AM 26/I.13m

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2013

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	23rd May 2013
TIME:	9.00 a.m. to 12.00 noon

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.

Question 1

a. Explain whether an equation which is homogeneous must be correct. Support your argument with an example. **[4 marks]**

b. Define the ampere. **[2 marks]**

c. Give the base units of magnetic flux density, B. **[3 marks]**

d. It is known that the total energy E for a mass-spring system is given by the equation:

$$E = ½ (mv^2 + kx^2)$$

where m represents mass, v represents speed, k is a constant and x represents displacement. Find the base units of k. Show all your working. **[3 marks]**

Question 2

a. Distinguish between vectors and scalars. **[2 marks]**

b. Give an example to show that the product of two vectors may be a scalar. **[2 marks]**

c. A boat was pulled forward at constant velocity by two equal forces of 500 N acting at an angle of 60° to each other, applied symmetrically to the front of the boat. Calculate:
   i. the resultant forward force on the boat; **[2 marks]**
   ii. the drag force on the boat. Explain how you arrived at your answer. **[2 marks]**

d. A long elastic string is stretched horizontally between two rigid retort stands, that are 80 cm apart. A 10 N weight is attached to the mid point of the string which in turn is extended downwards such that each half of the string is 50 cm long. Determine:
   i. the angle between the two halves of the string; **[2 marks]**
   ii. the tension in each section of the string. **[2 marks]**

Question 3

a. An archer stationed at the edge of a cliff shoots an arrow horizontally at 90 m s^{-1} (see Figure 1). The arrow falls down and hits a target. Assuming that the arrow is shot from a height of 20 m, calculate:
   i. how long it takes the arrow to reach the target; **[2 marks]**
   ii. how far horizontally the target is from the base of the cliff; **[1 mark]**
   iii. the resultant velocity at impact and the angle this makes with the vertical; **[4 marks]**

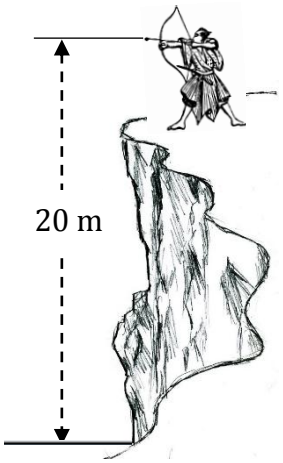


Figure 1

b. Mention one assumption made in order to calculate the above. **[1 mark]**

c. The archer then shoots an identical arrow upwards at an angle of 20° to the horizontal at the same speed. What is the new distance attained from the base of the cliff? **[5 marks]**

d. Assuming an arrow is shot at the same speed, at what angle should the archer shoot the arrow to attain maximum distance? **[1 mark]**

Question 4

a. When a metal surface is illuminated with light, electrons are liberated by a process known as the photoelectric effect.
   i. Describe three characteristics of the photoelectric effect that could not be explained by classical wave theory. **[3 marks]**
   ii. Explain what is meant by threshold frequency. **[1 mark]**

b. A metal surface which has a work function of 3.6 eV is illuminated with light of wavelength 253 nm . Calculate:
   i. the threshold frequency; **[2 marks]**
   ii. the maximum velocity of the liberated electrons; **[3 marks]**
   iii. the potential that must be applied in order to stop an electron from leaving the surface. **[3 marks]**

c. If the intensity of the light used in part (b) increases, what would be the effect, if any, on the velocity of the liberated electrons? Explain your answer. **[2 marks]**

Question 5

a. State two conditions necessary for static equilibrium. **[2 marks]**

b. A lorry of mass 40 000 kg crosses over a 30 m long bridge, as seen in Figure 2.

i. What is the additional reaction at the supports due to the lorry when it is at the centre of the bridge? **[2 marks]**

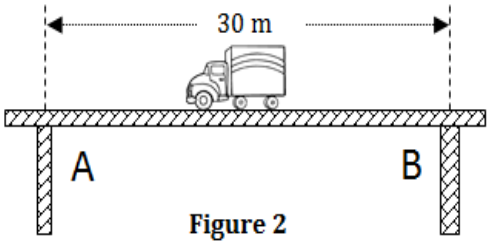


Figure 2

ii. At what distance from support B will the lorry be when the additional reaction at support A is 150 000 N? **[3 marks]**

iii. If the lorry is 5 m from one of the supports, calculate the additional upward reaction at each of the two supports due to the weight of the lorry. **[3 marks]**

iv. What has been ignored in these calculations? Explain why. **[2 marks]**

Question 6

a. Explain the difference between distance and displacement. **[2 marks]**

b. A car accelerates from rest at 0.15 m s^{-2} for two minutes and then continues to travel for five minutes at constant speed after which it decelerates to rest in one minute.

i. Sketch a velocity-time graph to show the motion of the car. Your sketch should be labelled with all the necessary values. **[3 marks]**

Using your graph, or otherwise, calculate:

ii. the total distance travelled; **[2 marks]**

iii. the rate of deceleration at the end of the journey. **[2 marks]**

c. On a separate graph, sketch the variation of acceleration with time. Label with all the necessary values. **[3 marks]**

Question 7

a. Derive an equation for the current I flowing through a conductor of cross-sectional area A, having n conduction electrons per unit volume and travelling at a drift speed v. The electrons carry a charge e. **[4 marks]**

b. On the basis of this equation, explain the difference between conductors and insulators. **[3 marks]**

c. A copper wire carries a steady current of 3 A. Calculate how many electrons flow past a point in the wire in 6 minutes. **[2 marks]**

d. A coil of wire has a resistance of 12.00 Ω at 70°C and 10.25 Ω at 20°C. Calculate the temperature coefficient of resistance of the wire. **[3 marks]**

Question 8

a. A body of mass 5 kg rests on a smooth horizontal surface. A force of 20 N is applied to the body for 6.0 s. Assuming that the body starts from rest, calculate:
   i. the final velocity; **[2 marks]**
   ii. the distance travelled; **[2 marks]**
   iii. the work done; **[1 mark]**
   iv. the final KE of the body. **[2 marks]**

b. The same force is applied for the same time to pull the mass up a smooth plane inclined at 15° to the horizontal.
   i. Find the velocity of the block at the end of the 6.0 s and its kinetic energy. **[3 marks]**
   ii. Explain the difference, if any, between this value and the answer to part (a)(iv). **[2 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.

Question 9

a. State Newton's third law of motion. **[2 marks]**

b. A 115 g ball is travelling to the left with a speed of 30 m s^{-1} when it is struck by a racket. The force on the ball, directed to the right and applied over 21 ms of contact time, as shown in the graph in Figure 3.

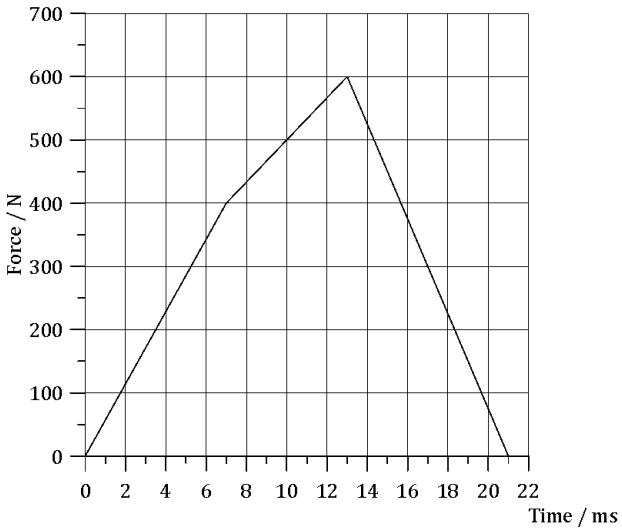


Figure 3

   i. What is the maximum magnitude of the force exerted on the ball? **[2 marks]**
   ii. State what the area under the graph represents, and hence calculate the average force acting on the ball during impact. **[2 marks]**
   iii. Calculate the speed of the ball immediately after it leaves the racket. **[2 marks]**

iv. Sketch a graph that shows how the force would have changed with time had the impact lasted longer than 21 ms while achieving the same momentum change in the ball. **[3 marks]**
v. On the basis of the answer to part (iv), what can be concluded? **[2 marks]**
vi. Describe one practical situation in which this conclusion may be applied. **[2 marks]**

c. State the principle of conservation of linear momentum. **[2 marks]**

d. An astronaut and his tools, have a total mass of 58 kg. The astronaut is in deep space when the tether connecting him to his spaceship breaks. He would like to move toward his spaceship, but his jet pack does not function. He throws a 720 g socket wrench with a speed of 5.0 m s^{-1} in a direction away from the ship. After 2.50 s, he throws an 800 g spanner in the same direction with a speed of 8.0 m s^{-1}.
i. Calculate the speed of the astronaut after he throws the socket wrench. **[2 marks]**
ii. With what speed does he hit the spaceship after throwing the spanner? **[3 marks]**
iii. Sketch a graph that shows how his speed changed with time, assuming it took negligible time for the astronaut to throw the tools. **[3 marks]**

Question 10

a. Jake took a homemade "accelerometer" to an amusement park. This accelerometer consists of a metal nut attached to a string and connected to a protractor, as shown in Figure 4. While riding a roller coaster that is moving at a uniform speed around a circular path, Jake held up the accelerometer and noticed that the string is making an angle of 55° with respect to the vertical with the nut pointing away from the centre of the circle, as shown.

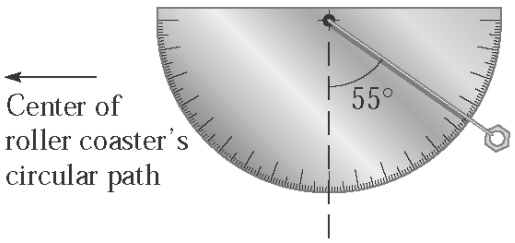


Figure 4

i. Explain why although the roller coaster is moving at uniform speed, it is still accelerating. **[1 mark]**
ii. Show that the acceleration of the roller coaster is given by the equation,

$$a = \frac{v^2}{R}$$

where v is the tangential velocity of the roller coaster and R is the radius of the circular path. **[4 marks]**
iii. Draw the forces acting on the nut, and calculate the radial acceleration of the roller coaster. **[4 marks]**
iv. If the roller coaster track has a radius of 80.0 m, calculate the speed with which Jake is moving. **[2 marks]**

b. A boy ties a small 10 g mass to a 75 cm long string and rotates it in a vertical circle at a constant speed of 50 revolutions in one minute. Assuming that the centre of the circle is 1 m above the ground, calculate:
i. the angular velocity of the mass; **[2 marks]**
ii. the linear speed of the mass; **[2 marks]**
iii. the tension in the string at the bottom of the circle; **[2 marks]**
iv. the most likely place that the mass would land if the string breaks, assuming the string can withstand a maximum breaking force of 0.25N. **[4 marks]**

c. A racing car of mass 750 kg goes round a circular track.
   i. Draw a labelled diagram showing all the forces acting if the track is banked at an angle of 25°. **[2 marks]**
   ii. Explain why it is necessary for the road to be banked. **[1 mark]**
   iii. Calculate the centripetal force. **[1 mark]**

Question 11

a. Give a qualitative explanation of the concept of moment of inertia. **[2 marks]**

b. The London Eye, a Ferris wheel on the banks of the Thames, has a radius of 67.5 m and a mass of 1.90×10^6 kg. At its cruising angular speed, it takes 30.0 minutes to make one complete revolution. Suppose that it takes 20.0 s to bring the wheel from rest to its cruising speed and that the angular acceleration is constant during start-up.

Assuming the mass of the wheel to be concentrated only along its rim, calculate:
   i. the angular acceleration during start-up; **[2 marks]**
   ii. the angular displacement of the wheel during start-up; **[2 marks]**
   iii. the torque needed to accelerate the wheel during start-up; **[2 marks]**
   iv. the work done by the electric pumps to bring the wheel to cruising speed. **[2 marks]**

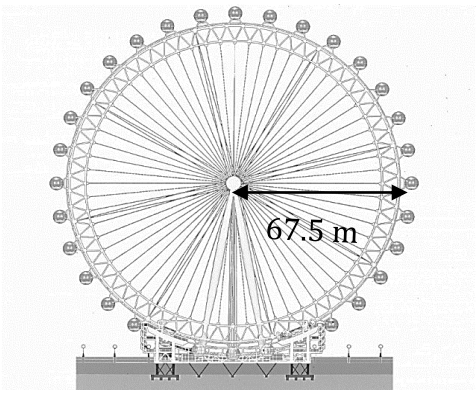


Figure 5

c. Define the principle of conservation of angular momentum. **[2 marks]**

d. A potter's turntable was rotating at 24 revolutions per minute when a piece of clay of mass 75 g was dropped on it. The mass fell onto a point 0.15 m from its axis of rotation. It was observed that on impact, the rate of rotation dropped to 10 revolutions per minute. Assuming that the turntable is frictionless:
   i. calculate the moment of inertia of the disc; **[5 marks]**
   ii. comment about the final rate of rotation, had the mass been dropped at the very edge of the disc. **[2 marks]**

e. A cylinder is rolled down a slope from rest. It is released down the slope from a height of 2.5 m above the horizontal ground. If the cylinder has a mass of 40 kg, a diameter of 0.4 m and a moment of inertia of 0.8 kg m^2, calculate:
   i. its speed when it reaches the end of the slope; **[4 marks]**
   ii. the value of the speed had the cylinder slipped, without rolling. **[2 marks]**

Question 12

a. Define stress, strain and Young modulus. **[3 marks]**

b. Describe an experiment to determine the Young modulus of a long thin metal wire. Your description should include:
   i. a list of equipment and materials to be used;
   ii. a labelled diagram of the set-up;
   iii. a description of the measurements that need to be taken;
   iv. a table of results;
   v. a sketch of the graph expected to be obtained from the results,
   vi. an indication of how the value of the Young modulus is to be determined. **[6 marks]**

c. A copper wire of diameter 0.35 mm and length 1.6 m is attached to one end of a steel wire of the same diameter but 1.3 m long. A load of 35 N is attached to the lower end of the steel wire while the copper end is attached to a rigid support. Given that the Young modulus of copper is 1.3×10^{11} N m^{-2} and that of steel is 2.0×10^{11} N m^{-2} :
   i. calculate the stress and strain of each wire; **[6 marks]**
   ii. what can be concluded from these calculations; **[2 marks]**
   iii. find the total extension of the two wires; **[3 marks]**
   iv. calculate the effective Young modulus for the whole system. **[2 marks]**

d. Engineers were investigating whether a 70 tonne train travelling at 0.45 m s^{-1} would be able to stop when running into an elastic system which obeys Hooke's law. Calculate the stiffness constant for such a system if it is to be compressed by 12 cm. **[3 marks]**

Question 13

a. On the basis of the band theory, explain the difference between intrinsic and extrinsic semiconductors. **[4 marks]**

b. Define the terms potential difference (p.d) and electromotive force (e.m.f.). **[4 marks]**

c. Derive an equation for the combined resistance of two resistors connected in parallel. **[3 marks]**

d. State Kirchoff's laws. **[2 marks]**

e. By making use of Kirchhoff's two laws, determine the currents I_1, I_2 and I_3 in the circuit of Figure 6.

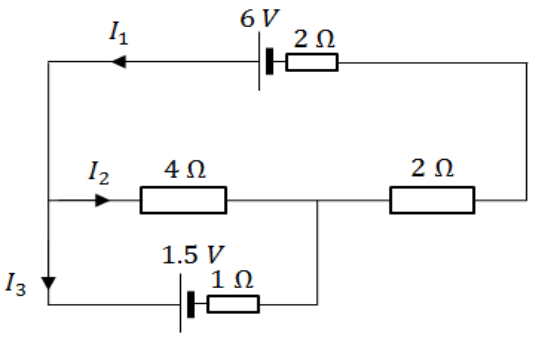


Figure 6 **[6 marks]**

f. A voltmeter has a switch that enables voltages to be measured with a maximum of 25.0 V or 10.0 V. For a range of voltages up to 25.0 V, the switch connects a resistor of magnitude 9850 Ω in series with the galvanometer. For a range of voltages up to 10.0 V, the switch connects a resistor of magnitude 3850 Ω in series with the galvanometer.

i. What is the name given to the resistor that is connected in series? **[1 mark]**

ii. Find the coil resistance of the galvanometer. **[3 marks]**

iii. Calculate the galvanometer current that causes a full-scale deflection. **[2 marks]**

Question 14

a. State Ohm's law. **[2 marks]**

b. One way to show whether a component is ohmic is by plotting its IV-characteristic. Describe an experiment to obtain such a characteristic for a filament lamp. Your description should include:

i. a list of equipment to be used;

ii. a diagram of the circuit used;

iii. a description of the measurements that need to be taken;

iv. a sketch of the graph expected to be obtained from the readings, and

v. two precautions that need to be taken during the experiment. **[6 marks]**

c. A circuit consists of a cell of e.m.f. 9 V and internal resistance 3 Ω connected to two resistors of 600 Ω and 400 Ω connected in parallel. Calculate the terminal p.d. of the cell. **[3 marks]**

d. Define resistivity. **[2 marks]**

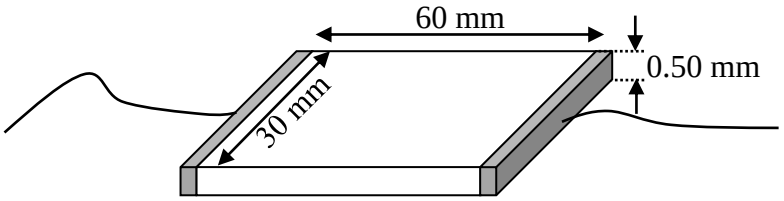


Figure 7

e. A slice of silicon which measures 30 mm by 60 mm and 0.50 mm thick is connected to a circuit by means of metal strips on the shorter sides of the slice, as shown in Figure 7. Calculate the resistance of the slice if the resistivity of silicon is $4 \times 10^3 \Omega$ m. **[2 marks]**

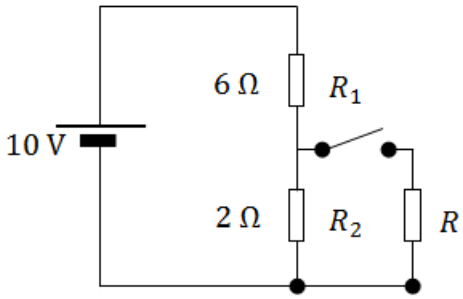


Figure 8

f. Using the values shown in the circuit diagram of Figure 8 and with the external load resistor R having a resistance of 5 Ω, calculate:
   i. the voltage across resistors R_1 and R_2 with the switch open; **[3 marks]**
   ii. the voltage across resistors R_1 and R_2 with the switch closed; **[3 marks]**
   iii. the power consumed by R with the switch closed; **[2 marks]**
   iv. the efficiency of the circuit by considering the ratio of the power delivered to the external load to the power delivered by the battery. **[2 marks]**

Question 15

a. A source of alpha particles is located in front of a thin metal foil such that a stream of alpha particles hit the surface perpendicularly. Explain why:
   i. most alpha particles manage to pass straight through the foil with just a slight deflection; **[2 marks]**
   ii. a few alpha particles are deflected back. **[2 marks]**

b. Define the half-life of a radioactive element. **[2 marks]**

c. It is found that the activity of a sample of polonium (Po) fell to one eight of its initial value in 420 days. Polonium decays by alpha emission into lead ($^{206}_{82}Pb$) and releases excess energy through a high energy electromagnetic wave.
   i. Calculate the half-life of polonium. **[2 marks]**
   ii. Write down the nuclear equation that represents the decay of polonium. **[3 marks]**

d. Potassium-44 ($^{44}_{19}K$) decays by changing into calcium-44 ($^{44}_{20}Ca$). Assuming that the half-life of potassium-44 is 20 minutes, calculate:
   i. the number of atoms in a 20 mg sample of potassium-44; **[2 marks]**
   ii. the initial activity of potassium-44 and its activity after an hour; **[4 marks]**
   iii. the ratio of potassium atoms to calcium atoms after one hour. **[4 marks]**

e. It is known that the mass of a neutron is 1.00898 u, the mass of a proton is 1.00759 u, the mass of nuclear deuterium $^{2}_{1}H$ is 2.01419 u, the mass of nuclear helium is $^{4}_{2}He$ 4.00277 u and 1 u is equivalent to 931 MeV. Calculate the energy liberated in MeV when a helium nucleus is produced by:
   i. fusing two neutrons and two protons, and **[2 marks]**
   ii. fusing two deuterium nuclei. **[2 marks]**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2013

SUBJECT:	PHYSICS
PAPER NUMBER:	II
DATE:	24th May 2013
TIME:	4.00 p.m. to 7.00 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.

Question 1

a. Explain what is meant by the specific latent heat of vaporization of a liquid. **[2 marks]**

b. Liquid A of mass 200 g is at a temperature of 100°C. Another liquid B of mass 100 g is at a temperature of 0°C. When the two liquids are mixed, the final temperature is 50°C. Which of the two liquids has the higher specific heat capacity? Show all your working. **[2 marks]**

c. A radiation heater is used to heat a glass container filled with 300 g of water initially at a temperature 55°C. A current of 10 A passes through the heater that has a potential difference of 250 V across it. All of the water is turned into steam at 110°C. Calculate the time taken for the above process assuming that there are no heat losses.

(Specific heat capacity of water $= 4181\ \text{J kg}^{-1}\text{K}^{-1}$, Specific heat capacity of steam $= 2080\ \text{J kg}^{-1}\text{K}^{-1}$, Latent heat of vaporization $= 2260 \times 10^3\ \text{J kg}^{-1}$, Heat capacity of container $= 75\ \text{J K}^{-1}$) **[6 marks]**

d. Explain carefully why the specific heat capacity of steam is less than that of water. **[2 marks]**

Question 2

a. i. Define the term thermal conductivity of a material and state a unit in which it is expressed in. **[2 marks]**

ii. It is estimated that the surface area of skin around an average human body is equivalent to the surface area of a cuboid of dimensions as given in Figure 1. Assuming the energy production to be 120 J s^{-1} and the internal and external temperatures to be 37°C and 33°C respectively, estimate the thermal conductivity of skin. Take the skin to have an average depth of 1.0 mm. **[5 marks]**

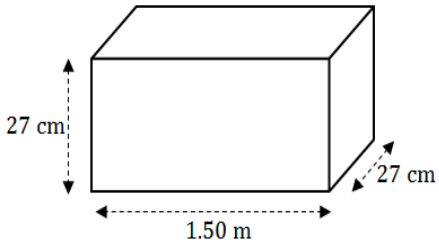


Figure 1

b. i. What is a temperature gradient in one dimension? **[1 mark]**

ii. A metal bar of length L connects a hot reservoir at a temperature T to a cold reservoir at room temperature. Sketch two graphs that show how the temperature changes with the length of the bar for the two cases when the bar is lagged and when it is not. **[2, 2 marks]**

iii. After some time a steady state is reached, what does this mean for the bar with no lagging? **[2 marks]**

Question 3

a. State Newton's law of Universal Gravitation and write down its mathematical representation. **[2, 1 mark]**

b. In terms of forces, what is the distinction between an electric field and a gravitational field? **[2 marks]**

c. Luke stands on a weighing scale in an elevator that has a constant upward acceleration. The scale reads 0.960 kN. When Luke picks up a box of mass 20.0 kg, the scale reads 1.200 kN. The acceleration remains the same.

i. Find Luke's weight. **[2 marks]**

ii. Find the acceleration of the elevator. **[2 marks]**

d. Io is one of Jupiter's 67 moons. Given that its orbital period is 1.769 days and its mean distance from Jupiter is 4.217×10^5 km, estimate Jupiter's mass if Io were to be moving along a circular path. **[3 marks]**

Question 4

a. State Coulomb's law for electrostatics. **[1 mark]**

b. Charge Q_1 of $+4.0$ μC is located at (0.0, 1.0) cm and charge Q_2 of $+2.0$ μC is located at (2.0, 2.0) cm as seen in Figure 2.

i. Define the electric field strength at a point and find its magnitude at point P. **[1, 3 marks]**

A negative charge $-q$ of 3 μC moves from a great distance to point P.

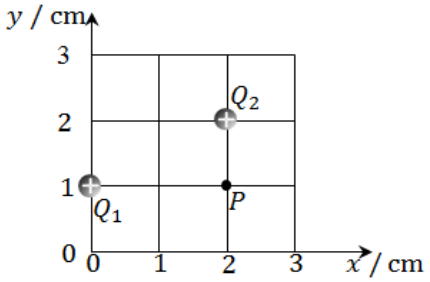


Figure 2

ii. Find the magnitude of the resultant force acting on the charge at P and determine the angle that the resultant force makes with the horizontal. **[2, 1 mark]**

iii. Find the electric potential at point P due to the two charges Q_1 and Q_2. **[4 marks]**

iv. What is the change in electric potential energy when the third charge is brought up to P? **[2 marks]**

Question 5

a. i. Define magnetic flux density. **[1 mark]**

ii. A rectangular coil of N turns of wire, area A and carrying a current I is in a uniform magnetic field of flux density B with its plane parallel to the field. Show that the torque τ on the coil is given by $\tau = BANI$. **[2 marks]**

iii. A particular current generation device uses heated steam to rotate a rectangular coil system in a magnetic field of flux density 1500 mT. The maximum torque acting on the coil is 50 Nm. The coil forms a square shape of side 10 cm. The system is used to produce a current not exceeding 3 A. Ignoring any resistive forces determine the maximum number of turns the coil system can have. **[2 marks]**

b. i. Figure 3 shows a current carrying semiconductor in a magnetic field. Explain what the Hall effect is and show that the Hall voltage is given by

$$V_H = \frac{BI}{net}$$

where B is the magnetic flux density, n is the number of charge carriers per unit volume and t is the thickness of the semiconductor. **[1, 3 marks]**

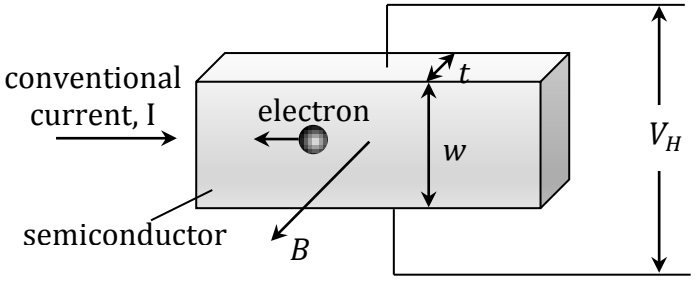


Figure 3

ii. A flat slab of semiconductor has thickness t of 0.50 mm. A current $I\ of$ 2.0 A flows along its length to the right as in Figure 3. A magnetic field of flux density $B\ of$ 0.25 T acts perpendicular to the flat surface of the slab. Assume that the carriers are electrons and that there are 7.0×10^{24} mobile electrons per m^3, calculate the magnitude of the Hall voltage across the slab and indicate which surface (top or bottom) is at the higher potential. **[2, 1 mark]**

Question 6

a. Distinguish between longitudinal and transverse waves. Mention four similar characteristics they share and one which they do not. **[2, 4, 1 mark]**

b. Explain how new wavefronts are created according to Huygen's principle. **[1 mark]**

c. i. Explain what is meant by a progressive wave. **[1 mark]**
ii. Draw a diagram to show what is meant by the phase difference between two waves. **[1 mark]**
iii. Briefly describe how progressive waves can be used to determine the speed of sound in a gas. **[2 marks]**

Question 7

a. i. State the principle of superposition as applied to waves. **[1 mark]**
ii. What happens when identical waves travelling in opposite directions superimpose on one another? What are nodes and antinodes? **[2, 2 marks]**

b. In Young's double slit experiment, two coherent light sources interfere to produce dark and bright fringes on a screen. In the double-slit arrangement the slit separation s is 0.150 mm, the distance from the screen D, is 120 cm and the light source has a wavelength λ of 833 nm.
i. How are the dark and bright fringes formed? **[2 marks]**
ii. Draw a diagram to show the setup and determine the path difference for the rays from the two slits arriving at a point P on the screen that is 2.00 cm above the central fringe. **[3 marks]**
iii. Express this path difference in terms of λ . **[1 mark]**
iv. Does point P correspond to a bright or a dark fringe? **[1 mark]**

Question 8

a. i. State Hubble's law and briefly explain any supporting evidence. **[2, 2 marks]**
ii. Cosmologists have calculated the Hubble constant H_0 to be given approximately by 20 km s^{-1} per million light years. Why is there some uncertainty on this value? Express H_0 in s^{-1}. **[2 marks]**
iii. How does Hubble's law lead to the Big Bang creation theory of the Universe? **[3 marks]**

b. i. Explain what is meant by the cosmological red-shift of spectral lines from distant galaxies. **[1 mark]**

ii. A small number of galaxies on the sky appear to be blue shifted. What conclusions can you deduce on the direction of motion of these Galaxies and state whether such conclusions have any effect on the Big Bang theory. **[2 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.

Question 9

a. i. State in words the first law of thermodynamics and give its mathematical representation. Clearly explain all the terms used. **[2 marks]**

ii. For each of the three diagrams (I), (II) and (III) in Figure 4, identify the process taking place for a gas initially at a pressure P_i and volume V_i and ends with a pressure P_f and volume V_f. **[3 marks]**

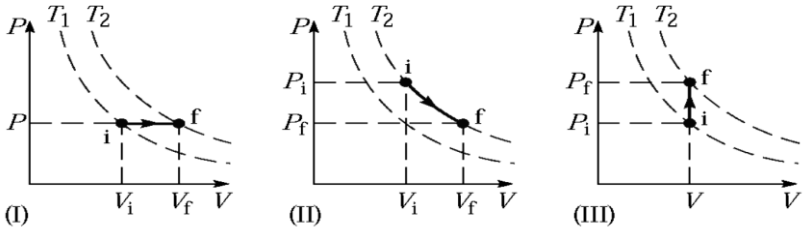


Figure 4

iii. An ideal gas held in a container by a frictionless cylindrical piston undergoes an isobaric expansion and moves from a height of 30 cm at 0°C to a height of 40 cm. Find the temperature of the gas after the process is complete and state any gas law used. **[2, 1 mark]**

iv. Show that the work done in an isobaric process is given by $F\Delta V$. **[2 marks]**

v. Calculate the work done in (iii) if the radius of the piston is 0.05 m and the pressure is kept constant, at 1.01×10^5 Pa. State clearly whether the work is done on the gas or by the gas. **[1, 1 mark]**

vi. If the process were changed to one that is isochoric, would any of this type of work be done? Explain. **[1 mark]**

vii. The isobaric process involves a heat input of 60 J. Briefly describe what internal energy is and calculate the change in internal energy of the gas. **[2 marks]**

b. In Figure 5, a heat engine is represented schematically where Q_H is the heat input from a high temperature reservoir, Q_C is the heat rejected in the cold reservoir and W_{net} is the work done on the surroundings.

i. Draw a similar labelled schematic diagram for the heat pump and explain any terms used. **[2 marks]**

ii. Briefly describe the function of the heat pump. **[2 marks]**

iii. State the second law of thermodynamics in terms of heat engines. **[1 mark]**

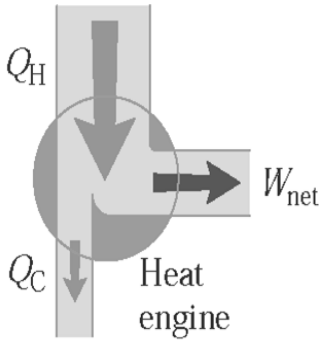


Figure 5

iv. Two engines operate between the same two temperatures of 750 K and 350 K and have the same rate of heat input. One of the engines is a reversible engine with a power output of 2.3×10^4 W. The second engine has an efficiency of 42%. What is the power output of the second engine? **[3 marks]**

v. Mention one limiting factor for efficiency in heat engines/pumps and one way in which the theoretical efficiency can be improved. **[2 marks]**

Question 10

a. i. Describe one of the visual pieces of evidence for the random motion of molecules in a gas. **[2 marks]**

ii. Given all the assumptions of the kinetic theory of gases, can an ideal gas form into a solid? Explain. **[1, 2 marks]**

iii. Name three other assumptions in the kinetic theory of gases not already mentioned. **[3 marks]**

b. For a mole of ideal gas with pressure p, volume V at an absolute temperature T , it is found that

$$pV = \frac{1}{3} N_A m\overline{c^2}$$

where N_A is Avogadro's constant and m is the mass of each molecule.

i. Given three molecules of respective speeds 1 m s^{-1}, 2 m s^{-1} and 3 m s^{-1}, determine $\overline{c^2}$ for this case. **[2 marks]**

ii. Show that the average kinetic energy of the gas particles is directly proportional to the temperature and find the constant of proportionality between them. **[4 marks]**

iii. What analogous microscopic mechanism does the kinetic theory of gases use to explain pressure? Explain. **[3 marks]**

c. An ideal gas at a temperature of 10°C and a pressure of 2.01×10^5Pa is held in a cubic box of side 22.786 cm.

i. If there are 1.01 moles of the gas, determine the number of molecules in the gas. **[2 marks]**

ii. Find a value for the molar gas constant. **[3 marks]**

iii. Find the average kinetic energy of a molecule of this gas. **[3 marks]**

Question 11

a. i. Define the capacitance of a capacitor. **[1 mark]**

ii. What does the term time constant refer to? **[2 marks]**

b. i. Discuss the **physical** reasons for the capacitance C of a parallel plate capacitor being proportional to the plate area A and inversely proportional to the plate separation d. **[3 marks]**

ii. The linear dependence of capacitance on area is a major engineering problem in small factor capacitor design. Mention one way of solving this issue and describe the capacitor that does this. **[2 marks]**

c. Two capacitors with capacitances C_1 and C_2 are setup in series and connected as shown in Figure 6. A resistor R is used to charge and discharge the two capacitors.

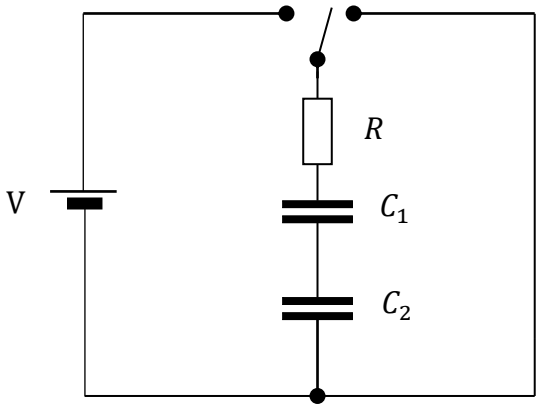


Figure 6

i. Derive a relation for effective capacitance of the two capacitors in series. **[3 marks]**

ii. What is the circuit time constant? **[1 mark]**

iii. Draw graphs of potential difference against time for the charging and discharging of a capacitor. **[2, 2 marks]**

iv. Comment on the addition of values from these two graphs at any point in time? **[1 mark]**

d. Show that the energy stored on a capacitor is given by $\frac{1}{2}QV$. Express this in terms of charge and capacitance. **[2 marks]**

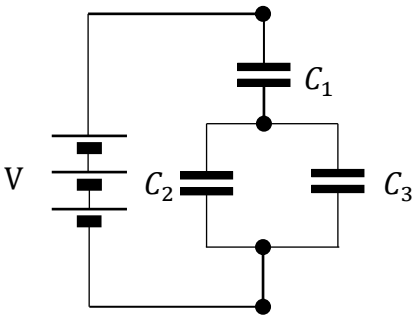


Figure 7

e. A circuit is composed of capacitors as shown in Figure 7 with capacitor values C_1 of 1.1 μF, C_2 of 0.1 μF and C_3 of 0.5 μF. The battery provides a potential difference of $9\,V$.

i. Calculate the charge and potential difference across each component. **[4 marks]**

ii. If a $1\,\text{M}\Omega$ resistor is connected in series with the capacitors what will the time constant be? **[2 marks]**

Question 12

a. State the laws of electromagnetic induction. **[2, 2 marks]**

b. Mention one important consequence that would follow if it were found that Lenz's law did not hold. **[2 marks]**

c. Describe an experiment to test Faraday's law. Your description should include:

i. a list of equipment and materials to be used;

ii. a labelled diagram of the set-up;

iii. a description of the measurements that need to be taken;

iv. a description of any calculations that need to be carried out;

v. a table of results;

vi. a sketch of the graph expected to be obtained from the results. **[6 marks]**

d. A narrow coil of 11 turns and area 16×10^{-2} m^2 is placed in a uniform magnetic field of flux density 1×10^{-2} T so that the flux links the coil normally. Calculate the average induced e.m.f. in the coil if it is removed completely from the field in 0.5 s. **[2 marks]**

e. A conducting rod PQ of length l moves up an inclined plane with a constant velocity v in a uniform magnetic field B directed vertically down.

i. Show that the induced e.m.f. is given by

$$\varepsilon = Blv\cos\theta.$$ **[3 marks]**

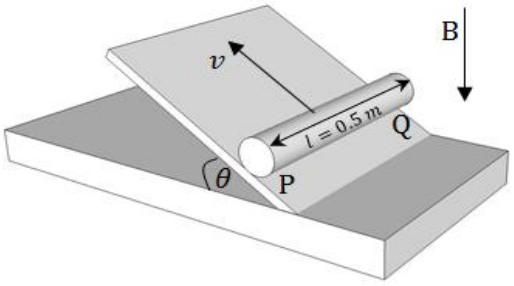


Figure 8

ii. Assuming that the magnetic field strength B is equal to 6×10^{-5} T, calculate the induced e.m.f. between the ends of the rod of length 0.5 m if it is moving at 2 m s^{-1} on the plane that is inclined at 25° to the horizontal. **[2 marks]**

iii. Which end of the rod is at a higher potential? **[1 mark]**

f. i. Define self-inductance. **[2 marks]**

ii. For a solenoid having N turns and cross-sectional area A, the magnetic field strength is given by $B = \frac{\mu_0 N}{l} I$. Show that the self-inductance is given by $L = \frac{\mu_0 A N^2}{l}$. **[3 marks]**

Question 13

a. Explain what is meant by the peak value and root-mean-square value of an alternating current. **[3 marks]**

b. A capacitor C of capacitance 1 μF is used in a radio circuit where the frequency is 1000 Hz and the current has a peak value of 2.828 mA.
   i. Define the reactance of a capacitor. **[2 marks]**
   ii. Calculate the r.m.s voltage across C. **[2 marks]**

c. i. Explain the terms forward bias and reverse bias for a p-n junction diode. **[2 marks]**
   ii. Sketch an I-V characteristic graph for a p-n junction diode. Label clearly the regions where the diode is in forward and reverse bias modes. **[4 marks]**
   iii. Sketch two circuit diagrams that show a diode connected in forward bias and reverse bias modes. **[2, 2 marks]**

d. In a d.c power supply a transformer, a capacitor, a load resistor and 4 diodes are used to convert high voltage alternating current into a low voltage direct current.
   i. What is the purpose of the 4 diodes in the power supply? **[2 marks]**
   ii. Draw a circuit diagram that shows how the components are connected together inside the power supply. **[2 marks]**
   iii. Distinguish between half-wave and full-wave rectifiers. **[1, 1 mark]**
   iv. Sketch the current output from a half- and a full-wave rectifier for a given sinusoidal alternating current input. **[1, 1 mark]**

Question 14

a. i. State the two conditions necessary for simple harmonic motion. **[2 marks]**
   ii. Define the terms displacement and amplitude for a particle undergoing simple harmonic motion. **[1, 1 mark]**
   iii. Derive a relationship for the period of the oscillation of a mass-spring system in a vertical orientation in terms of the mass m and the spring constant k alone. **[3 marks]**
   iv. A light helical spring is extended by 10 cm when loaded with a mass of 50 g. Calculate the period of the small vertical oscillations when the mass is displaced and released. **[2 marks]**

b. A particle undergoing simple harmonic motion has velocities of 4 cm s^{-1} and 3 cm s^{-1} at distances of 3 cm and 4 cm respectively from the equilibrium position. Given that the velocity of a particle undergoing simple harmonic motion with amplitude A and angular frequency ω is given by $v = \pm\omega\sqrt{A^2 - x^2}$ when it is distant x from equilibrium position, find:
   i. the amplitude of the oscillations; **[3 marks]**
   ii. the period and; **[2 marks]**
   iii. the velocity of the particle as it passes through the equilibrium position. **[1 mark]**

c. Sketch four displacement-time graphs that show free, lightly damped, heavily damped and critically damped oscillations. **[4 marks]**

d. A 1.50 kg object oscillates with an angular frequency ω of 10 Hz (rad s^{-1}) with simple harmonic motion. The maximum displacement of the oscillations is A and the maximum speed that the object reaches is 70 cm s^{-1}.

i. Show that the total mechanical energy is given by $E = \frac{1}{2}m\omega^2A^2$. **[3 marks]**

ii. Calculate the total mechanical energy of this system. **[2 marks]**

iii. Calculate the amplitude of the oscillatory motion. **[1 mark]**

Question 15

a. State the two predictions of the law of reflection. **[1, 1 marks]**

b. i. What is Snell's law of refraction? **[2 marks]**

ii. After sunset the sun's light is still seen. By using diagrams and Snell's law explain why this is observed. **[2 marks]**

iii. Describe the phenomenon of total internal reflection. **[1 mark]**

iv. Derive a relationship in terms of refractive indices only for the angle at which total internal reflection occurs. **[2 marks]**

c. Describe an experiment to determine the focal length of a lens. Your description should include:

i. a list of equipment and materials to be used;

ii. a labelled diagram of the set-up;

iii. a description of the measurements that need to be taken;

iv. a table of results;

v. a sketch of the graph expected to be obtained from the results;

vi. an indication of how the value of the focal length is to be determined. **[6 marks]**

d. What is the difference between a virtual and a real image? Describe a method for demonstrating the presence of a real image. **[1, 1, 1 mark]**

e. Define the magnification of a lens. **[2 marks]**

f. An object is placed 20 cm from a converging lens of focal length 15 cm.

i. Calculate the image position and magnification. **[2 marks]**

g. The lens is now replaced with a diverging lens of the same focal length. Calculate the image position and magnification. **[3 marks]**

Index No._____ **AM 26/III.13m**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2013

SUBJECT:	PHYSICS
PAPER NUMBER:	III – *Practical*
DATE:	12th June 2013
TIME:	2 hours

Experiment: Lenses

Apparatus: Filament lamp, convex lens, concave lens, lens holders, screen, metre ruler.

Important Note:

- Please take note that the filament lamp and surrounding box become very hot during the experiment. Take necessary precautions.
- The filament lamp is likely to get damaged if you handle roughly.

Failure to follow these instructions may incur damage to the apparatus and loss of time.

Diagram:

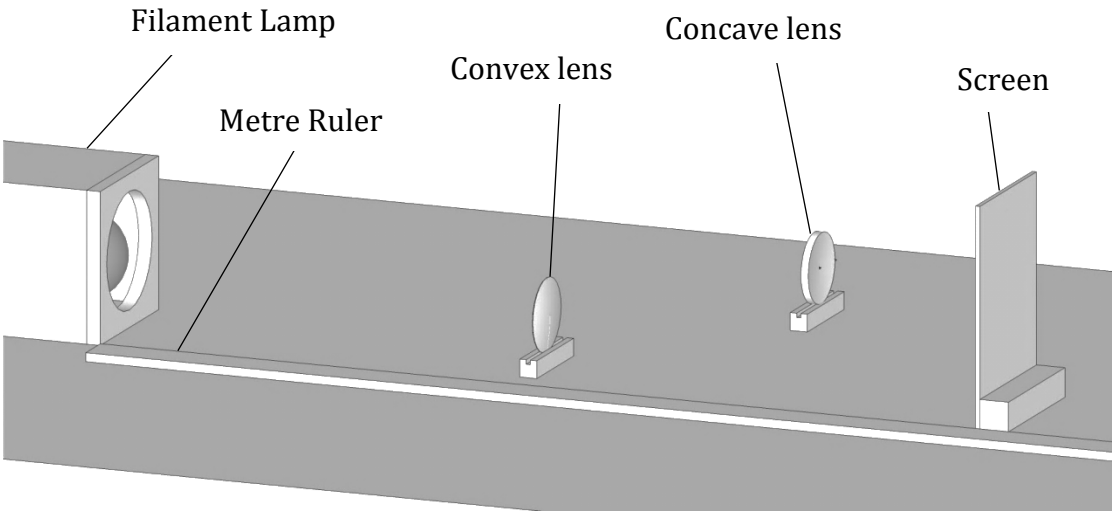


Figure 1 The experimental set-up.

Method – Part A:

1. Set up the optical system in the order shown in Figure 1. Place only the convex lens between the light bulb and the screen. The front face of the box containing the light bulb should be positioned next to the 0 cm mark of the metre ruler.
2. Move the screen such that the distance between the screen and the light bulb is about 70 cm.
3. Move the convex lens and find a position where a real image is formed on the screen. This procedure is useful to optimally align your optical system.

4. For *a given focal length of a lens, there exists a minimum distance between the object and the screen, below which it is not possible to obtain a real and sharp image of the object on the screen*.

   Devise a way how to investigate the statement in italics above and use it to determine this minimum distance. In the space provided below, describe the procedure that you followed, and show clearly how you arrived at your result.

[6 marks]

5. The minimum distance determined in step 4 is four times the focal length of the lens. A first approximation for the value of the focal length $f_1 =$ _____cm . **[1 mark]**

6. For object distances u (distance between the light bulb and the base of the lens holder) that range from 22 cm to 45 cm , use the metre ruler to measure the image distance v, the distance between the base of the lens holder and screen when the image is in focus.

   Take between a minimum of 10 and a maximum of 14 distances of u. It is advisable to take shorter intervals for u at distances in the neighbourhood of twice the focal length of the lens as determined in step 5. Record the measurements taken in Table 1.

Table 1

u /cm	v/cm	$u+v$ /cm

[14 marks]

7. Complete the above table by filling in the third column for $u+v$. **[4 marks]**

8. Plot a graph of $(u+v)/$ cm on the y-axis against u / cm on the x-axis. The graph should be a smooth curve with a minimum point. **[15 marks]**

9. From your graph determine the value of u and the corresponding value of $u+v$ at which the minimum point of the graph occurs. **[2 marks]**

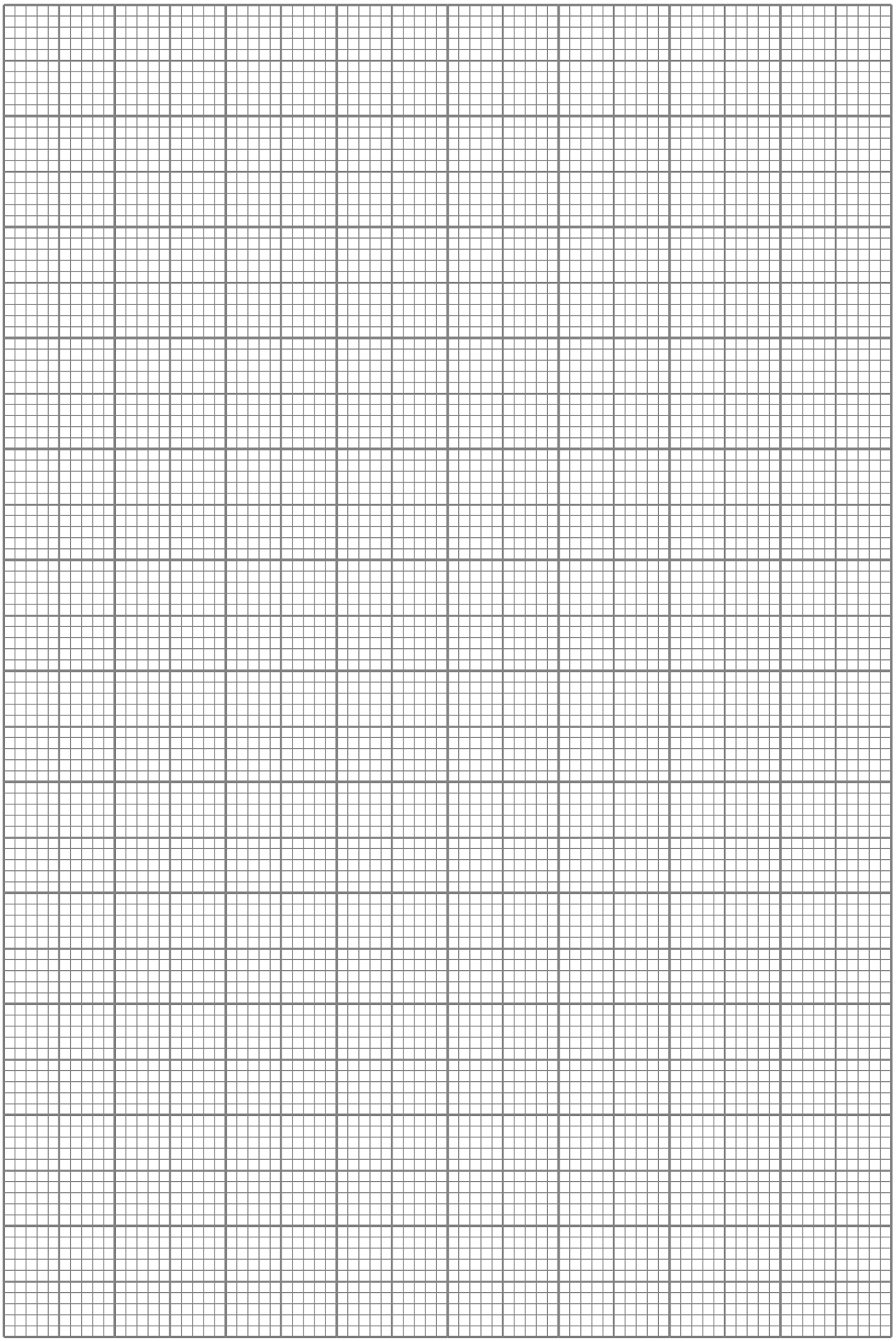
10. Given that the value of $u+v$ at the minimum point of the graph is 4 times the focal length of the convex lens, determine a second value for the focal length of the lens $f_2 =$_____ cm. **[1 mark]**

11. The gradient m of any tangent to the curve drawn at any point along the curve is related to the object distance u and the focal length of the lens f by the expression.

$$m = \frac{u^2 - 2uf}{(u-f)^2}$$

Given that the gradient at the minimum point on the plotted graph is zero, determine a third value for the focal length of the convex lens. $f_3 =$_____ cm. **[3 marks]**

12. Hence calculate the mean value for the focal length, f, of the convex lens $f =$_____ cm. **[1 mark]**



Method – Part B:

13. Position the convex lens at about 30 cm from the light bulb.

14. Adjust the position of the screen to obtain a sharp image, as in Figure 2.

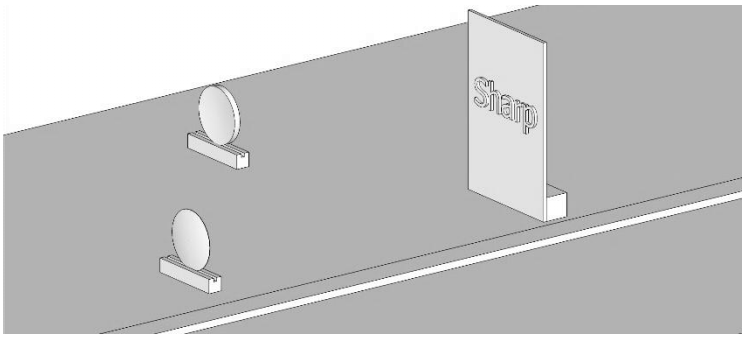


Figure 2

15. Interpose the concave lens between the convex lens and the screen and adjust the separation L (see Figure 3) between the two lenses to be equal to the first value shown in Table 2. The image on the screen should become blurred. In this **first position** of the screen, the distance between the screen and the concave lens may be considered to be the **virtual image distance**, v', for the concave lens.

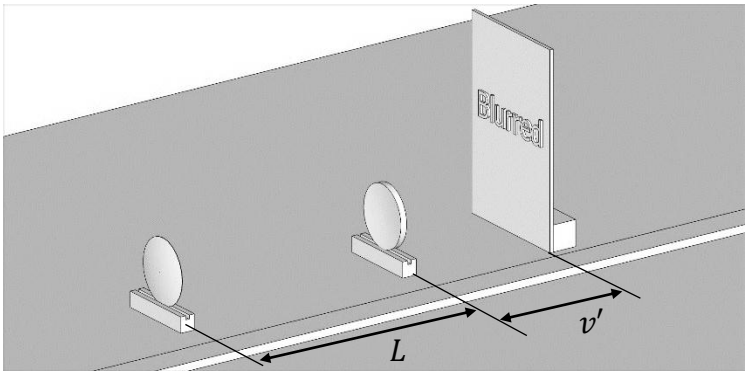


Figure 3

16. Moving the screen away from the lenses and light bulb should restore a sharp and clear image. In this **second position** of the screen, the distance between the screen and the concave lens is the **object distance**, u', for the concave lens (see Figure 4).

17. Briefly, explain why the image distances v' for the concave lens that will be measured should be recorded in Table 2 as negative values.

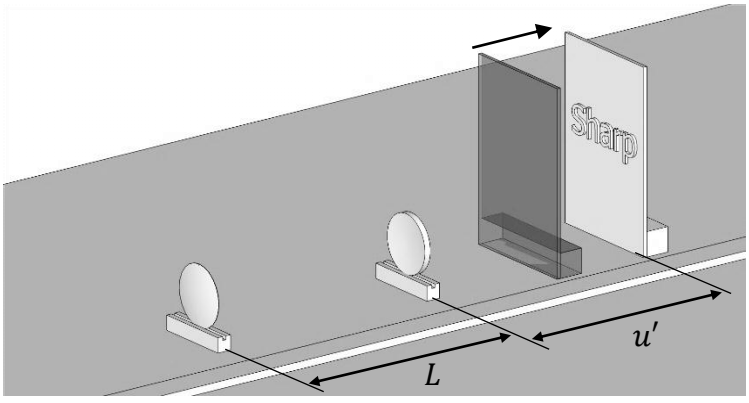


Figure 4

_____

_____

_____

[3 marks]

18. For the distances L between the convex lens and the concave lens given in Table 2, repeat steps 14 to 16, each time recording values for u' and v' as shown in Figures 3 and 4.

Table 2

$L\ /\ cm$	$v'/\ cm$	$u'/\ cm$	$\frac{1}{v'}/\ cm^{-1}$	$\frac{1}{u'}/\ cm^{-1}$
24.0				
25.0				
26.0				
27.0				
28.0				
29.0				

[18 marks]

19. Complete Table 2 by working out the missing values. **[6 marks]**

20. Plot a graph of $\frac{1}{v'}$ on the y-axis against $\frac{1}{u'}$ on the x-axis. The graph is a straight line with a negative gradient and intercept. **[15 marks]**

21. The thin lens equation is given by

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

where f' is the focal length of the concave lens.

By rearranging this equation and using the graph obtain a value for the focal length f' of the concave lens.

[2, 3 marks]

22. Identify and state **two** sources of error. For each source of error, indicate clearly whether it is a systematic or random error.

[4 marks]

23. State **two** precautions undertaken to minimize the errors identified in step 22.

[2 marks]