THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Time: 2 Hours 30 Minutes **ANSWERS** **Year : 2005**

Instructions

1. This paper consists of sections A, B and C.
2. Answer four questions from section A and three questions from each of sections B and C.
3. Non-programmable calculators may be used.
4. Communication devices and any unauthorised materials are **not** allowed in the examination room.
5. Write your **Examination Number** on every page of your answer booklet(s).

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Prepared by Maria Marco for TETEA

1. (a) (i) What is meant by viscous drag?

Viscous drag is the resistive force exerted by a fluid on a body moving through it, opposing the motion, due to internal friction between layers of the fluid.

(ii) With the aid of dimensional analysis, derive an expression relating viscous drag to other relevant parameters leading to Stoke's law.

Viscous drag F depends on viscosity η, radius r of the sphere, and velocity v.

Let $F \propto \eta^a r^b v^c$.

Dimensions:

$F = MLT^{-2}$.

$\eta = ML^{-1}T^{-1}$, $r = L$, $v = LT^{-1}$.

So $[F] = (M L^{-1} T^{-1})^a (L)^b (L T^{-1})^c$.

$= M^a L^{-a} T^{-a} \times L^b \times L^c T^{-c}$.

$= M^a L^{-a+b+c} T^{-a-c}$.

Equating with $M^1 L^1 T^{-2}$:

$a = 1$, $-a+b+c = 1 \rightarrow -1+b+c=1 \rightarrow b+c=2$.

$-a-c = -2 \rightarrow -1-c = -2 \rightarrow c=1$.

So $b=1$.

Therefore $F = k\,\eta r v$, with $k = 6\pi$ from experiment.

So $F = 6\pi\eta r v$ (Stokes' law).

(b) (i) Compare the time taken by two small spheres of the same material to fall the same height through a liquid after reaching their terminal velocity. The diameter of one sphere is three times that of the other.

Time = distance/velocity.

Terminal velocity $v \propto r^2$.

If diameter ratio = 3:1, radius ratio = 3:1.

So velocity ratio = 9:1.

Time ratio = 1/velocity ratio = 1:9.

So the larger sphere takes 1/9 the time of the smaller sphere.

(ii) Deduce the terminal velocity of an oil drop of radius 3×10^{-6} m falling through air. Neglect the density of air. ($\eta_{air} = 1.8 \times 10^{-5}$ Pa s, density of oil = 8×10^2 kg/m³).

Terminal velocity $v = 2r^2\rho g / 9\eta$.

$= (2\times(3\times10^{-6})^2\times800\times9.8)/(9\times1.8\times10^{-5})$.

$= (2\times9\times10^{-12}\times7840)/(1.62\times10^{-4})$.

$= (1.41\times10^{-7})/(1.62\times10^{-4})$.

$\approx 8.7\times10^{-4}$ m/s.

(c) A tank is filled with water to a height H. A small hole is punched at a depth h below the water surface. Show that the distance x from the base of the tank to the point at which the resulting stream strikes the ground is given by $x = 2\sqrt{h(H-h)}$.

Velocity of efflux $v = \sqrt{(2gh)}$.

Time to fall $(H-h) = \sqrt{(2(H-h)/g)}$.

Horizontal distance $x = v\times t = \sqrt{(2gh)} \times \sqrt{(2(H-h)/g)}$.

$= 2\sqrt{h(H-h)}$.

2. (a) (i) What is a centripetal force?

It is the force acting towards the centre of a circular path, keeping a body in circular motion.

(ii) Why does a centripetal force not do any work in a circular orbit?

Because the force is always perpendicular to the displacement, hence no work is done.

(iii) A conical pendulum is an example on which a force acts centripetally, show that the period T is given by $T = 2\pi\sqrt{(\ell \cos\theta / g)}$.

From equilibrium: $T\cos\theta = mg$, $T\sin\theta = mv^2/r$.

$r = \ell \sin\theta$.

So $\tan\theta = v^2/(rg)$.

$v^2 = rg \tan\theta = (\ell \sin\theta\ g \tan\theta)$.

Period $T = 2\pi r/v = 2\pi\ell\sin\theta/\sqrt{(\ell g \sin\theta \tan\theta)}$.

$= 2\pi\sqrt{(\ell \cos\theta/g)}$.

(b) (i) List two ways of describing "g" as applied to gravitation. Give its appropriate units in each case.

Gravitational field strength: force per unit mass, unit = N/kg.

Gravitational acceleration: acceleration produced on a freely falling body, unit = m/s^2.

(ii) Assuming the earth to be a uniform sphere of radius 6.4×10^6 m and mass 6×10^{24} kg, calculate the:

Gravitational potential at a point 6×10^5 m above the earth's surface.

$r = 6.4\times10^6 + 6\times10^5 = 7\times10^6$ m.

$V = -GM/r = -(6.67\times10^{-11} \times 6\times10^{24})/(7\times10^6)$.

$= -5.72\times10^7$ J/kg.

(iii) Work done in taking a 5.0 kg mass from the earth's surface to a point where the gravitational field of the earth is negligible.

Work = GMm/R.

$= (6.67\times10^{-11}\times6\times10^{24}\times5)/(6.4\times10^{6})$.

$= 3.12\times10^{8}$ J.

(c) What is the binding energy of the earth–sun system? Neglecting other planets or satellites.

Binding energy = GMm/2r.

$= (6.67\times10^{-11} \times 2\times10^{30} \times 6\times10^{24})/(2\times1.5\times10^{11})$.

$= 8.004\times10^{44}/3\times10^{11}$.

$= 2.67\times10^{33}$ J.

3. (a) (i) Write down the Van der Waal's equation and define each term in its usual meaning.

$(P + a/V^2)(V–b) = RT$.

P = pressure, V = molar volume, T = temperature, R = gas constant, a = correction for intermolecular forces, b = correction for finite size of molecules.

(ii) State the assumptions upon which the equation is derived from the ideal gas equation.

Molecules have finite size.

Molecules exert attractive forces on each other.

(b) (i) On the basis of the kinetic theory of gases, show that two different gases at the same temperature will have the same average value of the kinetic energy of the molecules.

Average KE = 3/2kT.

Since T is same for both gases, KE is same, independent of mass.

(ii) Determine the rms speed of air molecules at STP, given density of air = 1.29 kg/m³, density of mercury = 13600 kg/m³ and barometric height = 760 mm Hg.

Pressure = hρg = $0.76\times13600\times9.8 = 1.01\times10^{5}$ Pa.

Molar mass of air = 0.029 kg.

n = 1/0.029 mol/kg.

vrms = $\sqrt{(3P/\rho)}$.

$= \sqrt{(3\times1.01\times10^{5}/1.29)}$.

$= \sqrt{(2.35\times10^{5})} = 485$ m/s.

(c) Define mean free path λ of the molecules of a gas and state how it is affected by temperature.

Mean free path is the average distance traveled by a molecule between successive collisions. It increases with increase in temperature.

(d) If the mean free path of molecules of air at 0 °C and 1.0 atm pressure is 2×10^{-7} m, what will the mean free path be at 1.0 atm pressure and 27 °C?

$\lambda \propto T/P$.

$\lambda_2 = \lambda_1(T_2/T_1)$.

$= 2\times10^{-7} \times (300/273) = 2.2\times10^{-7}$ m.

4. (a) (i) What is fundamental interval? How would you use it to establish a scale of temperature?

Fundamental interval is the difference between the upper and lower fixed points of a thermometer. A scale is established by dividing the interval into equal parts.

(ii) Explain how the Kelvin absolute thermodynamic scale of temperature is defined.

It is defined based on absolute zero, the temperature at which the pressure of an ideal gas becomes zero. Zero kelvin is absolute zero.

(b) (i) State three laws of black body radiation.

Stefan-Boltzmann law: total radiated power $\propto T^4$.

Wien's law: wavelength of maximum emission is inversely proportional to temperature.

Planck's law: distribution of energy depends on frequency and temperature.

(ii) The roof measures 20 m by 50 m is blackened. Find solar energy incident onto the roof per minute if the temperature of the sun's surface is 6000 K, given that half of energy is absorbed.

$R_s = 7.5\times10^8$ m, distance $= 1.5\times10^{11}$ m.

Flux $= \sigma T^4(R_s^2/d^2)$.

$= 5.67\times10^{-8} \times (6000)^4 \times (7.5\times10^8/1.5\times10^{11})^2$.

$= 5.67\times10^{-8}\times1.3\times10^{15} \times (5\times10^{-3})^2$.

$= 7.37\times10^7\times2.5\times10^{-5} = 1.84\times10^3$ W/m².

Roof area = 1000 m².

Incident power $= 1.84\times10^3 \times1000 = 1.84\times10^6$ W.

Per minute $= 1.84\times10^6 \times60 = 1.1\times10^8$ J.

Absorbed half $= 5.5\times10^7$ J.

(c) (i) Define thermal conductivity of a material and state its units.

It is the rate of flow of heat per unit area per unit temperature gradient. Unit: $Wm^{-1}K^{-1}$.

(ii) What is the rate of flow of heat through a plaster ceiling of dimensions 5m×3m×15mm with 45mm insulating fibre glass layer if inside and outside are 15 °C and 5 °C?

Area = 15 m^2.

Temperature difference = 10 °C.

Thermal resistances: plaster thickness=0.015 m, k = 0.5 → R1=0.015/(0.5×15) = 0.002.

Fibre thickness = 0.045, k = 0.04 → R2 = 0.045/(0.04×15) = 0.075.

Total R = 0.077.

Heat flow = ΔT/R = 10/0.077 = 129 W.

5. (a) (i) What is the meaning of the terms "coherent waves" and "wave front"?

Coherent waves are waves that have a constant phase difference and the same frequency.

A wave front is the locus of points that are in the same phase of vibration.

(ii) State three basic differences between interference and diffraction.

Interference is due to the superposition of two or more coherent wave sources, while diffraction is the bending and spreading of waves when they pass through a narrow slit or obstacle.

Interference gives rise to regularly spaced bright and dark fringes, while diffraction produces a central maximum with weaker secondary fringes.

In interference the fringe width depends on the separation of sources, while in diffraction it depends on the width of the slit.

(iii) Can white light produce interference?

Yes.

(iv) If your answer is yes, what will be the outcome?

The outcome is colored fringes due to overlapping of different wavelengths in white light.

(b) (i) What is polarization?

Polarization is the process of restricting vibrations of a transverse wave to a single plane perpendicular to the direction of propagation.

(ii) Explain why light can be polarized but sound cannot.

Light is a transverse wave, so its vibrations can be confined to a single plane. Sound is a longitudinal wave with oscillations along the direction of travel, so it cannot be polarized.

(iii) List three uses of polaroids and state three ways in which light can be polarized.

Uses of polaroids: sunglasses to reduce glare, camera filters, and 3D cinema glasses.

Ways of polarizing light: reflection, scattering, and transmission through a polaroid filter.

(c) (i) Define the term diffraction.

Diffraction is the bending and spreading of waves around the edges of obstacles or through small apertures.

(ii) A diffraction grating has 500 lines per mm when used with monochromatic light of $\lambda = 6 \times 10^{-7}$ m at normal incidence. At what angles will bright diffraction images be observed?

Grating spacing $d = 1/(500\times10^3) = 2\times10^{-6}$ m.

Condition for maxima: $d \sin\theta = n\lambda$.

For n=1: $\sin\theta = \lambda/d = 6\times10^{-7} / 2\times10^{-6} = 0.3 \rightarrow \theta \approx 17.5°$.

For n=2: $\sin\theta = 1.2\times10^{-6} / 2\times10^{-6} = 0.6 \rightarrow \theta \approx 36.9°$.

For n=3: $\sin\theta = 1.8\times10^{-6} / 2\times10^{-6} = 0.9 \rightarrow \theta \approx 64.2°$.

For n=4: $\sin\theta = 2.4\times10^{-6} / 2\times10^{-6} = 1.2 \rightarrow$ not possible.

So bright images at 17.5°, 36.9°, and 64.2°.

6. (a) (i) Define and give the units of the terms electrochemical equivalent (e.c.e.) and Faraday as applied in electrolysis.

Electrochemical equivalent is the mass of a substance deposited per unit charge. Unit: kg/C.

Faraday is the charge of one mole of electrons, equal to 96500 C/mol.

(ii) List six important applications of electrolysis.

Electroplating, extraction of metals, purification of metals, production of chemicals like chlorine and sodium hydroxide, electrorefining, and anodizing of metals.

(b) (i) State Faraday's laws of electrolysis.

First law: mass deposited is proportional to the charge passed.

Second law: masses of different substances deposited by the same charge are proportional to their equivalent weights.

(ii) A circuit consists of a solution of silver salt and a coil of wire of resistance 20 Ω immersed in an oil bath in series. A constant current flows for 10 seconds and deposits 0.0279 g of silver. If the e.c.e of silver is 1.11×10^{-6} kg C^{-1}, calculate the heat energy developed in the oil bath.

Mass = 0.0279 g = 2.79×10^{-5} kg.

Charge = mass / e.c.e = 2.79×10^{-5} / 1.11×10^{-6} = 25.1 C.

Current = Q/t = 25.1/10 = 2.51 A.

Heat = $I^2Rt = (2.51)^2\times20\times10 = 1260$ J.

(c) (i) Discuss the back e.m.f. (polarization potential) in a water voltameter with platinum electrodes.

During electrolysis, gas bubbles accumulate on electrodes forming a layer that resists further current flow. This layer creates an opposing e.m.f. called back e.m.f., which reduces effective voltage and slows deposition.

(ii) Calculate the minimum potential difference required for the electrolysis of water, if 300 J are required to decompose 1.0 g of water.

Number of moles in 1 g = 1/18 = 0.0556 mol.

Electrons needed = 2 Faradays per mole = 2×96500×0.0556 = 10,720 C.

Potential difference = energy/charge = 300/10720 = 0.028 V.

(iii) Can a Daniel cell or a single Leclanché's cell electrolyse water?

No, because their emf is less than the decomposition voltage of water.

7. (a) (i) Define root mean square current hence show that it is represented by an equation Ir = 0.707 Io with Ir and Io in their usual meaning.

Root mean square current is the effective value of an alternating current which produces the same heating effect as a direct current.

$I_r = I_o/\sqrt{2} \approx 0.707\, I_o$.

(ii) If the effective current in a 50 Hz AC circuit is 50 A, calculate the value of the current 1/300 sec after it was zero.

$i = I_o \sin\omega t$, with $I_r = I_o/\sqrt{2} \rightarrow I_o = 50\sqrt{2} = 70.7$ A.

$\omega = 2\pi f = 2\pi\times50 = 314$ rad/s.

t = 1/300 s = 0.00333 s.

$\omega t = 314\times0.00333 = 1.047$ rad ($\approx 60°$).

$i = 70.7 \sin(60°) = 70.7\times0.866 = 61.2$ A.

(b) An a.c. generator of negligible internal impedance whose output voltage is 100 rms is connected in series with a resistor of 100 Ω and an inductor of 2 H. Calculate the:

(i) Frequency of the generator.

Reactance $X_L = \omega L = 2\pi f \times 2$.

Impedance $Z = \sqrt{(R^2+X_L^2)}$.

Voltage = $I_{rms} Z$.

Current = V/Z.

But insufficient data, assumed $f = 50$ Hz. Then $X_L = 2\pi \times 50 \times 2 = 628\ \Omega$.

(ii) Power dissipated in the resistor when the current is half its value.

Power = I^2R. If current is half, $P = (\frac{1}{2} I)^2R = \frac{1}{4} I^2R = \frac{1}{4} P_{max}$.

(c) (i) Define the terms capacitance and inductance.

Capacitance is the ability of a capacitor to store charge per unit potential difference. Unit farad.

Inductance is the property of a coil to oppose change of current by inducing emf. Unit henry.

(ii) A radio can tune over the frequency range of a portion of a MW broadcast band (800 Hz to 1200 Hz). If its LC circuit has an effective inductance of 200 μH, what must be the range of its variable capacitor?

$f = 1/(2\pi\sqrt{(LC)})$.

$C = 1/(4\pi^2Lf^2)$.

For f=800 Hz, $L=200\times10^{-6}$ H:

$C_{max} = 1/(4\pi^2\times200\times10^{-6}\times(800)^2)$.

$= 1/(4\times9.87\times200\times10^{-6}\times6.4\times10^5)$.

≈ 0.00031 F = 310 μF.

For f=1200 Hz:

$C_{min} = 1/(4\pi^2\times200\times10^{-6}\times(1200)^2)$.

≈ 140 μF.

Range: 140 μF to 310 μF.

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8. (a) (i) State Ampere's circuital law.

Ampere's circuital law states that the line integral of the magnetic field around a closed path is equal to μ_0 times the total current enclosed by the path.

$\oint B \cdot dl = \mu_0 I$.

(ii) A long straight wire is carrying a current of 100 mA. An electron is moving at 10^7 ms^{-1} in a direction parallel to the wire. What is the magnitude of the force on the electron when it is 10 cm from the wire?

Magnetic field around the wire $B = \mu_0 I / 2\pi r$.

$= (4\pi\times10^{-7} \times 0.1)/(2\pi\times0.1) = 2\times10^{-7}$ T.

Force $F = e\ v\ B = 1.6\times10^{-19} \times 10^7 \times 2\times10^{-7}$.

$= 3.2\times10^{-19}$ N.

(b) (i) Define Ampere.

One ampere is the current which when maintained in two long parallel conductors one meter apart in vacuum produces a force of 2×10^{-7} N per meter length of each conductor.

(ii) Explain the characteristics of the flux density and force for parallel conductors when like currents flow through them in the same direction. Give their magnitudes.

Two parallel currents in the same direction attract each other. The magnetic field around one conductor produces a force on the other.

Force per unit length $F/L = \mu_0 I_1 I_2 / 2\pi d$.

Flux density B at distance $d = \mu_0 I/2\pi d$.

(iii) What will happen when a current is sent through a vertical spring from whose lower end a weight is attached?

The spring will experience a magnetic field around it due to the current. If another magnetic field is present, a force will act on the spring causing it to twist or elongate depending on direction of current.

(c) (i) Distinguish between geographical meridian and magnetic meridian and define the angle of dip.

Geographical meridian is the vertical plane containing the geographic north and south poles.

Magnetic meridian is the vertical plane containing the magnetic north and south poles.

The angle of dip is the angle made by the earth's magnetic field with the horizontal.

(ii) A magnet suspended at 30° with the magnetic meridian makes an angle of 45° with the horizontal. What is the actual value of the angle of dip?

If θ is dip, $\tan\theta = BH/BV$.

From deflection, $\tan\theta' = (BH \cos 30)/BV$.

So $\tan\theta = \tan 45 / \cos 30 = 1 / 0.866 = 1.155$.

$\theta = 49°$.

9. (a) What is meant by:

(i) Fusion

Fusion is the combining of two light nuclei to form a heavier nucleus with release of energy.

(ii) Fission

Fission is the splitting of a heavy nucleus into two lighter nuclei with release of energy.

(b) State the similarity between the two terms in 9(a) above.

Both processes release large amounts of nuclear energy due to mass defect and binding energy changes.

(c) A deuteron strikes $^{8}O^{16}$ nucleus with the subsequent emission of an α–particle. Find the atomic number, mass number and the chemical name of the element produced.

Reaction: $^{1}H^{2} + {}^{8}O^{16} \rightarrow {}_{2}He^{4} + X$.

Mass number: 2+16 = 18. Subtract 4 gives 14.

Atomic number: 1+8 = 9. Subtract 2 gives 7.

So X = $^{7}N^{14}$ (Nitrogen).

(d) A parent radioactive substance with a very long half-life has a daughter with a very short half-life. Describe what happens to a freshly purified sample of the parent substance.

At first, the daughter builds up quickly as it is produced by decay of parent. Then, because the daughter decays rapidly, a state of equilibrium is reached where the rate of production equals rate of decay.

(e) (i) Light is both a wave and a particle. Comment on the statement by using examples.

Light shows wave nature in interference and diffraction. It shows particle nature in photoelectric effect and Compton scattering.

(ii) Compute the de Broglie wavelength of a 50 g rock with a speed of 40 ms^{-1}.

$\lambda = h/p$.

$p = mv = 0.05 \times 40 = 2$ kg m/s.

$\lambda = 6.63 \times 10^{-34} / 2 = 3.3 \times 10^{-34}$ m.

10. (a) (i) Define the terms logic gates and digital signal.

A logic gate is an electronic device that performs a logical operation on one or more binary inputs to produce a single binary output.

A digital signal is a signal that has discrete values, typically 0 and 1.

(ii) State one practical application of an OR gate.

It is used in alarm circuits, where an alarm is triggered if any one of several conditions is met.

(iii) Using a well labelled circuit diagram of an inverting amplifier, derive the closed-loop gain A. What would the value of A be when the input resistor equals the feedback resistor? Name the circuit.

For inverting amplifier: $A = -Rf/Rin$.

If $Rf = Rin$, $A = -1$. The circuit is a unity-gain inverter.

(b) The diagram below shows a differential op-amp circuit.

(i) Write down the relationship between the output voltage Vo and the input voltages V_1 and V_2 as applicable.

$Vo = (Rf/Rin)(V_2 - V_1)$. With resistors equal, $Vo = V_2 - V_1$.

(ii) What will be the output voltage Vo when $V_1 = 0.5$ V and $V_2 = 2.0$ V?

$Vo = 2.0 - 0.5 = 1.5$ V.

(c) Draw a truth table for the circuit below.

Inputs: A, B, C pass through OR and NOT before AND.

Truth table:

A	B	C	D (A OR B)	E (NOT C)	F (D AND E)
0	0	0	0	1	0
0	0	1	0	0	0
0	1	0	1	1	1

0	1	1	1	0	0
1	0	0	1	1	1
1	0	1	1	0	0
1	1	0	1	1	1
1	1	1	1	0	0