mass of the planet Mars. (5)

(Total: 25 marks)

Index No.________________ AM 26/III.17m

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2017

SUBJECT:	PHYSICS
PAPER NUMBER:	III – *Practical*
DATE:	6th June 2017
TIME:	2 hours 5 minutes

Experiment: Experiments with Lasers

Apparatus: stand and clamp, small laser diode, CD, small length of fibre optic, blue tack, battery compartment and switch

Important Note:

- Do not stare directly at the light emitted by the laser. This could damage your retina.
- Do not leave the laser turned on unnecessarily.

Diagram:

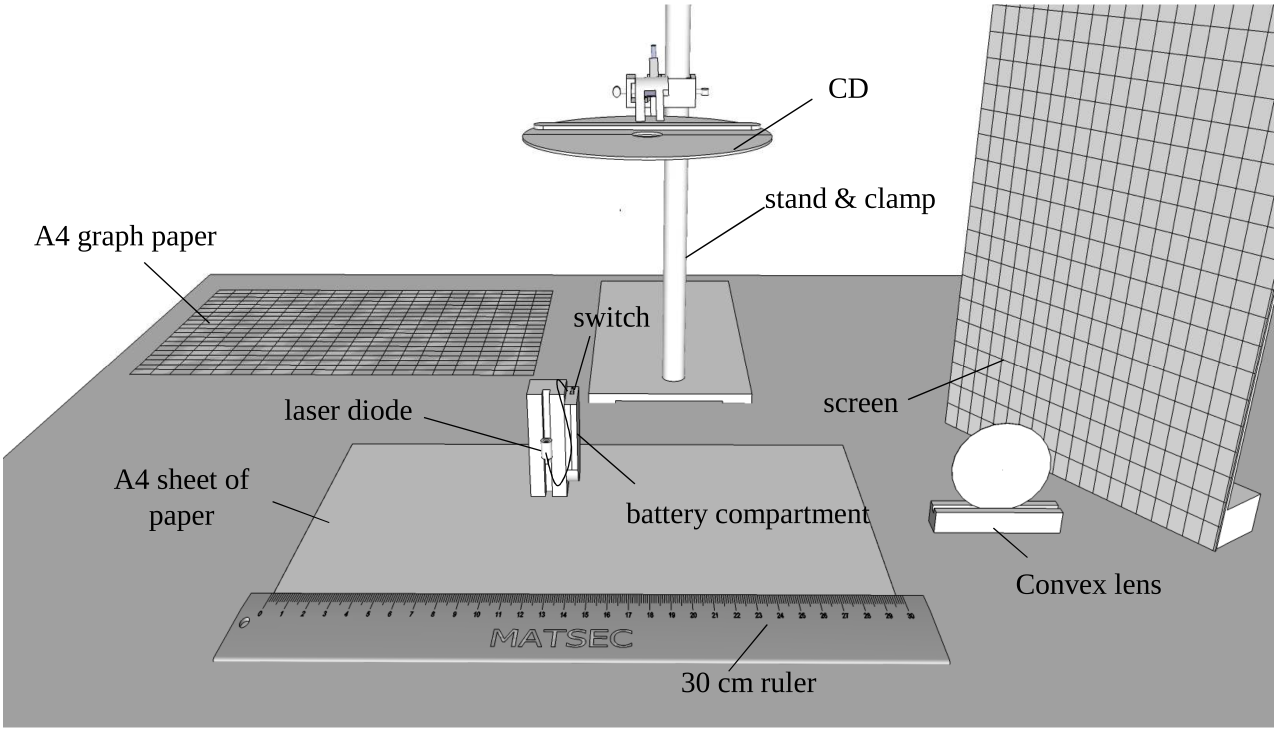


Figure 1: The experimental setup

Part A:

1. The apparatus is set up for you. Make sure that you have all the apparatus that is shown in the diagram of Figure 1.
2. In this first part of the experiment, the CD will be used as a diffraction grating. The CD will diffract monochromatic light from a laser diode and generate bright and dark fringes.

3. The laser diode is mounted on a wooden block and connected to the battery compartment. To turn the laser diode on and off, use the switch that is on the battery compartment.
4. Distance or height measurements will be measured using a 30 cm ruler. The 0 cm mark of the ruler provided might not be exactly on the ruler edge. Use the space below to determine the distance between the 0 cm mark and the edge of the ruler.

Distance between edge of ruler and 0 cm is __________ m. (4)

5. Note that this value is to be used to correct any length measurements, where necessary, from this point onwards.
6. The CD that is held on the stand is not mounted horizontally. It is slightly tilted. This was done on purpose. Also note that the CD has a line marked on it that passes through the centre.
7. Turn on the laser diode and position it under the CD that is mounted on the stand. Position the laser diode at the edge of the CD (avoid the transparent region) along the marked line.

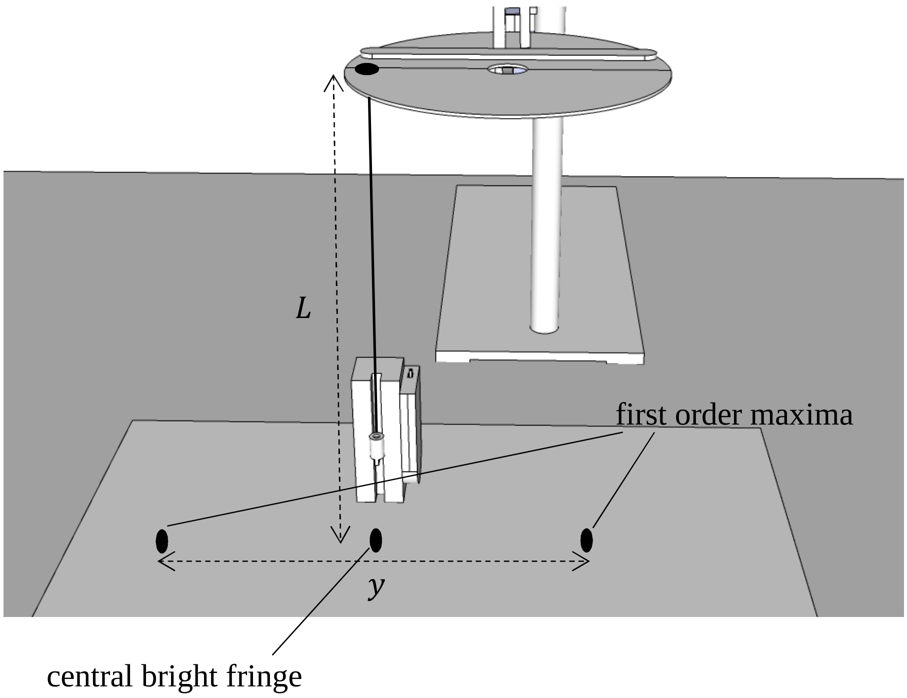


Figure 2

8. You will note that at least three light dots appear on the separate A4 sheet of paper provided. The central dot, that appears close to the wooden block and laser, is the central bright fringe. The two light dots on either side of the central bright fringe are the first order maxima or fringes.
9. State what happens to the distance between the first order maxima on either side of the central bright fringe when the distance between the CD and the sheet of paper decreases.

____

____

____

____

(4)

10. Adjust the height of the CD (by moving the clamp) above the sheet of paper such that the distance y between the first order maxima is within the measurable range of a 30 cm rule.
11. Use the ruler to measure the distance y between the first order maxima for at least seven different heights L of the CD above the A4 sheet of paper. Record these in the appropriate columns of Table 1. Note that the height of the CD above the A4 sheet of paper should be measured from the A4 sheet of paper to the point where the beam hits the CD. (14)
12. Turn off the laser if it is no longer needed. This will preserve battery life.
13. Complete Table 1 by working out the values in the third and fourth column. (14)

Table 1

Height L /m	Distance y /m	$\sqrt{L^2 + y^2}$ /m	$\frac{y}{2}$ /m
±	±		

DO NOT WRITE ABOVE THIS LINE

14. The equation relating the distance y between the first order maxima and the height L of the CD above the A4 sheet of paper is given by:

$$y = \frac{2\lambda}{d}\sqrt{L^2 + y^2}$$

where λ is the wavelength of light emitted by the laser diode and d is the separation of the tracks on the CD that constitute the diffraction grating.

15. Plot a suitable graph that will enable you to determine the separation d of the tracks on the CD. (15)

16. The wavelength of light emitted by the laser diode is 640 nm. Use your graph to determine the separation d of the tracks on the CD. Express your answer in nanometers.

____

____

____

(8)

Part B:

17. In this part of the experiment, the laser diode will be used to determine the focal length of a convex lens. The setup consists of a separate graph paper, a convex lens mounted on a wooden block, a laser diode and a screen (that consists of a graph paper glued to a wooden plane).

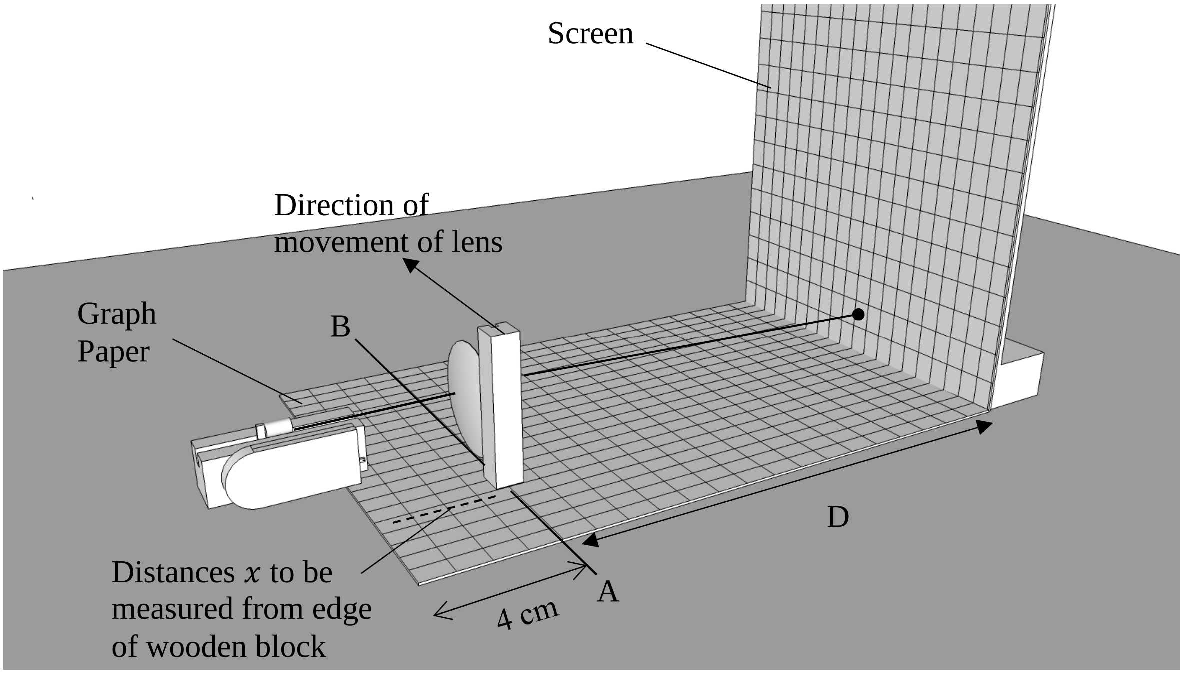


Figure 3

18. Both graph papers have 1 cm squares. Millimetre squares are not shown in the diagram.
19. Set up the laser, the separate graph paper provided and the screen as shown in Figure 3. Use blue tack to fix the laser in place. The screen should be aligned to the flat graph paper provided, as shown in the diagram.
20. Turn on the laser.
21. Position the convex lens on the line AB (4 cm from the edge = 4 × 1 cm squares) and in such a way that the laser light falls on the outer edge of the lens. A laser spot should be visible on the screen.
22. Record the distance D between the convex lens and the screen in Table 2. (2)
23. Mark the position of the initial spot (visible on the screen) on the flat graph paper, making sure that the flat graph paper is aligned with the screen. This position corresponds to the zero position of the lens, x = 0. It is important that no markings are done on the screen.
24. Move the lens distances x (given in Table 2) along the line AB in the direction shown on the diagram. It is suggested that the distances x moved by the lens are measured from the edge of the wooden block. For each distance x mark the corresponding position of the spot on the flat graph paper.
25. Measure the distances y moved by the spot relative to the initial marking ($x = 0$). (12)

Table 2

D /cm	
x /cm	y /cm
±	±
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	

26. Plot a graph of distance values y against distance values x. (15)

27. It is given that the focal length of the lens f is related to the distances moved by the lens x and the distances y moved by the laser light spot by the equation:

$$y = \left(\frac{D - f}{f}\right) x + k$$

28. Use the graph to determine the focal length of the lens.

(8)

29. State **TWO** sources of error and **TWO** corresponding precautions undertaken during the experiment.

(4)