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: 2020**

Instructions

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

1.(a)(i)State two factors which determine the magnitude of viscous force.
1. The viscosity of the fluid (η), which is a measure of internal friction within the fluid.
2. The velocity gradient (du/dy), which represents the rate of change of velocity across the layers of the fluid.

(ii)Identify two limitations and three importances of applying Stokes' law in fluids motion.

Limitations:
1. Stokes' law is only valid for small spherical objects moving at low velocities in a fluid.
2. It does not apply when turbulence occurs, meaning it is restricted to laminar flow conditions.

Importances:
1. Used in measuring the viscosity of a liquid using falling sphere viscometers.
2. Helps in understanding sedimentation processes in industries such as wastewater treatment.
3. Used in designing parachutes and other applications involving air resistance.

(b)A venture meter consists of two identical wide tubes A and B connected by a narrow tube C. The liquid enters through the wide tube A and after passing through the narrow tube C leaves through the other wide tube B. The entire arrangement is as shown in the figure. Use Bernoulli's theorem at points 1 and 2, to show that an expression for the rate of flow of the liquid is given by $Q = A_1A_2 \sqrt{(2gh / (A_1^2 - A_2^2))}$, where all symbols carry their usual meaning.

Applying Bernoulli's equation at points 1 and 2:
$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh$

Since heights are the same, ρgh cancels out:
$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

Rearranging for v_2:
$\frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 = P_1 - P_2$
$\frac{1}{2}\rho(v_2^2 - v_1^2) = P_1 - P_2$
$v_2^2 - v_1^2 = (2(P_1 - P_2)) / \rho$
$v_2 = \sqrt{(2(P_1 - P_2) / \rho + v_1^2)}$

Using the continuity equation:
$A_1v_1 = A_2v_2$
$v_1 = Q / A_1$
$v_2 = Q / A_2$

Substituting into Bernoulli's equation:
$(Q/A_2)^2 - (Q/A_1)^2 = 2(P_1 - P_2) / \rho$
$Q^2(1/A_2^2 - 1/A_1^2) = 2(P_1 - P_2) / \rho$
$Q^2 = (2(P_1 - P_2) / \rho) / (1/A_2^2 - 1/A_1^2)$

$Q = \sqrt{2(P_1 - P_2) / \rho} / \sqrt{1/A_2^2 - 1/A_1^2}$

Since pressure difference $P_1 - P_2$ is caused by height difference h:
$P_1 - P_2 = \rho gh$
$Q = A_1A_2 \sqrt{2gh / (A_1^2 - A_2^2)}$

(d)A cylindrical tank 1 m in radius rests on a platform 5 m high. Initially, the tank was filled with water to a height of 5 m. If a plug of area 10^{-2} m² is removed by an orifice on the side of the tank at the bottom, calculate the initial speed with which the water:

(i)Flows from the orifice.

Using Torricelli's theorem:
$v = \sqrt{2gh}$
h = 5 m
g = 9.81 m/s²
$v = \sqrt{2 \times 9.81 \times 5}$
$v = \sqrt{98.1}$
$v \approx 9.9$ m/s

(ii)Strikes the ground.

Time taken to fall from 5 m:
Using equation of motion:
$h = \frac{1}{2} gt^2$
$t = \sqrt{2h / g}$
$t = \sqrt{2 \times 5 / 9.81}$
$t = \sqrt{10 / 9.81}$
$t \approx 1.01$ s

Horizontal distance traveled before striking ground:
$x = v \times t$
$x = 9.9 \times 1.01$
$x \approx 10$ m

2. (a)What is the importance of each of the following in relation to the production of plane polarized light?

Dextro-rotatory substance: Rotates the plane of polarized light to the right.
Laevo-rotatory substance: Rotates the plane of polarized light to the left.
Optically active substance: Can rotate the plane of polarization of light.
Double refraction: Splits unpolarized light into two polarized rays traveling in different directions.

(b)Differentiate:

Polaroid from polarimeter: Polaroid is a material that polarizes light, while a polarimeter is an instrument used to measure optical rotation.
Plane of vibration from plane of polarization: The plane of vibration contains the electric field vectors, while the plane of polarization is perpendicular to it.
Ordinary light from plane polarized light: Ordinary light has vibrations in all directions, whereas plane polarized light vibrates in a single plane.

(c)Describe the construction of Nicol Prism.

A Nicol prism is made by cutting a calcite crystal into two halves at a specific angle, cementing them together with Canada balsam. The refractive indices of calcite and Canada balsam are such that one of the refracted rays undergoes total internal reflection and is absorbed, allowing only the plane-polarized ray to pass through.

(d)Briefly explain the observations made with regard to the formation of fringes in Newton's ring experiment when:

(i)The glass plate is silvered on its front surface: No interference fringes are observed because no light passes through the plate.
(ii)The sodium lamp is replaced by a white light: Colored fringes appear due to different wavelengths interfering constructively and destructively.
(iii)A few drops of a transparent liquid are introduced between the lens and the plate: The fringe pattern shifts because the refractive index of the medium changes.

(e)What governs the radius of the ring in Newton's ring experiment? Give two factors.

1. The wavelength of the light used.
2. The radius of curvature of the lens.

3.(a)(i)Briefly explain the following observations:

The rise of the liquid is affected if the top of the capillary tube is closed.

When the top of the capillary tube is closed, the air inside exerts pressure on the liquid, preventing it from rising. The capillary action depends on the atmospheric pressure pushing the liquid into the tube, which is not possible when the top is sealed.

(ii)Rain drops are spherical in shape.

Rain drops are spherical due to surface tension. The cohesive forces between water molecules cause the drop to minimize its surface area, forming a sphere, which has the least surface energy.

(b)(i)Why brick walls are plastered with cement?

1. Plastering fills the gaps between bricks, providing a smooth surface and preventing moisture penetration.
2. It increases the strength and durability of the wall.
3. It improves the appearance and provides thermal insulation.

(ii)A barometer contains two uniform capillary tubes of radii 6.5×10^{-4}m and 1.24×10^{-3}m. If the height of water in a narrow tube is 0.2 m more than that in the wide tube, calculate the true pressure difference.

Given:
Radius of narrow tube, $r_1 = 6.5 \times 10^{-4}$ m
Radius of wide tube, $r_2 = 1.24 \times 10^{-3}$ m
Height difference, h = 0.2 m
Density of water, $\rho = 1000$ kg/m³
Acceleration due to gravity, g = 9.81 m/s²
Surface tension of water, T = 0.0728 N/m

Using Jurin's law:
$h = (2T \cos\theta) / (\rho gr)$

For narrow tube:
$h_1 = (2 \times 0.0728 \times 1) / (1000 \times 9.81 \times 6.5 \times 10^{-4})$
$h_1 = (0.1456) / (6.3765 \times 10^{-1})$
$h_1 \approx 0.228$ m

For wide tube:
$h_2 = (2 \times 0.0728 \times 1) / (1000 \times 9.81 \times 1.24 \times 10^{-3})$
$h_2 = (0.1456) / (1.2154 \times 10^{-1})$
$h_2 \approx 0.12$ m

Pressure difference:
$\Delta P = \rho g(h_1 - h_2)$
$\Delta P = 1000 \times 9.81 \times (0.228 - 0.12)$
$\Delta P = 1000 \times 9.81 \times 0.108$
$\Delta P \approx 1.06 \times 10^3$ Pa

(c)(i)What is meant by surface tension? Give its S.I. units.

Surface tension is the force per unit length acting along the surface of a liquid, which tends to minimize its surface area. Its S.I. unit is N/m (Newton per meter).

(ii)During the rain, 64 rain drops combined into a single drop. Calculate the ratio of the total surface energy of the 64 drops to that of a single drop.

Given:
Number of small drops, $n = 64$
Let the radius of each small drop be r, then the volume of one small drop:
$V = (4/3)\pi r^3$
Total volume of 64 drops:
$V_{total} = 64 \times (4/3)\pi r^3$

Radius of the large drop, R:
Since volume is conserved,
$(4/3)\pi R^3 = 64 \times (4/3)\pi r^3$
$R^3 = 64r^3$
$R = 4r$

Surface area of 64 small drops:
$A_1 = 64 \times 4\pi r^2 = 256\pi r^2$

Surface area of large drop:
$A_2 = 4\pi R^2 = 4\pi(4r)^2 = 64\pi r^2$

Ratio of surface areas:
$A_1 / A_2 = 256\pi r^2 / 64\pi r^2$
$A_1 / A_2 = 4$

Since surface energy is proportional to surface area, the ratio of total surface energy of 64 small drops to that of a single drop is 4:1.

4.(a)(i)Give the meaning of the terms capacitance and relative permittivity.

Capacitance is the ability of a system to store charge per unit voltage. It is measured in farads (F).

Relative permittivity (ε_r) is the ratio of the permittivity of a material to the permittivity of free space (ε_0). It indicates how much a material can store electric charge compared to a vacuum.

(ii)Calculate the capacitance of a pair of parallel plates 0.1 m by 0.1 m with an air gap of 5 mm.

Given:
Plate area, $A = 0.1 \text{ m} \times 0.1 \text{ m} = 0.01 \text{ m}^2$
Separation distance, $d = 5 \text{ mm} = 5 \times 10^{-3} \text{ m}$
Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

Using capacitance formula:

$C = (\varepsilon_0 A) / d$
$C = (8.85 \times 10^{-12} \times 0.01) / (5 \times 10^{-3})$
$C = (8.85 \times 10^{-14}) / (5 \times 10^{-3})$
$C = 1.77 \times 10^{-12}$ F
$C \approx 1.77$ pF

(b)(i)What is a Van de Graaff generator?

A Van de Graaff generator is a device that produces high voltage by accumulating static electric charge on a large conducting sphere using a moving belt.

(ii)In a Van de Graaff generator, the shell electrode is at 25×10^5 V. If the dielectric strength of the gas surrounding the electrode is 5×10^7 V/m, calculate the minimum radius of the spherical shell.

Given:
Voltage, $V = 25 \times 10^5$ V
Dielectric strength, $E = 5 \times 10^7$ V/m

Using $E = V / r$
$r = V / E$
$r = (25 \times 10^5) / (5 \times 10^7)$
$r = (2.5 \times 10^6) / (5 \times 10^7)$
$r = 0.05$ m

(c)(i)State Coulomb's law of forces.

Coulomb's law states that the force between two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them.
$F = (k\, q_1\, q_2) / r^2$

(ii)An electron is situated in a uniform electric field of field strength of 1.2×10^6 V/m. Find the force acting on it and its acceleration if it has travelled 20 mm from rest.

Given:
Electric field strength, $E = 1.2 \times 10^6$ V/m
Charge of electron, $q = 1.6 \times 10^{-19}$ C
Mass of electron, $m = 9.11 \times 10^{-31}$ kg
Distance traveled, $d = 20$ mm $= 0.02$ m

Force on the electron:
$F = qE$
$F = (1.6 \times 10^{-19}) \times (1.2 \times 10^6)$
$F = 1.92 \times 10^{-13}$ N

Acceleration:
$a = F / m$
$a = (1.92 \times 10^{-13}) / (9.11 \times 10^{-31})$
$a = 2.11 \times 10^{17}$ m/s²

5.(a)(i)Distinguish between diamagnetic, paramagnetic, and ferromagnetic materials on the basis of relative permeability μ_r.

Diamagnetic materials: $\mu_r < 1$ (slightly repelled by a magnetic field).
Paramagnetic materials: $\mu_r > 1$ but small (weakly attracted to a magnetic field).
Ferromagnetic materials: $\mu_r >> 1$ (strongly attracted to a magnetic field and retains magnetism).

(ii)Give the meaning of magnetization I for a paramagnetic material and use Curie's law to show how it relates with the absolute temperature (T).

Magnetization I is the measure of the magnetic moment per unit volume of a material in response to an applied magnetic field.

Curie's law:
$I = C B / T$

Where C is Curie's constant, B is the applied magnetic field, and T is the absolute temperature. It shows that magnetization is inversely proportional to temperature.

(b)(i)Why the material used for making the core of a transformer should have a narrow hysteresis loop?

A narrow hysteresis loop reduces energy loss due to repeated magnetization and demagnetization, improving transformer efficiency.

(ii)A specimen of iron is uniformly magnetized by the magnetizing field of 300 A/m. If the magnetic flux density in the specimen is 0.4 Wb/m², find the relative permeability, susceptibility, and the permeability of the specimen.

Given:
$H = 300$ A/m
$B = 0.4$ Wb/m²
$\mu_0 = 4\pi \times 10^{-7}$ H/m

Permeability of specimen:
$B = \mu_0 \mu_r H$
$\mu_r = B / (\mu_0 H)$
$\mu_r = (0.4) / ((4\pi \times 10^{-7}) \times 300)$

$\mu_r = (0.4) / (3.77 \times 10^{-4})$
$\mu_r \approx 1060$

Magnetic susceptibility:
$\chi = \mu_r - 1$
$\chi = 1060 - 1$
$\chi = 1059$

Permeability of the specimen:
$\mu = \mu_0 \mu_r$
$\mu = (4\pi \times 10^{-7}) \times (1060)$
$\mu \approx 1.33 \times 10^{-3}$ H/m

(c)Consider two parallel co-axial circular coils of equal radius R, and number of turns N, carrying equal currents I in the same direction and separated by a distance λ. Show that $B = 0.72 (\mu_0 NI / R)$ where B is the field on the axis around the mid-point between the coils.

Using Biot-Savart's law, the magnetic field at a point on the axis of a single coil at a distance x from its center is:

$B_1 = (\mu_0 N I R^2) / (2(R^2 + x^2)^{(3/2)})$

For two coils, separated by a distance λ, the total field at the midpoint (x = λ/2) is:
$B_{total} = B_1 + B_2$
$B_{total} = (\mu_0 N I R^2) / (2(R^2 + (\lambda/2)^2)^{(3/2)}) + (\mu_0 N I R^2) / (2(R^2 + (\lambda/2)^2)^{(3/2)})$
$B_{total} = (\mu_0 N I R^2) / ((R^2 + (\lambda/2)^2)^{(3/2)})$

For Helmholtz coils, where λ = R:
$B = (\mu_0 N I R^2) / ((R^2 + (R/2)^2)^{(3/2)})$
$B = (\mu_0 N I R^2) / ((R^2 + R^2/4)^{(3/2)})$
$B = (\mu_0 N I R^2) / ((5R^2/4)^{(3/2)})$
$B = (\mu_0 N I R^2) / ((5\sqrt{5} R^3)/8)$
$B = (8\mu_0 N I) / (5\sqrt{5} R)$
$B \approx 0.72 (\mu_0 N I / R)$

6.(a)(i)Differentiate ionization energy from excitation energy.

Ionization energy is the energy required to completely remove an electron from an atom, making it a free electron.
Excitation energy is the energy required to move an electron from a lower energy level to a higher energy level within the atom without removing it.
(ii)Differentiate ionization potential from excitation potential.

Ionization potential is the potential difference needed to completely remove an electron from an atom. Excitation potential is the potential difference needed to move an electron from a lower to a higher energy level within the atom.

(b)(i)State Bohr's frequency condition.

Bohr's frequency condition states that the frequency of radiation emitted or absorbed during an electron transition between energy levels is given by:

$hf = E_2 - E_1$,

where h is Planck's constant, f is the frequency, and E_2 and E_1 are the energy levels of the electron.

(ii)Why is a very thin gold foil used in Rutherford's α-particle scattering experiment?

A very thin gold foil is used to allow α-particles to pass through with minimal interaction, ensuring that the scattering is due to single interactions with atomic nuclei rather than multiple collisions. This helps in studying the deflection pattern and structure of the atom.

(iii)It is found experimentally that -2.2×10^{-18} J is required to separate a hydrogen atom into a proton and an electron. Compute the orbital radius and the velocity of the electron in a hydrogen atom.

Given:

Energy required to separate the hydrogen atom, $E = -2.2 \times 10^{-18}$ J

Mass of electron, $m = 9.11 \times 10^{-31}$ kg

Charge of electron, $e = 1.6 \times 10^{-19}$ C

Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$

Using Bohr's equation for radius:

$r = (\varepsilon_0 h^2) / (\pi m e^2)$

Substituting values:

$r = (8.85 \times 10^{-12} \times (6.63 \times 10^{-34})^2) / (\pi \times 9.11 \times 10^{-31} \times (1.6 \times 10^{-19})^2)$

$r \approx 5.29 \times 10^{-11}$ m

Using Bohr's equation for velocity:

$v = (e^2) / (2\varepsilon_0 h)$

Substituting values:

$v = ((1.6 \times 10^{-19})^2) / (2 \times 8.85 \times 10^{-12} \times 6.63 \times 10^{-34})$

$v \approx 2.19 \times 10^6$ m/s

(c)What is meant by the following terms as applied in atomic and nuclear physics?

(i)Binding energy curve

A graph showing the binding energy per nucleon against mass number, indicating the stability of nuclei. The curve peaks around iron, meaning mid-sized nuclei are the most stable.

(ii)Nuclear mass

The total mass of a nucleus, which is always slightly less than the sum of the individual masses of its protons and neutrons due to mass defect.

(iii)Nuclear reaction

A reaction that involves changes in the nucleus of an atom, such as fission, fusion, or radioactive decay, often releasing large amounts of energy.

(iv)Artificial radioactivity

The process of inducing radioactivity in a stable nucleus by bombarding it with particles such as neutrons, protons, or α-particles.

(d)In an experiment, the activity of 1.6 mg of radioactive potassium chloride (chloride of isotope K - 40) was found to be 180 s^{-1}. Taking molar mass of K - 40 Cl to be 0.075 kg/mol, find the:

(i)Number of K - 40 atoms in the sample.

Given:
Mass of sample, $m = 1.6$ mg $= 1.6 \times 10^{-3}$ g $= 1.6 \times 10^{-6}$ kg
Molar mass, $M = 0.075$ kg/mol
Avogadro's number, $N_a = 6.022 \times 10^{23}$ atoms/mol

Number of moles:
$n = m / M$
$n = (1.6 \times 10^{-6}) / (0.075)$
$n \approx 2.13 \times 10^{-5}$ moles

Number of atoms:
$N = n \times N_a$
$N = (2.13 \times 10^{-5}) \times (6.022 \times 10^{23})$
$N \approx 1.28 \times 10^{19}$ atoms

(ii)Half-life of K - 40.
Using activity equation:
$A = \lambda N$
$\lambda = A / N$

Substituting values:
$\lambda = (180) / (1.28 \times 10^{19})$
$\lambda \approx 1.41 \times 10^{-17}\ s^{-1}$

Half-life:
$T_{1}/_{2} = 0.693 / \lambda$
$T_{1}/_{2} = 0.693 / (1.41 \times 10^{-17})$
$T_{1}/_{2} \approx 4.92 \times 10^{16}$ s

Converting to years:
$T_{1}/_{2} = (4.92 \times 10^{16}) / (3.154 \times 10^{7})$
$T_{1}/_{2} \approx 1.56 \times 10^{9}$ years
(e)How long can an electric lamp of 200 W be kept glowing by fusion of 3.0 kg of deuterium given that the fusion reaction taking place is

${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{2}He + {}^{1}_{0}n + 3.27$ MeV

Given:
Mass of deuterium, m = 3.0 kg
Energy released per reaction, E = 3.27 MeV
1 MeV = 1.6×10^{-13} J
Avogadro's number, $N_a = 6.022 \times 10^{23}$ atoms/mol
Molar mass of deuterium = 2 g/mol = 0.002 kg/mol

Number of deuterium atoms:
$N = (N_a \times \text{mass}) / \text{atomic mass}$
$N = (6.022 \times 10^{23} \times 3.0) / (0.002)$
$N \approx 9.03 \times 10^{26}$ atoms

Total energy released:
$E\_total = N \times (3.27 \times 1.6 \times 10^{-13})$
$E\_total = (9.03 \times 10^{26}) \times (5.23 \times 10^{-13})$
$E\_total \approx 4.72 \times 10^{14}$ J

Time the lamp can be kept glowing:
P = 200 W = 200 J/s
t = E_total / P
$t = (4.72 \times 10^{14}) / (200)$
$t = 2.36 \times 10^{12}$ s
Converting to years:
$t = (2.36 \times 10^{12}) / (3.154 \times 10^{7})$
$t \approx 7.48 \times 10^{4}$ years