MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2013

SUBJECT:	PHYSICS
PAPER NUMBER:	I
DATE:	3rd September 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. Give the dimensions of the following physical quantities: acceleration; force; work.
[3 marks]

b. A lead ball of mass 200 g is suspended from a string as shown in Figure 1.

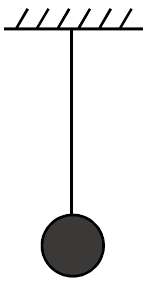


Figure 1

i. Draw a diagram to show the ball when the string makes an angle of 30° to the vertical. Indicate and label all the forces acting on it. [2 marks]
ii. Calculate the tension in the string. [3 marks]

c. The pendulum is then released and allowed to oscillate. The periodic time T of these oscillations is given by the equation:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length of string and g is the acceleration due to gravity.
i. Use dimensions or base units to show that the equation is physically homogenous.
[3 marks]
ii. Suggest one way by which you can make the pendulum oscillate faster. [1 mark]

Question 2

Figure 2 shows how the velocity of a van changes as it travels from one delivery point to another over a total time of 100 minutes.

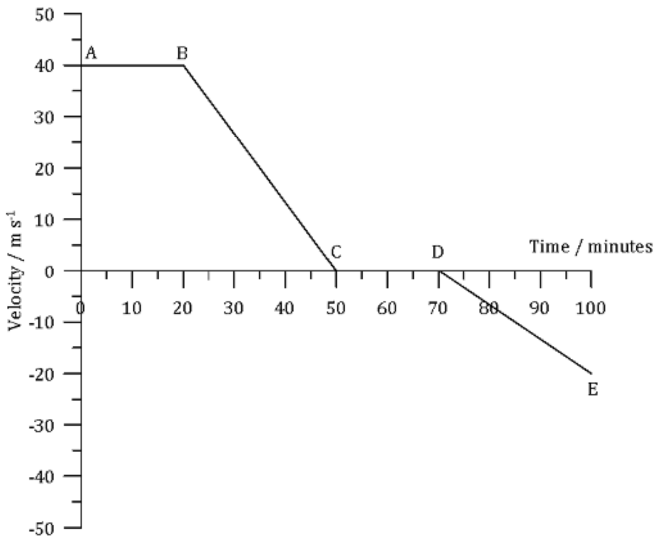


Figure 2

a. Calculate the duration of the trip between points A and E in seconds. [1 mark]

b. Describe carefully the type and direction of motion of the van at each stage between A and E. [4 marks]

c. Calculate:
   i. the total distance travelled by the van in metres; and [2 marks]
   ii. the average speed of the van in m s^{-1}. [2 marks]

d. Sketch a graph that shows the variation of distance with time between points A and E. Indicate clearly on your graph the values of distance and time at each stage. [3 marks]

Question 3

A wooden go-cart of mass 15.5 kg is released from rest down a slope of distance 100 m and inclined 15° to the horizontal (see Figure 3).

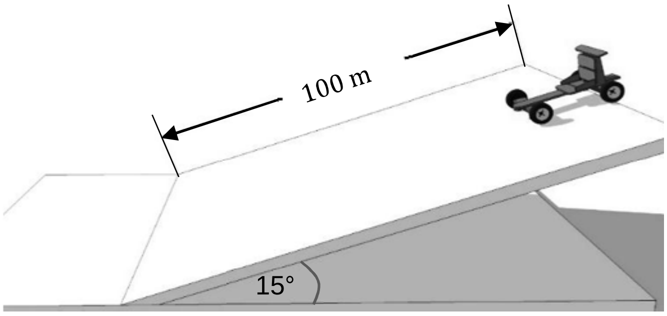


Figure 3

a. Calculate the go-cart's potential energy at the top of the slope. [2 marks]

b. Calculate the maximum velocity that the go-cart can achieve at the bottom of the slope. State any assumptions you make. [3 marks]

c. Calculate the velocity of the go-cart at the bottom of the slope if a boy of mass 40 kg sits in it as it goes down the slope and there is an average frictional force of 25 N present between the go-cart and the ground. [4 marks]

d. Explain why there is a difference between the velocities worked out for (b) and (c). [2 marks]

e. Suggest one way in which you can make the go-cart reach a greater velocity at the bottom without changing the angle of the slope. [1 mark]

Question 4

a. Explain why an object going round in a circle experiences an acceleration even if it is moving at the same speed. State the direction of this acceleration. [3 marks]

b. A bucket filled with water is rotated in a vertical circle as shown in Figure 4.
   i. Indicate at which point the tension in the string reaches a maximum and draw a diagram to show the forces acting on the bucket at this point. [3 marks]
   ii. Derive an equation for the tension T at this point in terms of the mass m of the bucket, the radius r, the velocity v at this point and the acceleration due to gravity g. [2 marks]
   iii. Calculate the value of this tension if the mass of the bucket is 2.3 kg and the string is 0.8 m long, and is rotated at a speed of 12 m s^{-1} . [2 marks]

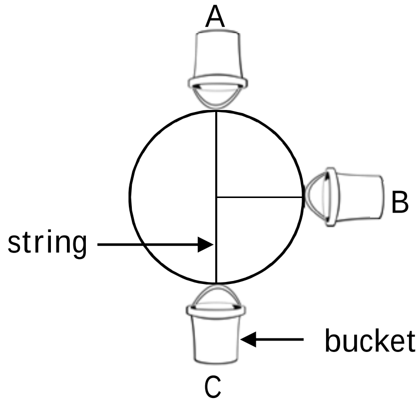


Figure 4

   iv. Show, with working, whether the water will fall out of the bucket or not at point A. [2 marks]

Question 5

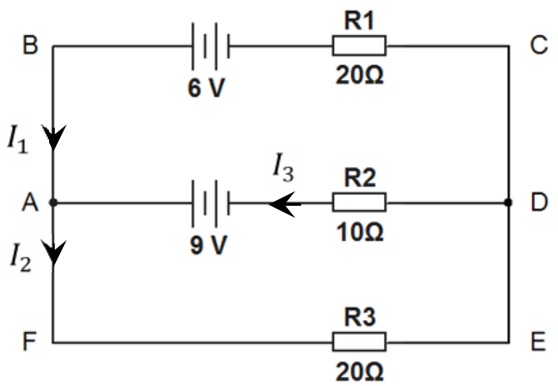


Figure 5

a. State Kirchhoff's Law related to current at a junction and use it to write down a relation between the currents at point A of the circuit. [2 marks]

b. State Kirchhoff's Law related to the e.m.f and apply it to the following loops:
   i. Loop ABCD
   ii. Loop AFED [3 marks]

c. Hence or otherwise determine the values of I_1, I_2 and I_3. [6 marks]

d. Calculate the power dissipated as heat in the circuit. [3 marks]

Question 6

The diagram in Figure 6 represents the first four energy states of a particular atom.

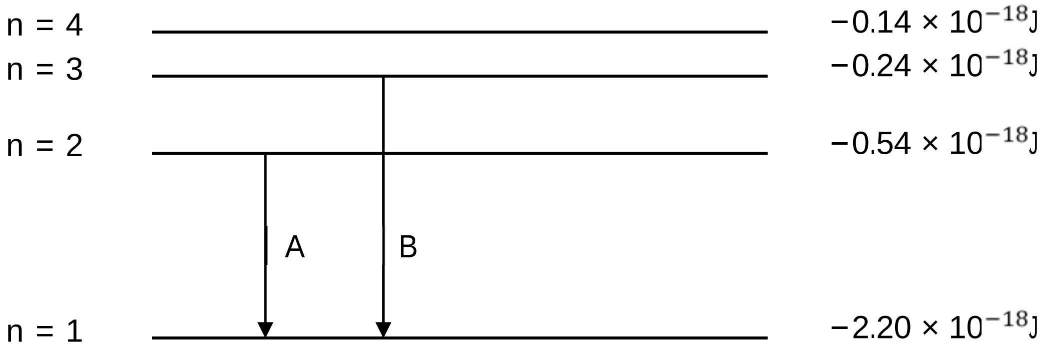


Figure 6

Two electrons in excited state fall to ground state in transitions A and B.

a.
   i. Explain the meaning of ground state and excited state. [2 marks]
   ii. Explain why the values of the energy levels are negative. [2 marks]
   iii. Give the value of the energy of the ground state in Joules and in electronVolts. [2 marks]

b. Calculate the wavelengths of the emitted radiations that will be produced in transitions A and B. [4 marks]

c. Explain why the emitted radiation can only have certain wavelengths and not others. [2 marks]

d. Explain what happens in terms of energy levels when an electron is excited to a level where it is completely detached from the atom. [2 marks]

Question 7

The circuit shown in Figure 7 was set up.

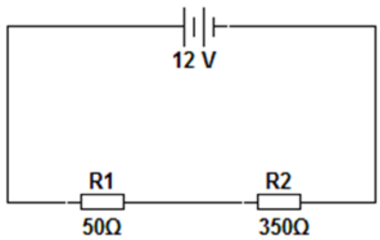


Figure 7

a. Work out the potential difference across each resistor. [2 marks]

b. A voltmeter of resistance 500 Ω is connected in parallel to the 50 Ω resistor.
   i. Calculate the voltage which the voltmeter would read. [4 marks]
   ii. Work out the reading on the voltmeter if it is then connected across the 350 Ω resistor. [4 marks]
   iii. Explain why the voltmeter gives different readings to those worked out in (a). [2 marks]

Question 8

A uniform ladder of length 8 m and mass 20 kg stands on rough ground and rests against a smooth wall at an angle of 70° to the horizontal.

a. Draw a diagram of the ladder and indicate clearly all of the following forces acting on the ladder: the weight W of the ladder, the reaction R_W at the wall and the resultant force F by the ground on the ladder. [4 marks]

b. Calculate the value of the reaction R_W at the wall and the resultant force F. Give the direction of the resultant force F. [4 marks]

c. A man of mass 70 kg climbs up the ladder along a distance of 5 m from the ground. Calculate the new values of R_W and F and the angle that F makes with the horizontal. [4 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. Electric current in any material depends on the presence of charge carriers which are free to move.
   i. Identify the type of charge carriers in a metal and in a pure semiconductor respectively. [2 marks]
   ii. Explain how current is conducted in each case. [2 marks]

b. Explain, in terms of charge carriers, the following experimental observations.
   i. The resistance of a length of copper wire increases as the temperature increases. [2 marks]
   ii. The resistance of a piece of silicon (semiconductor) decreases rapidly as the temperature increases. [2 marks]

c. It has been suggested that the resistance R_θ of a length of copper wire varies with temperature θ by the equation: $R_\theta = R_0(1 + \alpha\theta)$ where α is a constant. Describe an experiment to test this relationship. 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 procedure to follow and 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 to validate the relationship.

   [13 marks]

d. Give two sources of error and two corresponding precautions which one can take when carrying out this experiment. [4 marks]

Question 10

a. A bullet of mass 0.02 kg moving at 500 m s^{-1} lodges in a block of wood of mass 15 kg suspended by a cord of length 2.00 m. As the bullet lodges into the block, the block swings and moves upwards.

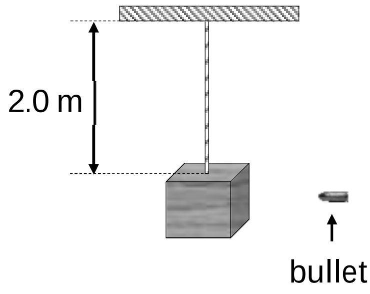


Figure 8

   i. Describe the energy changes from just before the bullet lodges into the block until the bullet and block rise to one side. [3 marks]
   ii. Calculate the velocity with which the block and bullet move together just as the bullet lodges in the block. Mention the principle which you are applying. [3 marks]
   iii. Determine the height through which the block rises. [2 marks]
   iv. Calculate the maximum angle through which the cord swings. [3 marks]

b. A tow-truck is pulling a 900 kg car at a constant speed up a hill that makes an angle α of 5.0° with respect to the horizontal. A rope is attached from the truck to the car at an angle β of 10° with respect to horizontal. The rope can withstand a maximum tension of 1500 N before breaking. Neglecting any frictional forces in this problem:

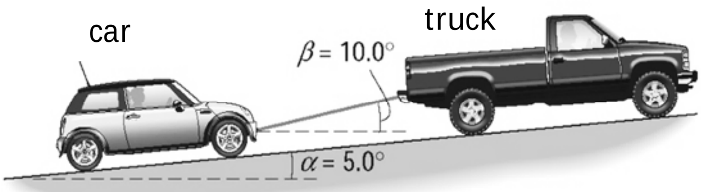


Figure 9

   i. draw a free body diagram showing all the forces on the car. Indicate the angle that each force makes with either the vertical or horizontal direction; [4 marks]
   ii. calculate the tension in the rope; [3 marks]
   iii. at one point the truck accelerates. Find the maximum acceleration the truck can have before the rope breaks. [3 marks]

c. Explain the following situations:
   i. a person falling down from a low wall can break his legs if he does not flex them as he lands; [2 marks]
   ii. a person falling from five storeys high onto the roof of a car may just walk away without getting hurt. [2 marks]

Question 11

a.
   i. Explain, with the aid of a stress-strain graph, what is meant by elastic behaviour and plastic behaviour of a wire when it is stretched. [2 marks]
   ii. On the same graph, add two curves that show the behaviour of a ductile and a brittle material. Label clearly the two curves and give one example of each type of material. [2 marks]

b. The deepest mines ever drilled are only about 16 km deep. The restrictions are mainly due to the materials available. Steel which is one of the mostly used materials in these mines has a density of 7900 kg m^{-3} and a breaking stress of 2.00×10^9 Pa.

i. Briefly explain why in the experiment to determine the Young modulus of steel it is preferable:

- to use a thin and long wire rather than a thick and short wire; [2 marks]
- to use two wires rather than just one [2 marks]

ii. A steel cable is lowered in a deep mine. Show that the stress σ on a steel cable due to its weight alone is given by $\sigma = mg/A$ where m is the mass of the cable and A is its cross-sectional area. [2 marks]

iii. Hence, show that under breaking stress σ_{max} the maximum length of cable is given by:

$$l_{max} = \frac{\sigma_{max}}{\rho g}$$

where ρ is the density of steel and l_{max} is the maximum length of cable. [4 marks]

iv. Calculate the maximum length of steel cable that can be lowered in the mine. Comment on this value in the context of the deepest mine ever drilled. [2 marks]

c. A solid cylinder of mass 30 kg, length of 1.10 m and a cross-sectional area of 8.00×10^{-5} m^2 falls vertically from rest so that its base drops from a height of 2.00 m above the ground. On hitting the ground, the cylinder behaves elastically and is compressed by a maximum of 1.6×10^{-3} m. Calculate:

i. the kinetic energy of the cylinder just before it hits the ground; [2 marks]

ii. the maximum strain on the cylinder; [2 marks]

iii. the maximum elastic potential energy stored in the cylinder; [1 mark]

iv. the maximum force the cylinder exerts on the ground; [2 marks]

v. the Young modulus of the material of the cylinder. State any assumptions involved. [2 marks]

Question 12

a. The angular momentum, L of an object rotating with angular speed, ω is given by $= I\omega$, where I is the moment of inertia of the object about a fixed axis.

i. Define moment of inertia and give its base units. [2 marks]

ii. State the principle of conservation of angular momentum. [1 mark]

b. A solid, uniform, frictionless cylindrical reel having a mass M of 2.80 kg and a radius R of 0.35 m is used to draw water from a well (see Figure 10). A bucket of mass m of 1.50 kg is attached to a cord that is wrapped around the cylinder. As the bucket accelerates downwards with an acceleration a, the tension in the cord is T and the cylindrical reel has an angular acceleration α.

Figure 10

i. Derive an expression for T in terms of the mass of the bucket m, its acceleration a and the acceleration due to gravity g. State any sign convention you adopt. [2 marks]

ii. Given that the moment of inertia of the cylinder is given by $I = \frac{1}{2}MR^2$, show that the torque τ produced by the tension in the cord on the cylinder is given by $\tau = \frac{1}{2}MRa$. [2 marks]

iii. Hence or otherwise show that the acceleration a of the bucket is given by $a = \frac{mg}{m+\frac{M}{2}}$ [3 marks]

iv. Calculate the value of the acceleration of the bucket. [1 mark]

v. If the bucket starts from rest at the top of the well and falls for 3.0 s before hitting the surface of the water, determine how far the bucket falls. [2 marks]

c. An empty oil barrel rolls down a sloped road through a height of 15 m. The barrel has a mass of 10 kg and radius 0.5 m.

i. Describe the energy changes that take place as the barrel rolls down the slope. [3 marks]

ii. Calculate the angular velocity of the barrel at the bottom of the slope. [4 marks]

iii. Calculate the linear velocity with which it is rotating. [2 marks]

iv. Calculate the energy lost if the actual linear velocity of the barrel at the bottom is 10 m s^{-1}. [3 marks]

Question 13

a.

i. Distinguish between fission and fusion, and explain why energy is released in each case. [3 marks]

ii. Give one example each of where fission and fusion takes place in practice. [2 marks]

iii. Calculate the energy in Joules released in the following reaction:

$$^3_1H + ^2_1H = ^4_2\alpha + ^1_0n + Q$$

where the mass of particles in atomic mass units are ^1_0n *neutron* = 1.00867 u; $^4_2\alpha$ *particle* = 4.00150 u; ^3_1H *nucleus* = 3.0155 u; ^2_1H *nucleus* = 2.01355 u; 1 u = 931 MeV of energy. [4 marks]

b. Nuclear reactors use radioactive material to obtain energy. Give two advantages and two disadvantages of nuclear power. [4 marks]

c. Iodine $^{131}_{53}I$ isotope is used in medicine to diagnose problems in the kidneys. $^{131}_{53}I$ has a half-life of 8.0 days.

i. Calculate the decay constant for Iodine – 131. [2 marks]

ii. If the activity of the radioactive substance must be 8×10^5 Bq when given to a patient, calculate the mass of radioactive Iodine that must be injected in the patient. [4 marks]

iii. Calculate the activity of the iodine 24 hours after it was administered. [4 marks]

iv. Explain why it is undesirable for a patient using Iodine to stay close to other persons during this period. [2 marks]

Question 14

a.

- i. Derive an equation for the current I flowing through a conductor of cross-sectional area A, having N conduction electrons per unit volume and a drift velocity v. [4 marks]
- ii. Explain the meaning of drift velocity in terms of particle movement. [2 marks]
- iii. Calculate the drift velocity of charge carriers in a copper wire of diameter 1.2 mm when a current of 3 A flows through it. Copper has 10^{29} charge carriers per unit volume. [3 marks]
- iv. Explain how the drift velocity will change if another metal wire of the same dimensions and but fewer charge carriers per unit volume, is used instead. Explain your reasoning. [2 marks]

b. A constantan wire of diameter 0.5 mm has a resistance of 15 Ω. Constantan has a resistivity of 5×10^{-7} Ω m.

- i. Define the term resistivity. [2 marks]
- ii. Calculate the length of the constantan wire. [3 marks]

c. In Figure 11, a 12 V battery with internal resistance 0.5 Ω has initially no load connected across its terminals. Switches S_1 and S_2 are then closed successively. The voltmeter (assumed ideal) thus shows a set of three successive readings.

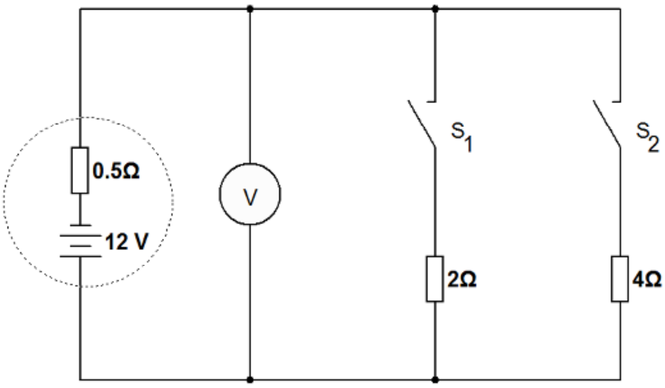


Figure 11

- i. Explain what is meant by e.m.f and terminal potential of a battery having an internal resistance. [4 marks]
- ii. Determine the set of the three readings on the voltmeter. [5 marks]

Question 15

a. An airplane tilts to one side as shown in Figure 12 below when going round in a circle.

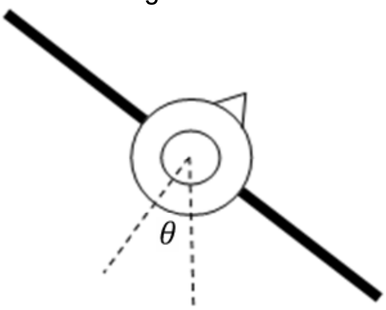
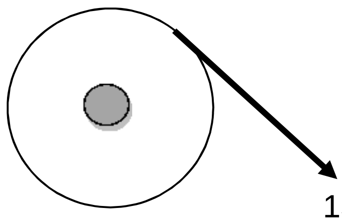


Figure 12

i. Explain why the airplane has to tilt when going round in a circle. [2 marks]
ii. Derive an equation for the angle θ through which the airplane has to tilt, explaining any symbols used in your derivation. [3 marks]
iii. Calculate the angle θ for the plane if the airplane travels at a speed of 600 km/hr and goes round in a circle of radius 1500 m. [3 marks]

b. The same principle is applied to banking of cars as they go round bends and roundabouts.
i. Draw a diagram to show the forces acting on a car when the road is banked at an angle θ to the horizontal such that it prevents slipping. [4 marks]
ii. Calculate the velocity in km hr^{-1} at which a car can go round a bend of radius 75 m without slipping if the angle of banking is 15°. [2 marks]
iii. Mention one other practical example where banking is used. [1 mark]

c. A flywheel of radius 15 cm and moment of inertia 0.12 kg m^2 is made to rotate by a string which is pulled with a force of 15 N for 5 s.



Calculate:
i. the torque acting on the flywheel; [2 marks]
ii. the acceleration of the flywheel; [2 marks]
iii. the angular velocity gained by the flywheel after 5 s if it was initially stationary; [3 marks]
iv. the number of revolutions turned by the flywheel in 5 s. [3 marks]

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SUBJECT:	PHYSICS
PAPER NUMBER:	II
DATE:	4th September 2013
TIME:	9.00 a.m. to 12.00 noon

A list of useful formulae and equations is provided.

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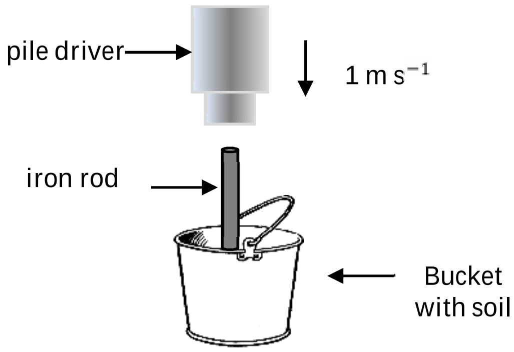
Section A

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

Question 1

a. Define the specific heat capacity of a substance. [2 marks]

b. A model 0.5 kg pile driver falls and strikes an iron rod at $1\ \mathrm{m\,s^{-1}}$. The iron rod is to be driven vertically into a bucket of soil. If the rod has a mass of 20 g and the pile driver is raised and dropped 15 times in a very short time, calculate the theoretical maximum temperature rise in the rod. (Take the specific heat capacity of iron to be $450\ \mathrm{J\,kg^{-1}\,K^{-1}}$) [3 marks]



c. In an experiment to determine the specific heat capacity of a liquid, a number of precautions need to be taken. Mention two important precautions and explain their significance. [2 marks]

d. Find the mass of a block of ice at −5°C placed in a 150 g copper container holding 250 g of water at 18°C assuming that when all the ice melts the temperature of the mixture is 15°C . [5 marks]
(Specific heat capacity of water is $4200\ \mathrm{J\,kg^{-1}K^{-1}}$; Specific heat capacity of ice at −5°C is $2100\ \mathrm{J\,kg^{-1}K^{-1}}$; Specific heat capacity of copper is $390\ \mathrm{J\,kg^{-1}\,K^{-1}}$; specific latent heat of fusion of ice is $3.33 \times 10^5\ \mathrm{J\,kg^{-1}}$).

Question 2

a. Define gravitational field strength at a point. [2 marks]

b. Sketch a labelled graph to show how the gravitational field strength varies with distance above the Earth's surface. [2 marks]

c. Derive an equation for the speed of a satellite orbiting at a distance R from a planet of mass M. [2 marks]

d. A student observes through a telescope a satellite orbiting close to Earth. She observes the same satellite passing from the same point 90 minutes later. Calculate:
   i. how far the satellite is from Earth; [3 marks]
   ii. the kinetic energy of the satellite per unit mass; [2 marks]
   iii. the value of the gravitational field strength at this level. [3 marks]
   [mass of Earth = $6 x 10^{24}$kg]

Question 3

a. State what is an ideal black body. [1 mark]

b. A survival manual suggests the following measures for keeping warm if stranded in a cold environment:
   - Make a 'blanket' using a number of newspaper layers.
   - Wrap aluminium foil around you.
   - Stay off metal surfaces.

   Explain the physics behind each of these recommendations. [6 marks]

c. A room has one of its sides overlooking a garden. This side is made of a glass wall 6 m by 4 m by 2.0 cm. The temperature inside is to be maintained at 24°C at all times even when the outside temperature is 20°C.
   i. Assuming that the thermal conductivity of glass is 0.84 J kg^{-1} K^{-1} and that heat is only lost from this wall, calculate the required power output of a heater that should be used to maintain a constant temperature inside. [2 marks]
   ii. If the glass wall had to be replaced by a different kind of wall of thermal conductivity 0.16 J kg^{-1} K^{-1} , calculate the energy that would be saved in a week as a result of using this type of wall. [3 marks]

Question 4

a. Define electric potential at a point in an electric field. [2 marks]

b. Two equal point charges of +4 μC are located in vacuum 4 mm away from each other. Taking the permittivity of free space to be 8.85×10^{-12} F m^{-1};
   i. find the magnitude and direction of the force each charge exerts on the other; [2 marks]

   For a point P which lies 3 mm from both charges, calculate:

   ii. the resultant electric potential at P; [2 marks]
   iii. the resultant electric field intensity at P. [4 marks]

c. In relation to the answers to part (b), explain the following:
   i. If the charges had opposite signs, what would have been the resultant potential at the point P? [1 mark]
   ii. If the charges had been located in a medium of relative permittivity 2, what would have been the effect on the value of the electric field intensity at point P? [1 mark]

Question 5

a. Starting with the force experienced by a wire in a uniform magnetic field, derive an equation for the force experienced by an electron in such a field. [4 marks]

b. A copper rod of mass 200 g is placed horizontally in a magnetic field of 0.4 T such that the north pole is above while the south pole is below it.
   i. Draw a labelled diagram to show the rod in the magnetic field and indicate clearly the direction of the current flow and the resulting force. [2 marks]
   ii. Calculate the size of the force if the length of the rod in the field is 15 mm and the current in it is 2.5 A. [2 marks]
   iii. Determine a value for the size of the current if the force on the rod is to be doubled. [2 marks]

c. An electron moving at a speed of 1.6×10^{7} m s^{-1} passes perpendicularly through a magnetic field of intensity 0.001 T. Calculate the radius of the circular path of the electron. [4 marks]

Question 6

a. In 1929, Hubble used the Doppler effect to measure the speed of a number of galaxies located at various distances from Earth.
   i. Represent Hubble's law graphically. [2 marks]
   ii. Briefly explain the significance of this law. [2 marks]
   iii. Briefly describe how it is possible to use the Hubble constant to establish the age of the Universe. [3 marks]

b. Light from distant galaxies is often said to be 'red shifted'. Explain the meaning of this term. [3 marks]

c. A galaxy is receding at a speed of about 5.9×10^{7} m s^{-1}. Given that the Hubble constant is equal to 1.7×10^{-18} s^{-1}, calculate how far this galaxy is from Earth. [2 marks]

Question 7

a. Explain the meaning of the term 'progressive wave'. [1 mark]

b. A student was investigating wave behaviour as part of a project. If the progressive wave observed had an amplitude of 0.8 m and wavelength 4.0 m, and assuming that, at start, the y displacement is zero at $x = 0$ m, calculate, at $t = 0$ s:
   i. the y displacement when $x = 1$ m; [2 marks]
   ii. the phase angle when $x = 1$ m; [2 marks]
   iii. the phase difference between two points 0.60 m apart. [2 marks]

c. In a Young's double slit experiment, red light of wavelength 0.65 μm was used to illuminate a pair of slits 0.5 mm apart.
   i. State the conditions necessary for significant interference effects to be observed. [2 marks]
   ii. If the screen is 0.75 m from the slits, calculate the fringe separation. [2 marks]
   iii. Describe what happens to the slit separation if green light is used instead. [1 mark]

Question 8

a. Define the principle of superposition of waves. [2 marks]

b. State three differences between stationary waves and progressive waves. [3 marks]

c. Light from two sources of light, one with a wavelength of 435 nm and another of 656 nm is incident on a diffraction grating of 500 lines per mm. Calculate the angular separation between the third-order fringes for these two waves. [4 marks]

d. Calculate the maximum number of orders that can be obtained using this grating in conjunction with the 656 nm light source. Explain your reasoning. [3 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. Explain the meaning of 'latent heat of vaporization' of a substance. [2 marks]

b. Describe an experiment to determine the latent heat of vaporisation of water at its normal boiling point, explaining any special features in the apparatus and procedure designed to minimise experimental errors. 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 procedure to follow and the measurements that need to be taken;
   iv. a table of results;
   v. an indication of how to determine the latent heat of vaporization of water. [10 marks]

c. A gas enclosed in a cylinder fitted with a moveable piston undergoes an adiabatic change between two isotherms at temperatures T_1 and T_2 with $T_1 > T_2$.
   i. Explain what is meant by adiabatic change and state how an adiabatic change can be achieved in practice. [2, 1 mark]
   ii. Draw a PV-diagram that shows this adiabatic change between the two isotherms. [2 marks]
   iii. Assuming the adiabatic relationship between pressure and volume, show that for one mole of an ideal gas undergoing an adiabatic change, $TV^{\gamma-1} = constant$, where γ is some constant. [2 marks]

d. 200 cm^3 of monatomic gas (γ = 1.67) at 10°C and at 10 atmospheres pressure are allowed to expand until the pressure falls to 1 atmosphere.
   i. Calculate the final volume and temperature if the expansion takes place under both isothermal and adiabatic conditions. [4 marks]
   ii. On the same diagram sketch two PV-curves that show the two processes indicating clearly any values of pressure, volume and temperature. [2 marks]

Question 10

a. Explain how an ideal gas exerts a pressure on the sides of a container. [1 mark]

b. The pressure p of an ideal gas is given by the equation, $p = \frac{1}{3}\rho\overline{c^2}$ where ρ is the density of gas and $\overline{c^2}$ is the mean square speed of the molecules.

   i. By considering gas contained in a cubic container, derive from first principles the equation for the pressure of an ideal gas. [8 marks]
   ii. State four assumptions you used in deriving the expression in part (i) and the practical evidence that support each assumption. [4, 4 marks]
   iii. Briefly explain why the mean square speed is considered in part (i) and not the square of the mean speed. [2 marks]

c. The escape speed for gas molecules in the atmosphere of Jupiter is 60 km s^{-1} and the surface temperature of Jupiter is typically −150□.

   i. Calculate the root-mean-square speed for the gases H_2, O_2 and CO_2 at this temperature. [3 marks]
   ii. If a gas only needs to reach 20% the escape speed to almost vanish from the atmosphere, which, if any, of these gases can be sustained in Jupiter's atmosphere? [3 marks]

   [Molar mass of H = 1.01 g mol^{-1}; Molar mass of O = 16 g mol^{-1}; Molar mass of C = 12 g mol^{-1}]

Question 11

a. A capacitor has parallel square conducting plates of side L a distance $d = L/100$ apart. It is filled with liquid of dielectric constant $\varepsilon_r = 2$ and connected to a fixed voltage V. The liquid slowly leaks out so that its level decreases with velocity v as shown in Figure 1.

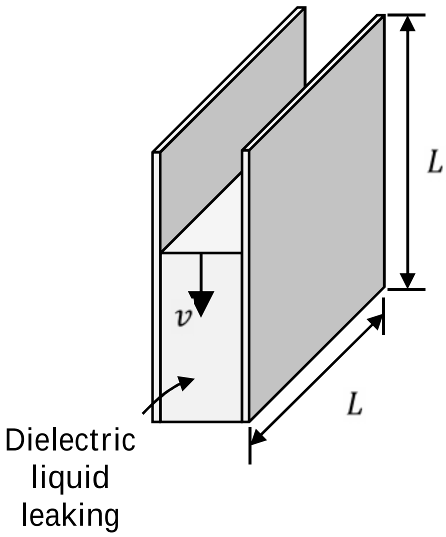


Figure 1

   i. Show that the vertical length of liquid remaining after time t is given by $L - vt$. [1 mark]
   ii. Hence, show that after time t the capacitance of the capacitor as a function of time with liquid as the only dielectric is given by:
   $$C_{liquid} = 200\varepsilon_0(L - vt)$$
   [4 marks]
   iii. By considering the capacitor with the dielectric being part air and part liquid, show that the capacitance as a function of time is given by $C(t) = 100\varepsilon_0(2L - vt)$. [4 marks]
   iv. One such capacitor has sides of length 20 cm. Determine its capacitance when full of liquid. [2 marks]
   v. Briefly state how the capacitance of the capacitor would change if a liquid with a higher relative permittivity fills the gap between the plates. [2 marks]

b. A capacitor C of capacitance 47 μF is first charged by a 9 V battery through a resistor R of 100 kΩ and then discharged through the same resistor using a two way switch.

   i. Draw a circuit that represents the setup. [3 marks]

ii. On the same axis of voltage against time, sketch two graphs that show the voltage on the capacitor V_C and the voltage on the resistor V_R during charging and discharging. Label clearly the charging and discharging curves. [4 marks]

c. A 13 μF capacitor is charged from a 40 V supply potential difference. It is then disconnected from the power supply and connected across an uncharged 47μF capacitor.
   i. Calculate the final potential difference across the couple. [2 marks]
   ii. Calculate the initial and final energies held in the capacitor system. Identify what happens with the lost energy. [2, 1 mark]

Question 12

a. Explain, with the aid of a diagram, the meaning of magnetic flux density. [3 marks]

b. State Lenz's law of electromagnetic induction and describe an experiment to test this law. This 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 procedure to follow;
   iv. an indication of how to verify Lenz's law. [8 marks]

c.
   i. Distinguish between self-inductance and mutual-inductance. [2 marks]
   ii. Define the Henry in the case of mutual inductance. State its base units. [2, 1 mark]
   iii. Two solenoids A and B are equal in length and radius, and the cores of both are identical cylinders of iron. However, solenoid A has three times the number of turns per unit length as solenoid B. Determine which solenoid has the larger self-inductance and calculate the ratio of the self-inductance of solenoid A to the self-inductance of solenoid B. [2, 2 marks]

d. A long solenoid with length l and a cross-sectional area A consists of N_1 turns of a length of wire. An insulated coil of N_2 turns is wrapped around it, as shown in Figure 2.
   i. Calculate the mutual inductance M, assuming that 95% of the flux from the solenoid passes through the outer coil. [2 marks]
   ii. Relate the mutual inductance M to the self-inductances of the solenoid and the coil. [3 marks]

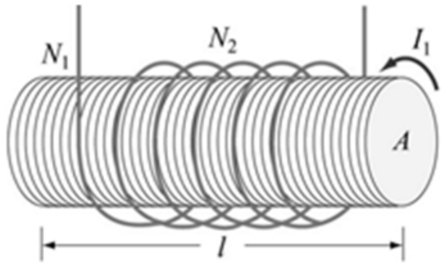


Figure 2

Question 13

a. Explain what is meant by the reactance of an inductor or capacitor. [2 marks]

b. A transformer is used to supply an alternating potential difference of 12 V at a frequency of 50 Hz (i) to an inductor and (ii) a capacitor.
   i. Describe and explain with the aid of appropriate graphs the phase lag or lead between the current and applied potential difference in each case. [6 marks]
   ii. Calculate the inductive reactance of an inductor of inductance 150 mH and the capacitive reactance of a capacitor of capacitance 10 μF. [4 marks]

iii. Determine the frequency f at which their reactances are equal in magnitude. [3 marks]
iv. Sketch a graph that shows how inductive reactance varies with the frequency of the alternating supply. [2 marks]

c. Electricity is transmitted through the grid system using a high voltage alternating current rather than direct current.
   i. What is the main advantage of using alternating current over direct current? [1 mark]
   ii. Explain how using high voltage improves the efficiency of the system. [1 mark]

d. A semiconductor diode is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals.
   i. Explain what is meant by the depletion region. [2 marks]
   ii. Sketch two diagrams to show the movement of charge carriers over the p-n junction for a diode connected in forward and reverse-bias modes. [2 marks]
   iii. For a diode connected in a reverse bias mode, explain what happens in terms of current when the breakdown voltage is reached. [2 marks]

Question 14

a. A light string has one end fixed to a rigid support and the other end attached to an object performing simple harmonic motion.
   i. Explain the meaning of the terms: amplitude, frequency and phase when applied to the oscillating object. [3 marks]
   ii. Using the same axes, sketch and label graphs that show the displacement, velocity and acceleration of the oscillating object for a time interval equivalent to two complete oscillations. [6 marks]
   iii. Sketch another graph that shows how the kinetic and potential energies of the object change during one oscillation. [2 marks]

b. Resonance phenomena occur with all types of vibrations or waves.
   i. Explain what is meant by resonance. [1 mark]
   ii. Describe an experiment that demonstrates the resonance of an object attached to a string performing simple harmonic motion. Include a diagram of the experimental setup, a brief description of the method and the expected graph. [2, 2, 2 marks]

c. A 500 g mass is vibrating in a system in which the total energy is 0.5 J. The amplitude of vibration is 20 cm.
   i. Determine the angular frequency of the system. [1 mark]
   ii. Show that the kinetic energy is half the total energy when the displacement is $\frac{A}{\sqrt{2}}$. [2 marks]
   iii. Express the displacement in terms of time. [2 marks]
   iv. Express the velocity as a function of time. [2 marks]

Question 15

a. Define the index of refraction of a material medium. [2 marks]

b. Light having a free-space wavelength of λ_0 = 540 nm passes from vacuum into diamond with refractive index n_d of 2.4. The frequency is unaltered as light traverses different substances. Calculate the wave's speed and wavelength in the diamond. [4 marks]

c. Figure 3 shows part of a straight 2 m long optical fiber with a diameter of 20 μm. The optical fiber has an index of refraction of 1.30.

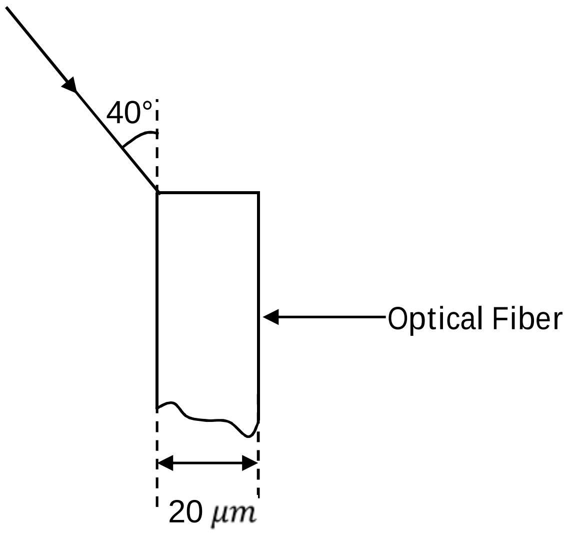


Figure 3

i. On a copy of the diagram, complete the path taken by the ray of light as it enters the optical fiber and travels to make its first total internal reflection. [1 mark]
ii. If the angle of incidence on the end of the fiber is 40°, calculate the angle of refraction inside the fiber. [2 marks]
iii. Calculate the distance travelled by the ray of light up to the point where the first total internal reflection occurs. [2 marks]
iv. Hence or otherwise determine how many internal reflections the light ray makes before emerging from the other end. [3 marks]
v. Briefly describe how the number of reflections changes if the optical fiber was bent. [2 marks]

d. Define the following properties of lenses: converging, diverging, principal focus and focal length. [4 marks]

e. An object is placed 20 cm in front of a diverging lens that has a focal length of −15 cm.
i. Calculate the distance where the image is formed and state two properties that define this type of image. [2, 2 marks]
ii. Determine the magnification of the lens. [1 mark]

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2013

SUBJECT:	PHYSICS
PAPER NUMBER:	III – *Practical*
DATE:	30th August 2013
TIME:	2 hours

Experiment: The use of a Light Dependent Resistor as a light intensity measuring device.

Apparatus: Filament lamp, LDR, multi-meter, metre ruler, beaker filled with 100ml of water, beaker with a stock solution of blue coloured liquid, pipette, glass rod.

Important Note:
- Please take note that the filament lamp becomes 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:

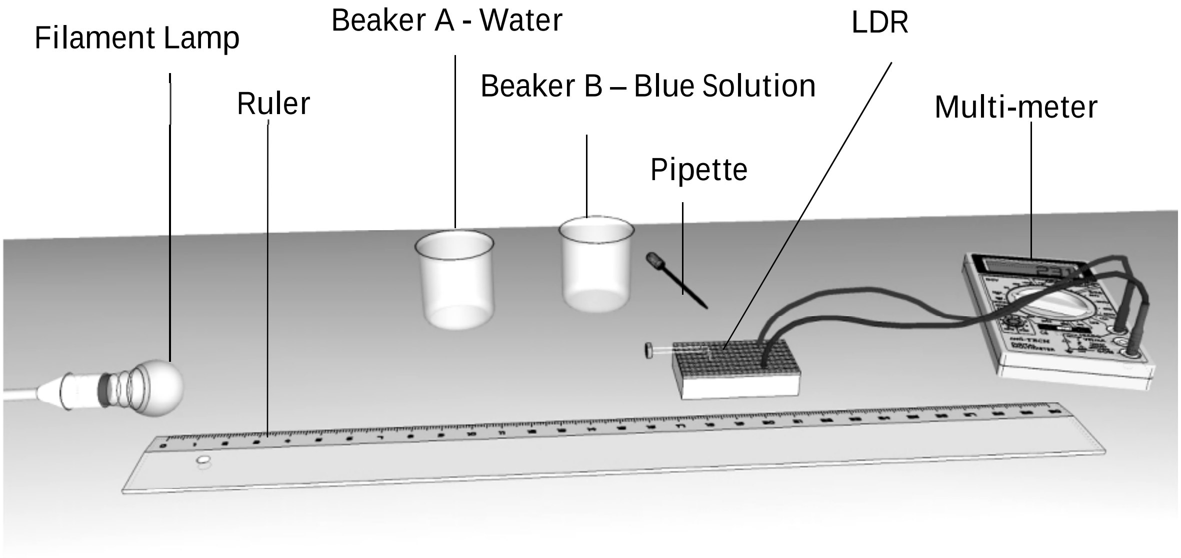


Figure 1 The experimental set-up.

Method – Part A:

1. Set up the apparatus in the order shown in Figure 1.
2. Switch on the filament lamp and if necessary adjust it as shown in the diagram of Figure 1.

3. The resistance of the Light Dependent Resistor (LDR) changes with light intensity. In the space provided below, describe the procedure you would follow in a simple experiment to check the statement in italics. Demonstrate the validity of the statement by taking a measurement of the LDR resistance when exposed to ambient light and when shielded from light. (Hint: you can use your hands to gently cover the LDR).

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[4, 2 marks]

4. Set the multi-meter on the 20 kΩ range and arrange the apparatus so that the filament lamp is next to 0 cm mark on the ruler.
5. Place the LDR at 3 cm away from the filament lamp and measure the resistance R_0 in kΩ.

R_0 =________________ kΩ.

[2 marks]

6. For the distances d between the filament lamp and the plane face of the LDR given in Table 1, use the multi-meter to measure the resistance R of the LDR at these distances. Record the values of the resistances R in Table 1.

[10 marks]

Table 1

d /m	R/kΩ	$\frac{R}{R_0}$	$\frac{I}{I_0}$	$\log\left(\frac{0.03}{d}\right)$	$\log\left(\frac{I}{I_0}\right)$
0.03					
0.06					
0.09					
0.12					
0.15					
0.18					
0.21					
0.24					
0.27					
0.30					

7. Complete the table by filling in the third column for $\frac{R}{R_0}$.

[5 marks]

8. It is known that for the provided LDR, the relation between the intensity of light falling on the LDR and its resistance is given by $\frac{I}{I_0} = \left(\frac{R}{R_0}\right)^{-2.2}$, where R_0 is the resistance of the LDR when the intensity of light is I_0 .

9. Use the expression in part 8 to work out the values for $\frac{I}{I_0}$ in Table 1. Hence complete the table by working out the missing values.

[15 marks]

10. The intensity of light follows an inverse square relationship with distance that is given by:

$$\frac{I}{I_0} = \left(\frac{0.03}{d}\right)^2$$

Show that the linear form of the above expression is given by $\log\left(\frac{I}{I_0}\right) = 2\log\left(\frac{0.03}{d}\right)$. Hence, plot a suitable straight line graph, work out its gradient and use the value of the gradient to verify the above relationship.

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[3, 15, 2 marks]

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Method – Part B:

11. In this part the LDR will be used to investigate how much light is absorbed when it passes through water having different concentrations of a blue solution.
12. Position beaker A which is filled with 100 ml clear water between the filament lamp and the LDR as shown in Figure 2. Make sure that the markings on the beaker do not interfere with the light path between the filament lamp and the LDR. Also make sure that the filament lamp is almost touching the beaker and that the LDR is pointing directly towards the lamp and almost touching the beaker too.

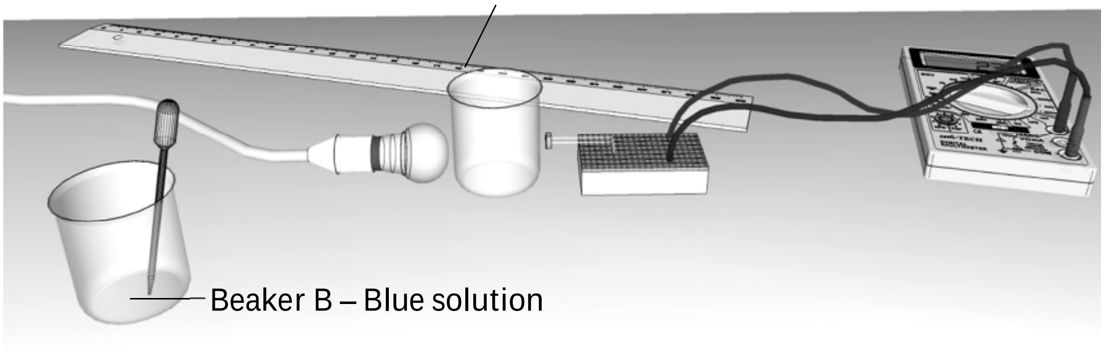

Figure 2

13. Place beaker B containing the blue solution within reach.
14. Before continuing, it is recommended that you test your skills in using the provided pipette to withdraw a sample of the blue solution from beaker B and <u>slowly drop back into the same beaker B</u> around 10 drops of the blue solution. Retry this step until you are confident enough to continue.
15. With only the clear water in beaker A (and hence with 0 drops of blue solution present in beaker A), measure the resistance R_0 in $k\Omega$ of the LDR.

    R_0 = ________________ $k\Omega$.

    [2 marks]
16. Use the pipette to withdraw a sample of blue solution from beaker B and release 10 drops of this blue solution in Beaker A.
17. Stir the water in beaker A thoroughly, using the stirrer provided.
18. Record the new resistance R in Table 2.
19. Repeat steps 16, 17 and 18 for the number of drops given in Table 2.

    [6 marks]

Table 2

No of drops	Concentration C $\times 10^{-4}$	R / $k\Omega$	Absorbance A
10	0.75		
20	1.49		
30	2.22		
40	2.94		
50	3.66		
60	4.37		

20. Absorbance A is a quantitative measure of light absorption by a material and is expressed as a logarithmic ratio between the radiation falling upon a material and the radiation that is transmitted through the material. Under the conditions of this experiment, the expression relating absorbance and intensity may be given by

$$A = -log\frac{I_t}{I_i}$$

where I_t is the intensity of the transmitted radiation and I_i is the intensity of the incident radiation.

21. Following the conclusions from part A, the relation for the absorbance with light intensity can be expressed in terms of the resistance of the LDR by:

$$A = 2.2\log\left(\frac{R}{R_0}\right)$$

Use this expression to complete the column for the absorbance A in Table 2 above.

[12 marks]

22. The concentration C of a sample liquid in a specific volume of another liquid is related to the absorbance A by the equation:

$$A = kC,$$

where k is a constant for the given liquid.

23. Plot a straight line graph of absorbance A on the y-axis against concentration C on the x-axis and hence determine the constant k.

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[15, 2 marks]

24. Identify one source of error and a possible precaution undertaken to minimize this error.

[2 marks]

25. Briefly explain how you would use an LDR to measure the concentration of an unknown solution.

[3 marks]

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