P510/1
PHYSICS
Paper 1
AUGUST 2022
2 ½ Hours

MASAKA DIOCESAN EXAMINATIONS BOARD

Uganda Advanced Certificate of Education

PHYSICS

PAPER 1

2 Hours, 30 minutes

INSTRUCTIONS TO CANDIDATES:

Attempt **five** *questions, including* **one** *but not more than* **two** *from each of the sections,* **A**, **B** *and* **C**. ***Any additional question(s) attempted will not be marked***.
Non-programmable scientific electronic calculators may be used.
Assume where necessary:

Acceleration due to gravity, g	=	$9.81\ \text{m s}^{-2}$
Electron charge, e	=	1.6×10^{-19} C.
Electron mass	=	9.11×10^{-31} kg
Mass of earth	=	5.97×10^{24} kg.
Planck's constant, h	=	6.6×10^{-34} J s.
Stefan's – Boltzmann's constant, σ	=	$5.7 \times 10^{-8}\ \text{Wm}^{-2}\ \text{K}^{-4}$
Radius of Earth	=	6.4×10^{6} m.
Radius of the sun	=	7×10^{8} m.
Radius of earth's orbit about the sun	=	1.5×10^{11} m
Speed of light in a vacuum, c	=	$3.0 \times 10^{8}\ \text{m s}^{-1}$
Thermal conductivity of copper	=	$390\ \text{W m}^{-1}\ \text{K}^{-1}$
Thermal conductivity of aluminium	=	$210\ \text{W m}^{-1}\ \text{K}^{-1}$
Specific heat capacity of water	=	$4200\ \text{J kg}^{-1}\ \text{K}^{-1}$
Universal Gravitational constant, G	=	$6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
Avogadro's number N_A	=	$6.02 \times 10^{23}\ \text{mol}^{-1}$.
Density of water	=	$1000\ \text{kg m}^{-3}$
Gas constant, R	=	$8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Charge to mass ratio, e/m	=	$1.8 \times 10^{11}\ \text{C kg}^{-1}$
The constant $\frac{1}{4\pi\varepsilon_o}$	=	$9.0 \times 10^{9}\ \text{F}^{-1}\ \text{m}$
Faradays constant, F	=	$9.65 \times 10^{4}\ \text{C mol}^{-1}$

SECTION A

1. (a) (i) Distinguish between a **scalar quantity** and a **vector quantity**. (1 mark)

(ii) Give two examples of each type of the quantity. (2 marks)

(b) Four forces of 12.0 N, 8.0 N, 7.0 N and F(N) act on a body as shown in the Figure 1.

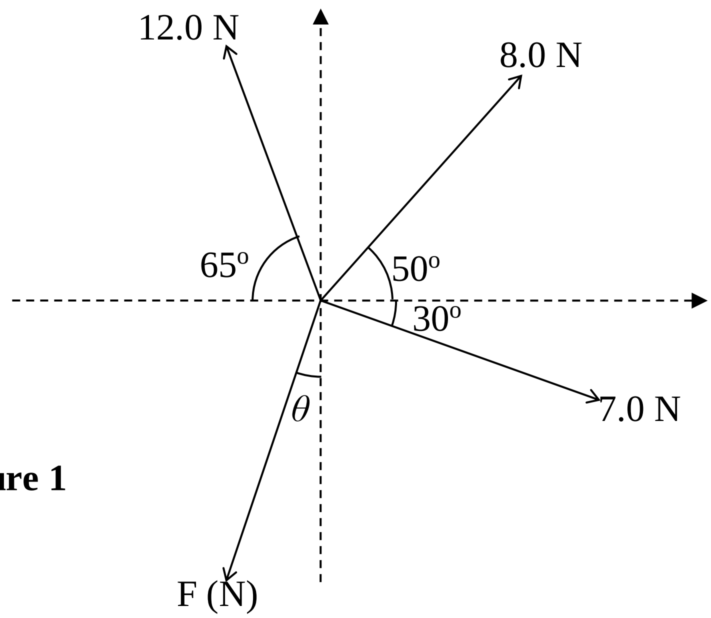

Figure 1

If the resultant force is zero, find the value of θ and F. (5 marks)

(c) (i) Suppose the velocity of a body changes from u to v when accelerated uniformly at a rate a m s^{-2}. Derive an expression of the distance s covered during the acceleration. (3 marks)

(ii) Show that the expression for s covered during the acceleration is dimensionally consistent. (2 marks)

(d) (i) What is meant by **uniform acceleration**. (1 mark)

(ii) Sketch a displacement – time graph showing uniform acceleration for a body starting from rest. (1mark)

(iii) A bus starts from rest at station A and accelerates at 1.25 ms^{-2} until it reaches a speed of 20 ms^{-1}. It then travels at this steady speed for a distance of 1.56 km and then decelerates at 2 ms^{-2} to come to rest at station B. Find the distance from A to B. (5marks)

2. (a) (i) Define **Young's modulus** of elasticity. (1 mark)

(ii) Explain the precautions taken in the determination of Young's modulus of elasticity of a wire. (6 marks)

(b) Why does a piece of rubber stretch much more than a metal wire of the same length and cross sectional area. (2 marks)

(c) (i) Define **surface tension**. (1 mark)

(ii) Explain the origin of surface tension. (3 marks)

(d) Explain the effect of increase in temperature on the surface tension of a liquid. (3 marks)

(e) Two soap bubbles of radii 2.5 cm and 3.5 cm respectively coalesce under isothermal conditions. If the surface tension of soap solution is 2.5×10^{-2} N m^{-1}, calculate the excess pressure inside the resulting soap bubble.

(4 marks)

3. (a) (i) State **Kepler's third law** of planetary motion. (1 mark)

(ii) A communication satellite is in a circular orbit at a height, h, above the Earth's surface. Show that the period of its motion is given by

$T = \frac{2}{r}\,(h + r)^{\frac{3}{2}}$, where r is the radius of the earth. (4 marks)

(iii) Explain why any resistance to the forward motion of a satellite results in an increase in speed. (2 marks)

(b) With aid of a labelled diagram, describe an experiment to determine the **Universal gravitational constant**, **G**. (5 marks)

(c) Derive the expression for **Bernoulli's equation**. (4 marks)

(d) An aeroplane has a mass of 8000 kg and a total wing area of 8.0 m^2. When moving through still air the ratio of its velocity to that of the air at its lower surface is 1.0 whereas the ratio of its velocity to that of the air above the wings is 0.25. At what velocity will the aeroplane be able to just lift off the ground? (Density of air = 1.3 kgm^{-3}) (4 marks)

4. (a) Define the following terms.

(i) **Coefficient of viscosity**. (1 mark)
(ii) **Terminal velocity**. (1 mark)

(b) Briefly explain using the kinetic theory of matter the effect of increase of temperature on the viscosities of fluids. (3 marks)

(c) Using a well labelled diagram, describe an experiment to determine the coefficient of viscosity of oil. (5 marks)

(d) (i) State **Archimedes principle**. (1 mark)
(ii) Show that the weight of fluid displaced by an object is equal to upthrust on the object. (4 marks)

(e) A piece of metal of mass 2.60×10^{-3} kg and density 8.4×10^{3} kg m^{-3} is attached to a block of wax of mass 1.0×10^{-2} kg and density 9.2×10^{2} kg m^{-3}. When the system is placed in a liquid, it floats with wax just submerged. Find the density of the liquid. (5marks)

SECTION B

5. (a) Define **specific latent heat of vaporisation**. (1 mark)

(b) Describe how you would determine the specific latent heat of vaporisation by method of mixtures. (6 marks)

(c) (i) State **Newton's law of cooling**. (1 mark)
(ii) Explain why a small body cools faster than a larger one of the same material. (3 marks)

(d) The pressure, $\boldsymbol{P}$, of an ideal gas is given by $\boldsymbol{P = \frac{1}{3}\rho\overline{C^2}}$ where, $\boldsymbol{\rho}$ is the density of gas and $\boldsymbol{\overline{C^2}}$ its mean square speed.
(i) Show clearly the steps taken to derive this expression. (5 marks)
(ii) State the assumptions made in deriving this expression. (2 marks)

(e) The root mean square speed of molecules of one mole of a gas is $44.72\ m\ s^{-1}$. Find the temperature of the gas if its density is $9.0 \times 10^{-2}\ kg\ m^{-3}$ and the volume is $42.0\ m^3$. (2 marks)

6. (a) Distinguish between a **saturated vapour** and **unsaturated vapour**. (2 marks)

(b) Explain why cloudy nights are warmer than cloudless ones. (4 marks)

(c) Two cylinders **A** and **B** each of volume 1.5 litres are joined in the middle by a tap and placed in a constant temperature bath at 60 °C as shown in Figure 2. **A** contains a vacuum while **B** contains air and saturated vapour. The total pressure in **B** is 200 mmHg. When the tap is opened, equilibrium is reached with water vapour remaining saturated. If the final pressure of the cylinder is 150 mmHg. Calculate the saturated vapour pressure of water at 60 °C. (5 marks)

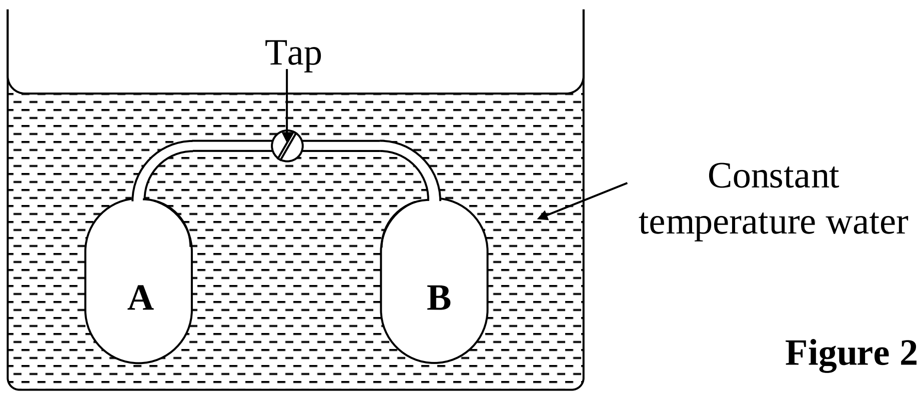

Figure 2

(d) Describe with the aid of a diagram how the saturated vapour pressure of a liquid can be determined at a given temperature. (6 marks)

(e) The equation of state for one mole of real gas of volume V and pressure P at a temperature T is given by $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, where a and b are constants. Explain the significance of the terms $\frac{a}{V^2}$ and b. (3 marks)

7. (a) State **Prevost's' theory of heat exchanges**. (1 mark)

(b) A solid copper sphere of diameter 10.0 mm and at a temperature of 150 K is placed in an enclosure maintained at a temperature of 290 K. Calculate stating any assumptions the initial rate of raise of temperature of the sphere. (Density of copper = 8.93×10^3 kg m^{-3}, specific heat capacity of copper = 3.7×10^2 J kg^{-1} K^{-1}) (5 marks)

(c) (i) What is a **black body**. (1 mark)

(ii) Explain how one can approximate a black body in the laboratory. (4 marks)

(d) (i) Define **thermal conductivity**. (1 mark)

(ii) Describe an experiment to determine the thermal conductivity of glass. (8 marks)

SECTION C

8. (a) Distinguish between **excitation energy** and **ionization energy**. (2 marks)

(b) Figure 3 shows the energy levels of a neon atom.

E_∞	… … …	0.00 eV
E_4	… … …	–0.81 eV
E_3	… … …	–2.77 eV
E_2	… … …	–4.87 eV
E_1	… … …	–21.47 eV

Figure 3

(i) Calculate the wavelength of radiation emitted when there is a transition from E_3 to E_2 . (4 marks)

(ii) In what region of the electromagnetic spectrum does the radiation emitted in this transition? (1 mark)

(c) (i) Show that when an alpha particle of mass, $\boldsymbol{m}$, moving with a speed, $\boldsymbol{v}$, collides head on with an atom of atomic number $\boldsymbol{Z}$, the closest distance of approach to the nucleus, $x_o = \dfrac{ze^2}{\pi m v^2 \varepsilon_0}$ where $\boldsymbol{e}$ is the electronic charge ε_o is permittivity of free space, (4 marks)

(ii) In a head on collision between an alpha particle and a gold nucleus, the minimum distance of approach is 5.0×10^{-14} m. Calculate the energy of the alpha particle.
(Atomic number of gold = 79) (3 marks)

(d) (i) Explain the observations made in the Rutherford $\alpha-$paricle scattering experiment. (6 marks)

(ii) Why is a vacuum necessary in this experiment? (1 mark)

9. (a) Define the following

(i) **Photoelectric effect**. (1 mark)

(ii) **Threshold frequency**. (1 mark)

(b) Explain using quantum theory the laws of photoelectric emission. (5 marks)

(c) (i) Draw and label the parts of an X–ray tube. (2 marks)

(ii) Explain how X-rays are produced. (3 marks)

(d) Using a suitable sketch graph describe how X–ray spectra in an X-ray tube are formed. (6 marks)

(e) A beam of X–rays of wave length 8.42×10^{-11} m is incident on a sodium chloride crystal of interplanar separation 2.82×10^{-11} m. Calculate the first order diffraction angle. (2 marks)

10. (a) Define **specific charge of an electron**. (1mark)

(b) Describe Thomson's experiment to determine the specific charge of an electron. (7 marks)

(c) In the measurement of electric charge by Millikan's apparatus, a p.d of 1.6 kV is applied between two horizontal plates14.0 mm apart. With the p.d switched off an oil drop is observed to fall with a constant velocity of 4.0×10^{-4} ms^{-1}. When the p.d is switched on, the drop rises with a constant velocity of 8.0×10^{-5} ms^{-1}. If the mass of the drop is 1.0×10^{-14} kg, find the number of electron charges on the drop.
(Assume air resistance is proportional to the velocity of the oil drop and neglect the upthrust due to the air) (6 marks)

(d) (i) Define **half-life** of a radio isotope. (1 mark)

(ii) Given the radioactive law, $N = N_O e^{-\lambda t}$ obtain the relationship between λ and the half-life, $T_{\frac{1}{2}}$. (2 marks)

(e) At a certain time, an α-particle detector registers a count rate of 32 s^{-1}. Exactly 10 days later, the count rate dropped to 8 s^{-1}. Find the decay constant. (3 marks)

END