THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

031/1 **PHYSICS 1**

(For Both School and Private Candidates)

Time : 2 ½ Hours **ANSWERS** **Year : 2002**

Instructions

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

1. (a) (i) Explain briefly the meaning of an error and a mistake.

An error is the difference between the measured value and the true value of a physical quantity. It arises due to limitations of instruments, environmental conditions, or human estimation, and it is usually unavoidable in measurements.

A mistake is a wrong action caused by human carelessness, misunderstanding, or incorrect operation of equipment. Unlike an error, a mistake can be avoided if proper care and attention are taken.

(ii) The resistivity ρ of the material of a wire of resistance R, length ℓ and diameter d, is given by

$\rho = (R\pi d^2) / (4\ell)$

(b) Derive the expression of the percentage error in the resistivity ρ.

The general rule for percentage error states that if a quantity depends on measured variables raised to some powers, then the percentage error in the quantity is obtained by summing the percentage errors in each variable multiplied by their respective powers.

$\rho = (R\pi d^2) / (4\ell)$

Taking logarithms:

$\ln \rho = \ln R + \ln \pi + 2 \ln d - \ln 4 - \ln \ell$

Differentiating:

$\Delta\rho/\rho = \Delta R/R + 2\Delta d/d + \Delta\ell/\ell$

Therefore, the percentage error in ρ is:

$(\Delta\rho/\rho) \times 100\% = (\Delta R/R + 2\Delta d/d + \Delta\ell/\ell) \times 100\%$

(b) (i) What are dimensional equations? State any two uses of dimensional equations.

Dimensional equations are equations that express a physical quantity in terms of the fundamental dimensions such as mass [M], length [L], time [T], temperature [Θ], current [I], luminous intensity [J], and amount of substance [N].

One use of dimensional equations is to check the correctness of physical formulas by ensuring dimensional consistency on both sides of the equation.

Another use of dimensional equations is to derive relations between physical quantities when the dependence of one quantity on others is known in terms of proportionality.

(b) (ii) A gas bubble from an explosion under water is found to oscillate with a period T, which is proportional to P^a, d^b and E^c where P is the pressure, d is the density and E is energy of the explosion. Find the values of a, b and c; hence determine the units of the constant of proportionality.

Period T has the dimension of time [T].
Pressure P has dimension $[ML^{-1}T^{-2}]$.
Density d has dimension $[ML^{-3}]$.
Energy E has dimension $[ML^{2}T^{-2}]$.

Let $T \propto P^a d^b E^c$

So, $[T] = [ML^{-1}T^{-2}]^a [ML^{-3}]^b [ML^{2}T^{-2}]^c$

= M^(a+b+c) L^(-a-3b+2c) T^(-2a-2c)

Equating powers with $[T^1]$:
For M: a + b + c = 0
For L: -a - 3b + 2c = 0
For T: -2a - 2c = 1

From T equation: -2a - 2c = 1 → a + c = -0.5

From M equation: a + b + c = 0 → b = -a - c

Substitute into L equation: -a - 3(-a - c) + 2c = 0
= -a + 3a + 3c + 2c = 0
= 2a + 5c = 0 → a = -2.5c

Now substitute into a + c = -0.5:

-2.5c + c = -0.5 → -1.5c = -0.5 → c = 1/3

Then a = -2.5(1/3) = -5/6

b = -a - c = 5/6 - 1/3 = 5/6 - 2/6 = 3/6 = 1/2

So values: a = -5/6, b = 1/2, c = 1/3

Now the constant k: $T = k P^a d^b E^c$

Dimensions of k = [T] / ($P^a d^b E^c$)

= $[T] [ML^{-1}T^{-2}]^{5/6} [ML^{-3}]^{-1/2} [ML^2T^{-2}]^{-1/3}$

= $[T] M^{(-5/6 - ½ - 1/3)} L^{(5/6 + 3/2 - 2/3)} T^{(10/6 + 2/3)}$

= $M^{(-5/3)} L^{(5/3)} T^3$

Thus, the constant of proportionality has units: $kg^{(-5/3)} m^{(-5/3)} s^3$

(ii) A package of medical supplies is released from a small plane flying over an isolated jungle settlement. The plane flies horizontally with a speed of 20 m/s at an altitude of 20 m. Where will the package strike the ground?

The plane is flying at 20 m/s and the package is dropped from a height of 20 m. First, I find the time it takes to hit the ground. The formula is t = √(2h/g). Substituting the numbers: t = √(2 × 20 / 9.8) = √(40/9.8) ≈ 2.0 s.

Now, in that time, the package keeps moving forward at 20 m/s. So the horizontal distance = velocity × time = 20 × 2.0 = about 40 m.

So, the package lands roughly 40 m ahead of the point directly below where it was dropped.

4. (a) (i) A mass m (kg) is attached to the end of a spring of force constant k (Nm^{-1}). Show that $k = m\omega^2$, where ω is the angular velocity. (02 marks)

For a body on a spring, the restoring force is $F = -kx$. But from Newton's law, force is also $F = ma$. In SHM, acceleration is $a = -\omega^2 x$. So we can write $ma = -m\omega^2 x$. Comparing this with $F = -kx$, we get $k = m\omega^2$.

(ii) From the equilibrium position a particle oscillating in a SHM is displaced by a distance x measured in metres, given by equation $x = 0.08 \sin 9t$, where t is time in seconds measured from an instant when $x = 0$. Determine the period of oscillations and maximum acceleration of the particle.

Equation is $x = 0.08 \sin 9t$. Comparing with general form $x = A \sin \omega t$, we see $A = 0.08$ m, $\omega = 9$ rad/s.

Period $T = 2\pi/\omega = 2\pi/9 \approx 0.698$ s.

Maximum acceleration $= \omega^2 A = 9^2 \times 0.08 = 81 \times 0.08 = 6.48$ m/s².

4. (b) A body oscillates vertically in simple harmonic motion with an amplitude of 30 mm and a frequency of 5.0 Hz. Calculate the acceleration of the particle:

(i) at the extremities of the motion (02 marks)

Amplitude $A = 0.030$ m, frequency $f = 5$ Hz.
Angular frequency $\omega = 2\pi f = 2\pi \times 5 = 31.4$ rad/s.
Maximum acceleration $= \omega^2 A = (31.4)^2 \times 0.030 = 986 \times 0.030 \approx 29.6$ m/s².

So, at the extremes, acceleration = 29.6 m/s².

(ii) at the centre of the motion

At the mean position, acceleration is zero because the restoring force is zero there.

(iii) at the position midway between the centre and the extremity.

At halfway, displacement $= A/2 = 0.015$ m.
Acceleration $= -\omega^2 x = (31.4)^2 \times 0.015 = 986 \times 0.015 = 14.8$ m/s².

So, the acceleration midway = 14.8 m/s².

5. (a) (i) Define thermodynamic temperature scale.

The thermodynamic temperature scale is an absolute scale of temperature that is independent of the properties of any particular substance, and is based only on the laws of thermodynamics.

(ii) How is thermodynamic temperature denoted and what is its SI unit?

The thermodynamic temperature is denoted by T and its SI unit is the kelvin (K).

(iii) Explain why a gas thermometer is seldom used for temperature measurement in the Laboratory.

A gas thermometer is seldom used because it is bulky, delicate, and slow in response. It is also difficult to use in ordinary laboratory experiments since it requires careful handling and precise calibration.

(b) Study the table below and answer the questions which follow:

Type of thermometer	**Property**	**Value of property**
		Ice point
Gas	Pressure in mmHg	760.0
Thermistor	Current in mA	12.0

(i) Calculate the temperature of the room for each thermometer.

For gas thermometer:
0 °C corresponds to 760 mmHg,
100 °C corresponds to 1240 mmHg.
Change = 1240 – 760 = 480 mmHg.

At 895 mmHg: difference from ice point = 895 – 760 = 135 mmHg.
Fraction = 135/480 = 0.281.
Temperature = 0 + (0.281 × 100) ≈ 28.1 °C.

For thermistor:

0 °C corresponds to 12.0 mA,

100 °C corresponds to 70.0 mA.

Change = 70 – 12 = 58 mA.

At 28.0 mA: difference = 28 – 12 = 16 mA.

Fraction = 16/58 = 0.276.

Temperature = 0 + (0.276 × 100) ≈ 27.6 °C.

So the room temperature is about 28 °C for both.

(ii) Explain why the thermometers disagree in their value for room temperature.

The gas thermometer and the thermistor are based on different physical properties, so their calibration may not be perfectly linear across the range. The gas thermometer depends on the pressure of a fixed volume of gas, while the thermistor depends on resistance change with temperature. This difference leads to slight variations in their readings.

(iii) What are the advantages of gas thermometers over liquid-in-glass thermometers?

Gas thermometers are more accurate over a wide range of temperatures since gases expand almost uniformly with temperature.

They are less affected by impurities or evaporation problems that can affect liquid-in-glass thermometers.

Gas thermometers can measure very high and very low temperatures, where liquid thermometers cannot be used reliably.

6. (a) (i) The thermal conductivity β of a substance may be defined by the equation $dQ/dt = -\beta A d\theta/dx$. Identify briefly each term in this equation, and explain the minus sign.

dQ/dt is the rate of heat flow through the material.

A is the cross-sectional area through which heat flows.

$d\theta/dx$ is the temperature gradient along the material.

β is the thermal conductivity constant of the material.
The minus sign shows that heat flows from regions of higher temperature to regions of lower temperature, opposite to the direction of the temperature gradient.

(ii) Describe briefly one method of measuring the thermal conductivity of a bad conductor in the form of a disc.

One method is Lee's disc method. A thin disc of the bad conductor is placed between a steam chamber and a metal disc of known mass and specific heat. Steam is passed through the chamber until steady temperature is reached. The metal disc is then removed and allowed to cool. The rate of cooling is used to calculate the rate of heat flow through the bad conductor. From this, the thermal conductivity is determined using the known thickness and area of the sample.

(b) One end of a lagged copper rod is placed in a steam chest and a 0.6 kg mass of copper is attached to the other end of the rod which has an area of 2 cm^2. When steam at 100 °C is passed into the chest and a steady state is reached the temperature of the mass of copper rises by 4 °C per minute. If the temperature of the surrounding is 15 °C, calculate the length of the rod.

Mass = 0.6 kg, specific heat of copper ≈ 390 J/kgK.
Heat gained per second = $mc\Delta\theta/t$.
$= 0.6 \times 390 \times 4 / 60$
$= 0.6 \times 390 \times 0.0667 = 15.6$ J/s.

Heat flow through rod = $\beta A \Delta\theta / L$.
For copper, $\beta \approx 400$ W/mK.
$A = 2\ cm^2 = 2 \times 10^{-4}\ m^2$.
$\Delta\theta = 100 - 15 = 85$ K.

So, $15.6 = (400 \times 2\times10^{-4} \times 85)/L$.
$= (6.8)/L$.
$L = 6.8 / 15.6 = 0.436$ m.

Length of rod = about 0.44 m.

7. (a) (i) Give three basic differences between light waves and sound waves.

Light waves are electromagnetic while sound waves are mechanical.
Light waves can travel through a vacuum, but sound needs a medium.
Light waves are transverse, while sound waves are longitudinal in nature.

(ii) A vibrator attached and resting on the surface of water generates plane water-waves and propagation is found to take 50 seconds to reach a floating cork 65 cm away. If the cork subsequently vibrates with SHM of a period 3.8 seconds, determine the wavelength of the water-waves produced by the vibrator. (03 marks)

Speed of wave = distance / time = 0.65 / 50 = 0.013 m/s.
Period T = 3.8 s.
Wavelength = vT = 0.013 × 3.8 = 0.0494 m ≈ 0.05 m.

(b) Part of a beam of light incident on a transparent rectangular glass prism of refractive index 1.5 is refracted and the other is reflected. If both, the refracted and reflected rays, are perpendicular to one another, determine:

(i) the angle of refraction

Angle between reflected ray and refracted ray = 90°.
By geometry, angle of incidence i + r = 90°.
So, r = 90° – i.
Using Snell's law: sin i = μ sin r = 1.5 sin(90 – i) = 1.5 cos i.
So, tan i = 1.5.
i = $\tan^{-1}(1.5)$ ≈ 56.3°.
So r = 90 – 56.3 = 33.7°.

(ii) the velocity of the light beam in a glass.

Refractive index μ = c/v.
v = c/μ = $3 \times 10^8 / 1.5 = 2 \times 10^8$ m/s.

8. (a) (i) State the Ohm's law and define the resistivity of a material and its unit.

Ohm's law states that the current through a conductor is directly proportional to the potential difference across it provided temperature and other physical conditions remain constant.

Resistivity is the resistance of a unit cube of material of side 1 m. Its SI unit is ohm metre (Ωm).

(ii) Show that the resistance R of a conductor is given by: $R = m\ell / (ne^2tA)$ (03½ marks)

From drift velocity $v = \ell/t$, current density $J = ne\ v\ e = ne(\ell/t)$.
Resistance $R = V/I$. Using Ohm's law and relations of drift, one arrives at $R = m\ell / (ne^2tA)$.

(b) Two electric-light bulbs both marked 0.3 A, 4.5 V are connected (a) in parallel (b) in series, across a 4.5 V battery of negligible internal resistance. Assume that the resistance of the filament does not change in each case.

(i) State what might be seen.

In parallel: both bulbs light normally.
In series: both bulbs glow dimly since each gets half the voltage.

(ii) Calculate the current through each bulb.

Resistance of each bulb $R = V/I = 4.5/0.3 = 15\ \Omega$.

In parallel: total resistance = 15/2 = 7.5 Ω.
Current from battery = 4.5/7.5 = 0.6 A.
So current through each bulb = 0.3 A.

In series: total resistance = 15 + 15 = 30 Ω.
Current from battery = 4.5/30 = 0.15 A.
So current through each bulb = 0.15 A.

(iii) Calculate the current supplied by the battery.

In parallel: 0.6 A.

In series: 0.15 A.

9. (a) (i) Define flux and state its unit.

Magnetic flux is the product of the magnetic field and the area it passes through, perpendicular to the field. Its unit is weber (Wb).

(ii) A circular metal disc with a radius of 10 cm rotates at 10 revolutions per second. If the disc is in a uniform magnetic field of 0.020 T at right angles to the plane of the disc, calculate the e.m.f induced between the centre and rim of the disc.

Radius $r = 0.1$ m, $B = 0.020$ T, $f = 10$ rev/s, angular velocity $\omega = 2\pi f = 62.8$ rad/s.

Induced e.m.f $= \frac{1}{2} B \omega r^2 = 0.5 \times 0.020 \times 62.8 \times (0.1)^2$

$= 0.01 \times 62.8 \times 0.01 = 0.00628$ V.

So e.m.f ≈ 6.3 mV.

(b) A search coil with 20 turns, each of area 2.0×10^{-4} m² is connected to a ballistic galvanometer, the total circuit resistance being 100 Ω. What charge will flow through the galvanometer when the coil is moved from a region, where the flux density at right angles to the plane of the coil is 0.10 T to a region where it is negligible?

Number of turns $N = 20$, area $A = 2 \times 10^{-4}$ m², $B = 0.10$ T.

Flux per turn $= BA = 0.10 \times 2 \times 10^{-4} = 2 \times 10^{-5}$ Wb.

Total flux $= N \times BA = 20 \times 2 \times 10^{-5} = 4 \times 10^{-4}$ Wb.

Change in flux linkage $= 4 \times 10^{-4}$ Wb.

Charge $Q = \Delta\Phi / R = 4 \times 10^{-4} / 100 = 4 \times 10^{-6}$ C.

So charge through the galvanometer = 4 μC.

10. (a) (i) What is the logic gate?

A logic gate is an electronic device that performs a basic logical operation on one or more input signals to produce an output. Examples of common logic gates include AND, OR, and NOT gates. They are the building blocks of digital circuits.

(ii) Draw the truth table of the circuit below (Figure 1), showing all values of A, B, C, D, E and F.

From the figure:

D = A AND B

E = NOT C

F = D OR E

Truth table:

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

(b) Figure 2 below is an operational amplifier circuit where $R_1 = R_3 = 10\ k\Omega$ and $R_2 = 10\ R_1$

(i) Determine the output voltage Vo if the input voltages $V_1 = 3.0$ V and $V_2 = 5.0$ V.

This is a difference amplifier. The formula is:
$Vo = (R_2 / R_1)(V_2 - V_1)$

Here, $R_2 / R_1 = 10$.
So, $Vo = 10(5.0 - 3.0) = 10 \times 2 = 20$ V.

(ii) Name the practical use of such a circuit.

It is used as a difference amplifier, which is common in instrumentation for amplifying the difference between two input signals while rejecting any common voltage.

11. (a) Write down an expression for the variation of charge with time t in a capacitor during the charging process through resistor R and define its terms.

The charge at any time is given by:
q = Q(1 – e^(-t/RC))

Here, Q is the maximum charge, R is the resistance, C is the capacitance, and t is the time.

(b) A 5.0 μF capacitor is charged by a 12 V supply and then discharged through a 2.0 MΩ resistor.

(i) Find the charge on the capacitor at the start of the discharge.

$Q = CV = 5.0 \times 10^{-6} \times 12 = 6.0 \times 10^{-5}$ C.

(ii) If the time used was 5.0 seconds after the discharge process calculate:

The time constant = $RC = 2.0 \times 10^{6} \times 5.0 \times 10^{-6} = 10$ s.

Charge after 5 s: q = Q e^(-t/RC) = 6.0×10^{-5} e^(-0.5).
e^(-0.5) ≈ 0.607.
So $q \approx 6.0 \times 10^{-5} \times 0.607 = 3.64 \times 10^{-5}$ C.

Potential difference: $V = q/C = (3.64 \times 10^{-5}) / (5 \times 10^{-6}) = 7.28$ V.

Current: $I = V/R = 7.28 / (2.0 \times 10^{6}) = 3.64 \times 10^{-6}$ A.

So after 5 s: charge = 3.64×10^{-5} C, p.d = 7.28 V, current = 3.64 μA.

12. (a) Show that the path followed by an electron of charge e and mass m moving horizontally at a speed v at right angles to an electric field E is a parabola.

In the x direction, motion is uniform: $x = vt$.
In the y direction, electron experiences acceleration $a = eE/m$.
So displacement $y = ½ at^2 = ½(eE/m)t^2$.

From $x = vt \rightarrow t = x/v$.
Substitute: $y = (½)(eE/m)(x^2/v^2)$.
This is of the form $y \propto x^2$, which is a parabola.

(b) An electron emitted from a hot cathode in an evacuated tube is accelerated by a p.d of 1.0×10^4 V. Calculate:

(i) the kinetic energy acquired by the electron.

$KE = eV = 1.6 \times 10^{-19} \times 1.0 \times 10^4 = 1.6 \times 10^{-15}$ J.

(ii) the velocity of the electron.

$KE = ½mv^2 \rightarrow v = \sqrt{(2KE/m)}$.
$= \sqrt{(2 \times 1.6 \times 10^{-15} / 9.11 \times 10^{-31})}$.
$= \sqrt{(3.52 \times 10^{15})}$.
$\approx 1.88 \times 10^7$ m/s.

(iii) the radius of its path if it enters at right angles a uniform magnetic field of flux density 1×10^{-3} T.

$r = mv / (eB)$.
$= (9.11 \times 10^{-31} \times 1.88 \times 10^7) / (1.6 \times 10^{-19} \times 1 \times 10^{-3})$.
$= 1.71 \times 10^{-23} / 1.6 \times 10^{-22} = 0.107$ m.

So radius ≈ 0.11 m.

13. (a) (i) Define the "ground state" and "excited state" of an atom.

The ground state of an atom is the lowest energy state where all electrons occupy the lowest available energy levels.

An excited state is any state of the atom where one or more electrons have absorbed energy and moved to higher energy levels.

(ii) Write down two postulates suggested by Bohr in his model of hydrogen atom.

Electrons revolve around the nucleus in certain stable orbits without emitting radiation.

An electron can only gain or lose energy when it jumps between allowed orbits, and the energy difference is emitted or absorbed as a photon.

(iii) Calculate the corresponding range of frequencies for the emitted radiation in the Lyman series.

Lyman series corresponds to transitions to n=1.
Range is from n=2 → n=1 (lowest frequency) to n=∞ → n=1 (highest).
Using Rydberg's formula:
$\nu = Rc (1/1^2 – 1/n^2)$.

For n=2: $\nu = Rc (1 – 1/4) = Rc (3/4)$.
For n=∞: $\nu = Rc (1 – 0) = Rc$.

So frequency range is 0.75 Rc to Rc.
Taking $Rc = 3.29 \times 10^{15}$ Hz,
Range = 2.47×10^{15} Hz to 3.29×10^{15} Hz.

(b) The first four lowest energy levels in a mercury atom are: –10.4 eV, –5.5 eV, –3.7 eV and –1.6 eV. Calculate the ionization energy of mercury.

Ionization energy is the energy to remove electron from ground state (–10.4 eV) to free state (0 eV).
So ionization energy = 10.4 eV.

(c) What is likely to happen if a mercury atom in the ground state is bombarded with an electron of energy:

(i) 4.4 eV: No excitation, as energy is less than the gap.

(ii) 6.7 eV: Electron may excite atom from –10.4 eV to –3.7 eV level.

(iii) 11.2 eV: Enough to ionize atom, since energy exceeds 10.4 eV.

14. (a) (i) What is the importance of ionosphere to mankind?

The ionosphere reflects radio waves back to the earth, allowing long-distance communication.

(ii) Explain why transmission of radio waves is better at night than at day time.

At night, ionospheric layers are more stable and less disturbed by solar radiation, so reflection of radio waves is stronger and clearer. During the day, ionization is stronger and causes absorption and scattering, reducing quality.

(b) (i) What is an earthquake?

An earthquake is the sudden shaking or vibration of the earth's crust due to the release of stored energy from geological faults or volcanic activity.

(ii) Explain briefly any four causes of earthquake.

One cause is movement of tectonic plates which collide or slide past each other.

Another cause is volcanic activity, where magma movement creates pressure that breaks rocks.

A third cause is collapse of underground caverns which creates ground shocks.

A fourth cause is human activities like mining and nuclear explosions which can trigger seismic waves.