THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2021**

Instructions

1. This paper consists of six questions.
2. Answer five questions.
3. Each question carries twenty marks.

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1.(a)(i)Critical velocity

Critical velocity is the maximum velocity at which a fluid can flow through a pipe without becoming turbulent.

(ii)Incompressible fluid

An incompressible fluid is a fluid whose density remains constant regardless of pressure or temperature changes.

(iii)Streamline flow

Streamline flow is a type of fluid motion in which the fluid particles move in parallel layers with no disruption between them.

(iv)Turbulent flow

Turbulent flow is a type of fluid motion characterized by chaotic changes in pressure and velocity, causing eddies and vortices.

(b)(i)Water flows through a pipe of internal diameter 20 cm at the speed of 1 m/s. What would be the radius of the nozzle if water is expected to emerge at the speed of 4 m/s?

Given:
Initial diameter, d_1 = 20 cm = 0.2 m
Initial velocity, v_1 = 1 m/s
Final velocity, v_2 = 4 m/s

Using the continuity equation:
$A_1V_1 = A_2V_2$

$\pi r_1^2V_1 = \pi r_2^2V_2$

$r_2^2 = (r_1^2V_1) / V_2$

$r_2^2 = ((0.1)^2 \times 1) / 4$

$r_2^2 = 0.0025$

$r_2 = 0.05$ m or 5 cm

(ii)Determine the coefficient of viscosity of the liquid of density 1.47×10^3 kg/m³ if an air bubble of radius 1 cm is moving through it at the steady rate of 0.2 cm/s.

Given:
Density of liquid, $\rho = 1.47 \times 10^3$ kg/m³
Radius of bubble, r = 1 cm = 0.01 m
Velocity, v = 0.2 cm/s = 0.002 m/s
Density of air inside bubble, $\rho_a \approx 1.2$ kg/m³
Acceleration due to gravity, g = 9.81 m/s²

Using Stokes' Law:
$F = 6\pi\eta rv$

Buoyant force:
$F\_b = (4/3)\pi r^3 g(\rho - \rho_a)$

Equating:
$6\pi\eta rv = (4/3)\pi r^3 g(\rho - \rho_a)$

Solving for η:
$\eta = (2/9) \times r^2 g(\rho - \rho_a) / v$

$\eta = (2/9) \times (0.01)^2 \times 9.81 \times (1.47 \times 10^3 - 1.2) / (0.002)$

$\eta = (2 \times 9.81 \times 1.4688 \times 10) / (9 \times 0.002)$
$\eta \approx 1.59 \times 10^{-3}$ Pa·s

(c)(i)Write Stoke's equation as applied to motion of a body in a viscous medium and define all symbols used.
Stokes' equation:
$F = 6\pi\eta rv$

where,
F = viscous drag force
η = coefficient of viscosity
r = radius of the sphere
v = velocity of the sphere

(ii)State two conditions under which Stoke's equation is valid.

- The flow must be laminar.
- The object must be spherical in shape.

2.(a)(i)What are four distinctive properties between progressive and stationary waves based on the nature and its conditions?

- Progressive waves transfer energy from one point to another, while stationary waves do not transfer energy.
- In progressive waves, all particles oscillate with the same amplitude, while in stationary waves, some points (nodes) remain at rest.
- Progressive waves have crests and troughs moving in a given direction, while stationary waves have fixed nodes and antinodes.
- Progressive waves have a uniform phase difference between adjacent points, while in stationary waves, particles between two consecutive nodes oscillate in phase.

(ii)A 320 cm long string has two adjacent resonances at 170 Hz and 204 Hz respectively. Calculate the fundamental frequency and the speed of the wave.

Given:
L = 320 cm = 3.2 m
$n_1 f_1 = 170$ Hz
$n_2 f_2 = 204$ Hz

The difference in resonant frequencies corresponds to the fundamental frequency:

$f_0 = f_2 - f_1$

$f_0 = 204 - 170$

$f_0 = 34$ Hz

The speed of the wave is given by:

$v = 2Lf_0$

$v = 2 \times 3.2 \times 34$

$v = 217.6$ m/s

(b)(i)Identify four methods used to form interference pattern apart from Young's double slit experiment.

- Thin film interference
- Newton's rings
- Lloyd's mirror experiment
- Michelson interferometer

(ii)An open and closed pipes of 40 cm and 33 cm long respectively both being of the same diameters sound their first overtone and are in unison. Determine the end correction of the pipes.

For an open pipe, the first overtone is the second harmonic:

$f_{open} = v / (2L)$

For a closed pipe, the first overtone is the third harmonic:

$f_{closed} = 3v / (4L)$

Equating the frequencies:

$v / (2 \times 40) = 3v / (4(L + e))$

Solving for e:

$e \approx 0.5$ cm

(c)(i)In Young's double slit experiment, the distance of the screen from the two slits is 0.9 m. When light of wavelength, $\lambda = 7.5 \times 10^{-7}$ m is allowed to fall on the slits, the width of the fringes obtained on a screen is 2.5 mm. If the wavelength of the incident light is 5.5×10^{-7} m, determine:

The distance between the slits.

Using fringe width formula:
$\Delta y = (\lambda D) / d$

$d = (\lambda D) / \Delta y$

$d = (7.5 \times 10^{-7} \times 0.9) / (2.5 \times 10^{-3})$

$d = 2.7 \times 10^{-4}$ m

(ii)The width of the fringes.

$\Delta y' = (\lambda' D) / d$

$\Delta y' = (5.5 \times 10^{-7} \times 0.9) / (2.7 \times 10^{-4})$

$\Delta y' \approx 1.83$ mm

3.(a)(i)Use mathematical expressions to distinguish between Young's modulus of a material and Young's modulus of rigidity.

Young's modulus:
E = (Stress) / (Strain) = (F/A) / (ΔL/L)

Shear modulus (Rigidity modulus):
G = (Shear stress) / (Shear strain) = (F/A) / (θ)

(ii)With the aid of a sketch graph, explain what happens when steel is stretched gradually by an increasing load until it breaks.

The graph of stress vs. strain shows:

- Proportional limit where stress is directly proportional to strain.
- Elastic limit where the material deforms elastically.
- Plastic region where permanent deformation occurs.
- Necking and fracture at the breaking point.

(b)(i)Determine the height at which water will rise in a capillary tube of radius 5.0×10^{-5} m if the angle of contact between water and the material of the tube is approximately zero.

$h = (2T \cos\theta) / (\rho g r)$

$h = (2 \times 0.0728 \times \cos 0) / (1000 \times 9.81 \times 5.0 \times 10^{-5})$

$h \approx 2.97$ m

(ii)A vertical steel beam of length 4.0 m and cross-sectional area of 8.0×10^{-3} m² supports a load of 6.0×10^{4} N. To what extent does the steel beam would be compressed along its length?

$\Delta L = (FL) / (AE)$

$\Delta L = (6.0 \times 10^{4} \times 4) / (8.0 \times 10^{-3} \times 2 \times 10^{11})$

$\Delta L \approx 1.5 \times 10^{-5}$ m

(c)If the surface tension of mercury at room temperature is 4.72×10^{-1} N/m, determine the excess pressure inside a drop of mercury of radius 0.2 cm.

$\Delta P = 2T / r$
$\Delta P = (2 \times 4.72 \times 10^{-1}) / (2 \times 10^{-3})$

$\Delta P \approx 472$ N/m²

4.(a)(i)State two relations which exist between field lines and electric fields.

1. Electric field lines represent the direction of the electric field, which is tangent to the field line at any point.
2. The density of electric field lines indicates the strength of the electric field; closer lines mean a stronger field.

(ii)ABC is a right-angled triangle, where the right angle is at B as shown in Figure 1 and charges of -246 μC, +278 μC, and +71 μC are placed at A, B, and C respectively. If AB = 4 cm and BC = 3 cm, determine the electric field at the foot of the perpendicular drawn from B on the side AC.

Given:
Charge at A, $q_1 = -246\ \mu C = -246 \times 10^{-6}$ C
Charge at B, $q_2 = +278\ \mu C$ (not affecting field at G since it's at the same point)
Charge at C, $q_3 = +71\ \mu C = 71 \times 10^{-6}$ C
AB = 4 cm = 0.04 m
BC = 3 cm = 0.03 m

Using Pythagoras theorem:
$AC = \sqrt{(AB^2 + BC^2)}$
$AC = \sqrt{(0.04^2 + 0.03^2)}$
$AC = \sqrt{(0.0016 + 0.0009)}$
$AC = \sqrt{0.0025}$
AC = 0.05 m

The electric field at point G is the vector sum of fields due to A and C. Applying Coulomb's law:
$E = k|q| / r^2$

Electric field due to A:
$E_1 = (9 \times 10^9 \times 246 \times 10^{-6}) / (0.04^2)$
$E_1 = (2.214 \times 10^6) / 0.0016$
$E_1 = 1.38 \times 10^9$ N/C

Electric field due to C:
$E_2 = (9 \times 10^9 \times 71 \times 10^{-6}) / (0.03^2)$
$E_2 = (6.39 \times 10^5) / 0.0009$
$E_2 = 7.1 \times 10^8$ N/C

Resultant field:
$E = \sqrt{(E_1^2 + E_2^2)}$
$E = \sqrt{((1.38 \times 10^9)^2 + (7.1 \times 10^8)^2)}$
$E = 1.57 \times 10^9$ N/C

(b)(i)What is an electric line of force?

An electric line of force is an imaginary line that represents the direction of the electric field at various points, showing the path a positive test charge would take under the influence of the field.

(ii)Carefully study Figure 2 and then calculate the work done in moving a third charge (Q_3) from B to A along the diagonal of the rectangle.

Given:
$Q_1 = -5 \times 10^{-5}$ C
$Q_2 = +2 \times 10^{-6}$ C
$Q_3 = 3 \times 10^{-6}$ C

Distance along diagonal:
$d = \sqrt{(3^2 + 2^2)}$
$d = \sqrt{(9 + 4)}$
$d = \sqrt{13}$
$d \approx 3.61$ m

Electric potential difference between A and B:
$V = k(Q_1 / d_1 + Q_2 / d_2)$

Work done:
$W = Q_3V$

Substituting values gives:
$W \approx 0.15$ J

(c)(i)What would happen when two spheres of different capacitances are charged to different potentials and then joined by a wire?

When two spheres of different capacitances are connected by a wire, charge will flow from the sphere at higher potential to the sphere at lower potential until both attain the same potential.

(ii)A parallel plate capacitor has plate area of 4 m² spaced by three layers of different dielectric materials. If the relative permittivities and thicknesses are 3, 6, 9 and 1.0, 3.0, 0.6 mm respectively, calculate the capacitance of the capacitor.

Given:
$A = 4$ m²
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$d_1 = 1.0$ mm $= 1.0 \times 10^{-3}$ m
$d_2 = 3.0$ mm $= 3.0 \times 10^{-3}$ m

$d_3 = 0.6$ mm $= 0.6 \times 10^{-3}$ m
$\varepsilon_1 = 3\varepsilon_0$, $\varepsilon_2 = 6\varepsilon_0$, $\varepsilon_3 = 9\varepsilon_0$

Capacitance:
$1/C = (d_1 / (\varepsilon_1 A)) + (d_2 / (\varepsilon_2 A)) + (d_3 / (\varepsilon_3 A))$

Solving gives:
$C \approx 6.02 \times 10^{-12}$ F

5.(a)(i)Identify four useful applications of eddy currents.

1. Magnetic braking in trains.
2. Induction heating in metal processing.
3. Eddy current testing for material flaws.
4. Energy loss reduction in transformer cores.

(ii)A rectangular loop is partially held in a uniform magnetic field B which is perpendicular to the plane of the paper as shown in Figure 3. If the loop is moved towards right in the plane of the paper and perpendicular to the field with constant velocity v, derive an expression for the mechanical power P needed to move the loop in terms of the magnetic field B, the length of the plane L, the constant velocity v and the total resistance of the loop R.

Induced emf:
$\varepsilon = BLv$

Induced current:
$I = \varepsilon / R$
$I = (BLv) / R$

Magnetic force:
$F = BIL$
$F = B(BLv/R)L$
$F = B^2L^2v / R$

Power required:
$P = Fv$
$P = (B^2L^2v^2) / R$

(b)(i)What is an electromagnetic induction?

Electromagnetic induction is the process by which a changing magnetic field induces an electromotive force (emf) in a conductor.

(ii)Mention three methods of producing induced e.m.f.

1. By changing the magnetic field strength.
2. By changing the area of the loop exposed to the magnetic field.
3. By moving the conductor in a magnetic field.

(c)Why spark is produced in the switch of a fan when it is switched off?

A spark is produced due to the sudden collapse of the magnetic field around the coil, inducing a high voltage across the switch terminals, which ionizes the air and causes a spark.

(d)A toroid solenoid with air core has an average radius, cross-section area and number of turns of 15 cm, 18 cm² and 1500 respectively. If another coil of 600 turns is wound closely to the toroid, the current in the primary coil is changed from zero to 3 A in 0.06 seconds. Calculate the:

(i)Self-inductance of the toroid.

Given:
$r = 15$ cm $= 0.15$ m
$A = 18$ cm² $= 18 \times 10^{-4}$ m²
$N = 1500$
$\mu_0 = 4\pi \times 10^{-7}$ H/m

$L = (\mu_0 N^2 A) / l$
$L = (4\pi \times 10^{-7} \times 1500^2 \times 18 \times 10^{-4}) / (2\pi \times 0.15)$

$L \approx 0.85$ H

(ii)Induced e.m.f in the second coil.

Given:
$N_2 = 600$
$\Delta I = 3$ A
$\Delta t = 0.06$ s

Mutual inductance:
$M = (\mu_0 N_1 N_2 A) / l$

Induced emf:
$\varepsilon = -M(\Delta I/\Delta t)$

Solving gives:
$\varepsilon \approx 25.5$ V

6.(a)(i)Activity

Activity is the rate at which a radioactive substance undergoes decay, measured in disintegrations per second or becquerels (Bq).

(ii)Chain reaction

A chain reaction is a self-sustaining nuclear reaction where the products of one reaction initiate further reactions, as seen in nuclear fission.

(iii)Half-life

Half-life is the time required for half of the radioactive nuclei in a sample to decay.

(iv)Critical mass

Critical mass is the minimum amount of fissile material needed to sustain a chain reaction.

(b)How many disintegrations per second occur in 1 g of uranium ($_{92}U^{238}$) of half-life 4.5×10^9 years when under goes alpha (α) decay?

Given:
Half-life, $T_1/_2 = 4.5 \times 10^9$ years $= 4.5 \times 10^9 \times 3.154 \times 10^7$ s
Molar mass of U^{238} = 238 g
Avogadro's number, $N_a = 6.022 \times 10^{23}$ atoms/mol

Number of atoms in 1 g of U^{238}:
$N = (N_a \times \text{mass}) / \text{molar mass}$
$N = (6.022 \times 10^{23} \times 1) / 238$
$N \approx 2.53 \times 10^{21}$ atoms

Decay constant:
$\lambda = 0.693 / T_1/_2$
$\lambda = 0.693 / (4.5 \times 10^9 \times 3.154 \times 10^7)$
$\lambda \approx 4.87 \times 10^{-18}\ s^{-1}$

Activity:
$A = \lambda N$
$A = (4.87 \times 10^{-18}) \times (2.53 \times 10^{21})$
$A \approx 1.23 \times 10^4$ disintegrations per second

(c)Given that the mass of deuterium nucleus, neutron and one isotope of helium are 2.015 u, 3.017 u and 1.009 u respectively;

(i)Calculate the energy released by the fusion of 1 kg of deuterium.

Given:
Mass of deuterium, $m_1 = 2.015$ u
Mass of neutron, $m_2 = 1.009$ u
Mass of helium isotope, $m_3 = 3.017$ u

Mass defect:
$\Delta m = (2m_1 + m_2) - m_3$
$\Delta m = (2 \times 2.015 + 1.009) - 3.017$
$\Delta m = (4.03 + 1.009) - 3.017$
$\Delta m = 2.022$ u

Energy released per reaction:
$E = \Delta m \times 931.5$ MeV/u
$E = (2.022 \times 931.5)$
$E = 1883$ MeV
Number of deuterium atoms in 1 kg:
$N = (N_a \times \text{mass}) / \text{atomic mass}$
$N = (6.022 \times 10^{23} \times 1000) / 2.015$
$N \approx 2.99 \times 10^{26}$ atoms

Total energy released:
$E\_total = N \times E$
$E\_total = (2.99 \times 10^{26}) \times (1883 \times 1.6 \times 10^{-13})$
$E\_total \approx 8.99 \times 10^{14}$ J

(ii)How many days would the station be able to function if 50% of the energy obtained in (c)(i) was continuously used to produce 1 MW of electricity?
Given:
Power, $P = 1$ MW $= 1 \times 10^6$ W
Energy available, $E = 0.5 \times 8.99 \times 10^{14}$ J
$E = 4.495 \times 10^{14}$ J

Time:
$t = E / P$
$t = (4.495 \times 10^{14}) / (1 \times 10^6)$
$t = 4.495 \times 10^8$ s

Converting to days:
$t = (4.495 \times 10^8) / (86400)$
$t \approx 5200$ days