L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2019 SECOND SESSION

SUBJECT:	**Physics**
DATE:	5th September 2019
TIME:	9:00 a.m. to 12:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ ms^{-2}$ unless otherwise stated.

SECTION A
Attempt all 9 questions in this section. This section carries 50% of the total mark for this paper.

1. a. Mass, length and time are considered as base quantities. State **TWO** other base quantities and their respective SI units. (2)
   b. The following equation relates the viscous force, F_d, acting on a small sphere moving through a viscous fluid, with the velocity, v, with which the sphere moves through the fluid:

   $$F_d = 6\pi\mu Rv$$

   In the equation, π is a numerical constant, μ is a constant representing the coefficient of viscosity and R is the radius of the sphere.
   Given that the equation is homogenous find the units of μ. (3)

(Total: 5 marks)

2. A ball F is projected horizontally with a velocity of 5 ms^{-1} from the end of a table of height 0.9 m. A similar ball G is projected from the same point on the table with an initial horizontal velocity of 3 ms^{-1}.
   a. Calculate the time taken for each ball to hit the ground. (2)
   b. What is the horizontal distance between the points of impact of the two balls on the ground? (2)

(Total: 4 marks)

3. A student is preparing to carry out an experiment to determine the specific heat capacity of aluminium (c_{Al}). The apparatus provided includes an aluminium block with lagging, an electric heater and a thermometer, both of which are fitted into the block, as shown in Figure 1.
   a. Name **ONE** piece of apparatus which is not shown in the diagram but which is required for the student to be able to complete the experiment. (1)
   b. Briefly describe an experiment to find c_{Al}. The description must include:
      - the readings to be taken and the graph to be plotted, clearly indicating the variables used on the x and y axes;
      - how c_{Al} may be found from the graph. (3)

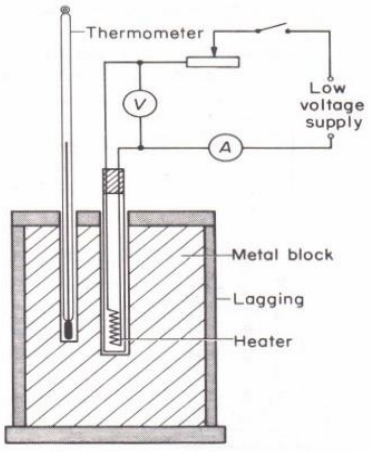

Figure 1

   c. State **ONE** source of error in this experiment and **ONE** possible precaution that can be taken to minimise this error. (2)

(Total: 6 marks)

4. Figure 2 shows the stress-strain graphs for three different materials A, B and C which are used in construction.
   a. Define Stress and Strain. (2)
   b. State **ONE** specific characteristic of each material. (3)
   c. What does the gradient of the stress-strain graph of material B represent? (1)

   (Total: 6 marks)

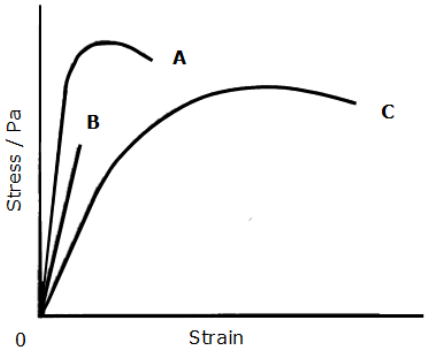

Figure 2

5. Our solar system is in the Milky Way Galaxy. The nearest galaxy is Andromeda. The two galaxies are separated by a distance of 2.4 $x10^{22}$ m. The mass of the Milky Way Galaxy is 6.0 x 10^{41} kg and the mass of the Andromeda Galaxy is 1.8 $x10^{42}$ kg.
   a. Calculate the magnitude of the gravitational force between the two galaxies. State the assumption you made in your calculation. (3)
   b. It is being reported that Andromeda Galaxy moved 3.5 million km closer to the Milky Way Galaxy. Explain how this would affect the value calculated in part (a). (2)

   (Total: 5 marks)

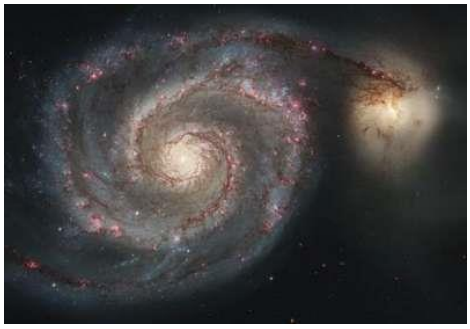
https://www.britannica.com

Figure 3

6. An electron enters a region of uniform magnetic field with flux density, B, equal to 7.6 x 10^{-3} T (see Figure 4). The electron leaves the magnetic field region at right angles to its original path, as shown in the diagram. The speed of the electron is 2.8 x 10^{7} ms^{-1}.

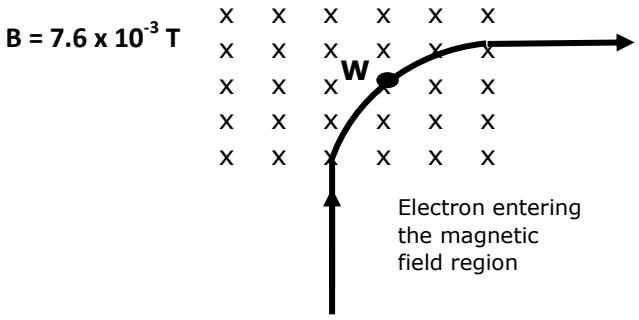

Figure 4

   a. Copy the diagram and include an arrow at point W to show the direction of the force on the electron. (1)
   b. Calculate the value of this force. (2)
   c. Explain the effect, if any, on the kinetic energy of the electron, caused by the presence of the magnetic field within the region indicated. (2)

   (Total: 5 marks)

7. Figure 5 shows a stationary wave set up on a string. The speed of the wave is 3.2 ms^{-1}.
   a. Explain how a stationary wave can be formed, in practice. (1)
   b. How many nodes does the wave shown in Figure 5 have? (1)
   c. Calculate the frequency of the wave. (2)
   d. Describe **TWO** differences between a stationary and a progressive wave. (2)

(Total: 6 marks)

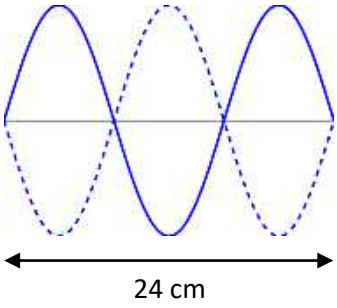

Figure 5

8. In 1801, Thomas Young performed what is now referred to as the double slit experiment. In this experiment, monochromatic light may be used to illuminate two slits, producing two coherent light sources.
   a. Explain how the double slit experiment confirms the wave-like nature of light. (2)
   b. Give the meaning of the word monochromatic. (1)
   c. With the aid of a diagram, carefully explain how fringes result in the double slit experiment. (3)
   d. State **ONE** difference that would be observed in the fringe formation when white light is used instead of monochromatic light. (1)

(Total: 7 marks)

9. The Bohr model of the Hydrogen atom is based on the assumption that the electron in the atom travels around the nucleus in a circular orbit. Moreover, the electron can only be found in specific orbits, with specific energies.

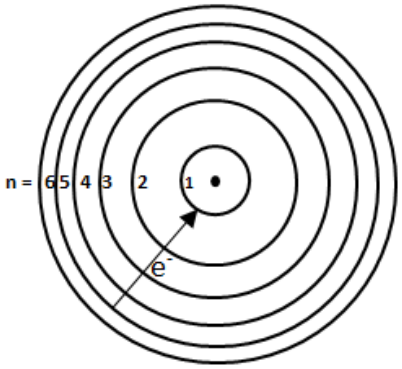

Figure 6a: showing circular electron orbits

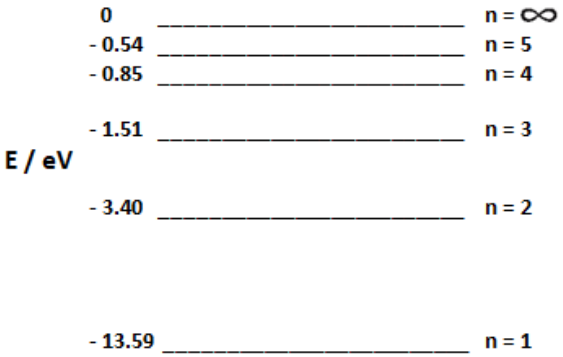

Figure 6b: showing energy levels for the hydrogen atom

   a. Figure 6a shows circular orbits for the electron in the hydrogen atom. In the electron transition shown, would energy be released or absorbed by the atom? Explain. (2)
   b. Figure 6b shows energy levels for the hydrogen atom. Using the given data, calculate the wavelength associated with the energy transfer referred to in part (a). (2)
   c. With reference to Figure 6b, explain what the zero (0) energy level represents. (1)
   d. By making reference to the energy levels shown in Figure 6b, explain which one of the levels indicates the most stable state for the hydrogen atom, giving a valid reason for the answer. (1)

(Total: 6 marks)

SECTION B

This question carries 14% of the total mark of this paper and must be attempted.

10. A uniform wooden metre ruler is used as a cantilever (see Figure 7). One end of the ruler is clamped on to a laboratory bench. A 300 g mass, M, is attached to the free end of the ruler. This causes the ruler to bend. Different lengths, L, of the ruler can be set, whilst the depression, d, of the free end where the mass is attached is measured for each length L set.

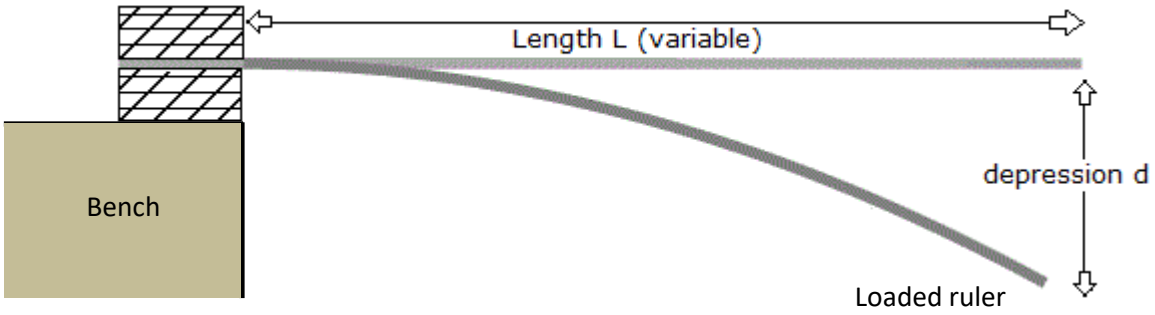

Figure 7

The following table shows different values of the length of ruler L/m and the corresponding values of the depression at the free end, d/m, as recorded by a student doing this cantilever experiment.

Table 1

L / m	**d / m**	**L^3 / m^3**
0.90	0.12	
0.80	0.09	
0.70	0.06	
0.60	0.04	
0.50	0.02	

The equation relating the depression, d/m to the length, L/m, of the cantilever is:

$$d = \frac{4MgL^3}{Ybt^3}$$

where g is the acceleration due to gravity, Y is Young Modulus of the wood from which the ruler is made, b is the width of the ruler and t is the thickness.
The ruler dimensions are as follows:
b = 25.5 mm and t = 5 mm.

a. Copy Table 1 and fill in the missing values. (2)
b. Copy the given equation and by comparing it to the general equation of a straight line y = mx + c, clearly indicate the x and y variables, as well as indicating the gradient in terms of the given letters and the value of the y-intercept. (3)
c. Plot a suitable straight line graph using the variables as indicated in part (b). (5)
d. Use the graph to find the value of Young Modulus, Y, of the wood from which the cantilever is made, clearly indicating the units of your answer. (4)

(Total: 14 marks)

SECTION C

Answer any TWO questions from this section. Each question carries 18 marks. This section carries 36% of the total mark for this paper.

11. a. Briefly explain what is meant by:
    i. an isobaric process; (1)
    ii. an isochoric process. (1)

    b. A constant mass of gas is contained in a cylinder by a frictionless gas-tight piston. Figure 8 shows the variation of the pressure of the gas, as the volume of the gas changes.

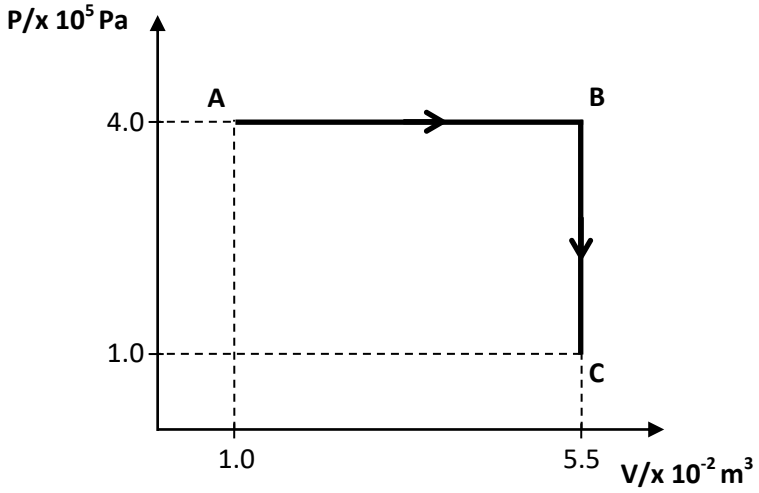

Figure 8

    i. Identify which of the processes marked on the graph is isobaric and which is isochoric. (2)
    ii. How can the work done by or on the gas be found from the graph? (1)
    iii. Calculate the work done, if any, in both processes AB and BC marked on the graph. (2)
    iv. During the process AB, is work done on the gas or by the gas? Explain your answer. (1)
    v. Copy Figure 8 and on the sketch show how the gas can return to the original conditions, back to A from C, following first an isobaric and then an isochoric process. (2)
    vi. What does the enclosed area within the resulting sketch for part (v) represent? (1)
    vii. State the First Law of Thermodynamics. (1)
    viii. During the process AB, 25 kJ of thermal energy were supplied to the gas. Calculate the change in the internal energy of the gas. (2)
    ix. What does the answer of part (viii) indicate about the gas temperatures at points A and B on the graph? (2)

    c. The mass of gas in the cylinder was 50 g and the specific heat capacity of the gas for the process BC is 0.718 kJ kg^{-1} K^{-1}.
    i. Given that 7 kJ of energy is extracted from the gas in going from B to C, calculate the change in temperature experienced by the gas. (1)
    ii. Is this difference a rise or a decrease in temperature? Explain your answer. (1)

(Total: 18 marks)

12. a. A copper wire has a current *I* / Amperes flowing through it. The wire has n free electrons per meter cubed drifting through it at a velocity v / ms^{-1}. Each electron has a charge *e* / Coulombs. The cross sectional area of the wire is A / m^2. Derive an expression for the current through the copper wire, in terms of the drift velocity of the electrons flowing through it. (2)

b. The number of conduction electrons for a material A is 8.46×10^{28} m^{-3}. For a material B, the value is 9.65×10^{15} m^{-3}. Two samples, one made from material A and the other made from material B are available. Each sample has a uniform cross-sectional area of 3.46×10^{-6} m^2. An electric circuit consisting of the two samples connected in series with a power supply has a current of 5 mA flowing through it.

i. Calculate the drift velocity of the electrons in the sample made from material A. (1)

ii. Identify which material is a conductor and which is a semiconductor. Give reasons for your answer. (1)

iii. How can one exclude that any one of the materials is an insulator? (1)

iv. Why is it that the circuit starts functioning immediately, despite the slow drift velocity of the electrons calculated in part (i)? (1)

c. With reference to the electric circuit shown in Figure 9:

i. calculate the current in the 2 Ω and the 3 Ω resistors; (6)

ii. calculate the useful power output in the circuit; (3)

iii. why can it be said that there is a waste of power in the circuit? Explain and calculate this wasted power. (3)

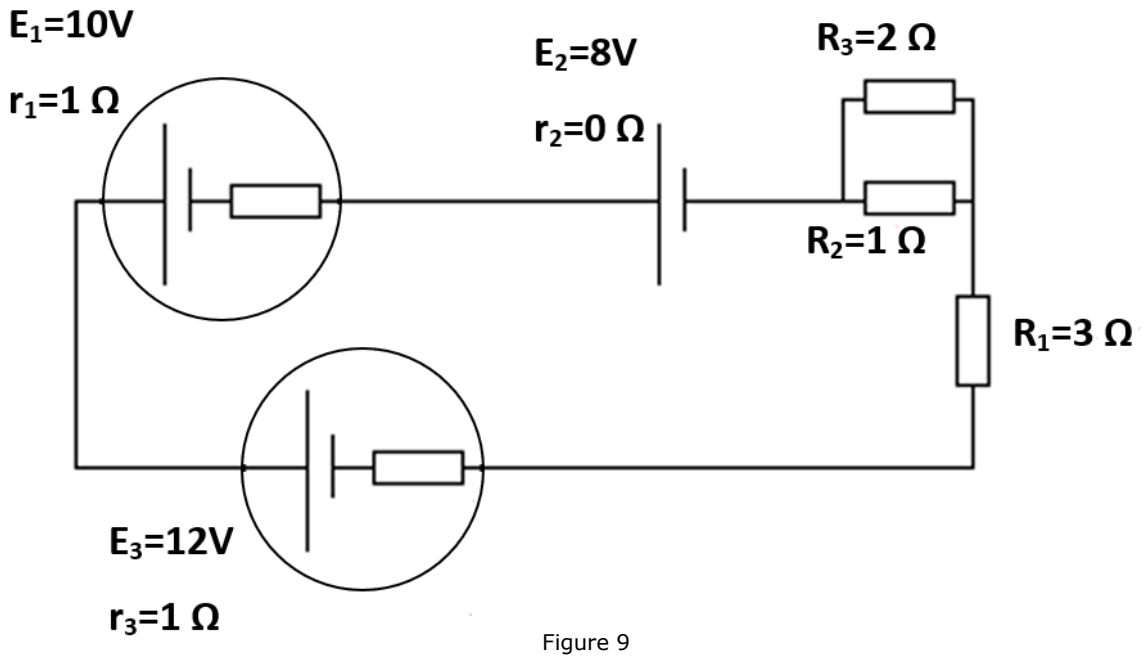

Figure 9

(Total: 18 marks)

13. a. Double Prisms used in binoculars are needed to change the path of the incident light falling onto the eyepiece (see Figure 10). Two types of glass may be used in making these prisms, namely BaK4 and BK7. Both prisms would be either of one type or of the other. The refractive index of BaK4 is 1.5688, while that of BK7 is 1.5168.

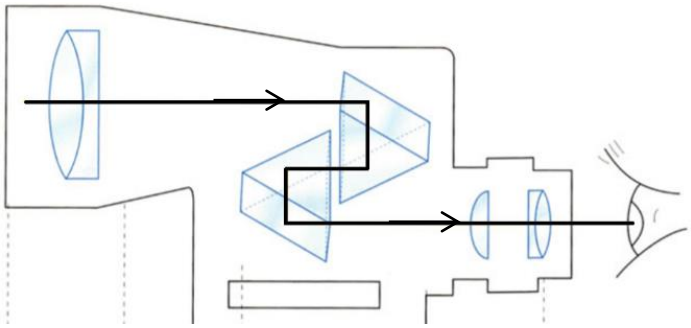

Figure 10

i. With reference to Figure 10, state what happens to the ray of light as it passes through the two prisms. (2)

ii. Calculate the critical angle of both types of glass which can be used. (2)

Figure 11 shows light passing through the two types of glass used. In one of them, namely Type 1, part of the light intensity is refracted at the glass-air interface and part is reflected internally. In the other, namely Type 2, the light ray is totally internally reflected.

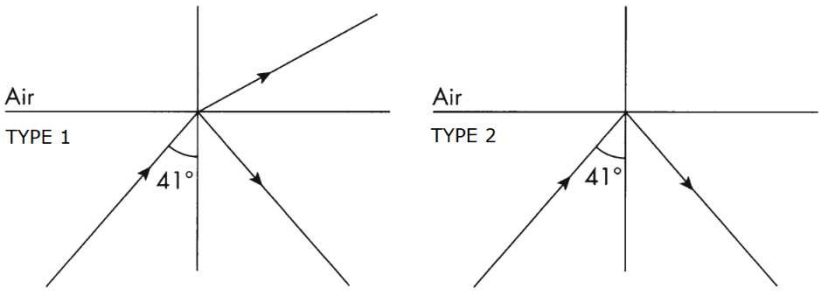

Figure 11

iii. Identify which of the two types of glass mentioned in part (a) is Type 1 and which is Type 2, giving reasons for your answer. (3)

b. A student found information about how to use a smartphone and a converging lens to build a simple projector. The student needed to find the focal length of the lens before planning the dimensions of the simple projector.

i. Describe a simple experiment that can be used by the student to estimate the focal length of the lens. (3)

ii. Describe an experiment that the student can use to find a more precise value of the focal length of the lens. In your answer, include:

- a diagram of the set up; (1)
- a statement saying what measurements need to be taken and recorded; (2)
- an explanation of how the lens equation may be used by the student so that a graph may be plotted, from which the focal length may be found. (2)

iii. The student used a lens with a focal length of 18 cm. The image formed by the projector was three times larger than the smartphone screen. Suggest a value for the distance between the lens and the smartphone and then calculate the image distance from the lens. (3)

(Total: 18 marks)

14. Figure 12 shows a graph of the current, I / μA, against time, t / s, for a capacitor as the latter is being charged through a resistor of resistance 47 kΩ.

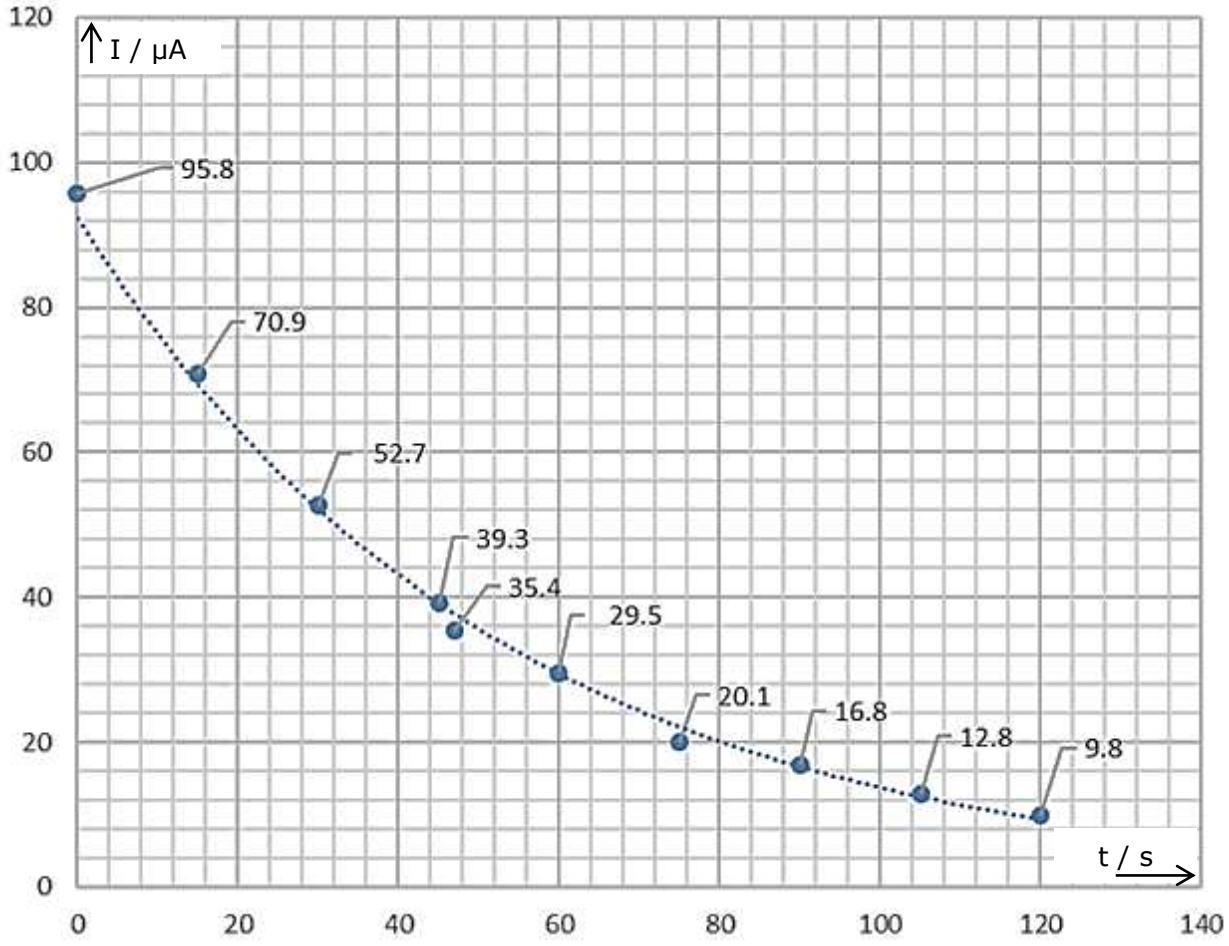

Figure 12

a. Use the graph to read the current, in μA, at the start of the charging process. (1)
b. Define the time constant of the circuit. (2)
c. By using the graph, determine the time constant. (2)
d. Q_0 represents the full charge that the capacitor can store. Express the charge that accumulates on the capacitor plates after a time equal to the time constant has elapsed, as a percentage of Q_0. (2)
e. Using the value of the time constant and the given value of the resistance, calculate the value for the capacitance of the capacitor. (2)
f. State the **THREE** physical quantities upon which the capacitance of a parallel plate capacitor depends. (3)
g. On a sketch of the graph shown in Figure 12, include **TWO** other curves to show how the given curve would change if the same capacitor was to be charged first using:
   - a 60 kΩ resistor;
   - and later, a 40 kΩ resistor;

   connected in series with the capacitor. Distinguish clearly between the two curves. (5)
h. State how a graph of current plotted against time can be used to find the charge accumulated on a capacitor during a specific period of time during the charging process. (1)

(Total: 18 marks)