THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/1 **PHYSICS 1**

(For Both School and Private Candidates)

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

Instructions

1. This paper consists of sections Section A and B with total of ten questions.

2. Answer all questions in section A and two questions in section B.

1. a) In a simple pendulum experiment a period of 40 seconds was measured for 20 oscillations when the length of the pendulum was taken to be 100 cm. Calculate:

i) the maximum error in measuring the acceleration due to gravity, g, given that the smallest readable units of stopwatch and meter rule were 0.1 seconds and 0.1 cm respectively.

The period of a simple pendulum is given by:

$T = 2\pi\sqrt{(L/g)}$

Squaring both sides:
$T^2 = (4\pi^2 L) / g$

Rearranging for g:
$g = (4\pi^2 L) / T^2$

Fractional error formula:
$\Delta g/g = \Delta L/L + 2(\Delta T/T)$

Given:
L = 100 cm = 1 m
T = 40 s / 20 = 2 s
ΔL = 0.1 cm = 0.001 m
ΔT = 0.1 s

Substituting:

$\Delta g/g = (0.001 / 1) + 2(0.1 / 2)$
$\Delta g/g = 0.001 + 0.1$
$\Delta g/g = 0.101$

$g = (4\pi^2 \times 1) / 4$
g = 9.869 m/s²

Maximum error in g:
$\Delta g = 9.869 \times 0.101$
Δg = 0.996 m/s²

ii) the percentage error of acceleration due to gravity, g, if its actual value at a particular place is 9.79 m/s².
Percentage error = [(measured value - actual value) / actual value] × 100
= [(9.869 - 9.79) / 9.79] × 100
= (0.079 / 9.79) × 100
= 0.81%

b) Figure 1 shows a body of mass 20 kg and radius 0.2 m having a moment of inertia of 0.4 kgm^2 rolling down a slope of height 3.0 m. Calculate its speed at the foot of the slope.

Using energy conservation:

$mgh = 1/2\ mv^2 + 1/2\ I\omega^2$

Since $v = r\omega$, we substitute:

$mgh = 1/2\ mv^2 + 1/2\ I(v^2/r^2)$

Substituting given values:

$(20 \times 10 \times 3) = (1/2 \times 20 \times v^2) + (1/2 \times 0.4 \times (v^2/0.2^2))$

$600 = 10v^2 + 5v^2$

$600 = 15v^2$

$v^2 = 40$

$v = 6.32$ m/s

2. a) i) Distinguish between damped oscillations and undamped oscillations.

- Damped oscillations: The amplitude of oscillations decreases over time due to resistive forces like friction or air resistance.
- Undamped oscillations: The amplitude remains constant with time as there are no energy losses.

ii) Elaborate three characteristics of simple harmonic motion (S.H.M).

- The restoring force is directly proportional to displacement and acts in the opposite direction.
- The acceleration of the oscillating body is also proportional to displacement.
- The motion is periodic, meaning the object repeats its motion at regular intervals.

2. b) When a body of mass m was attached to the lower end of a spiral spring and slightly released, it caused an extension of 1.5 cm. If it then set into vertical oscillations of small amplitude, calculate its periodic time.

The formula for the period of a spring is:

$T = 2\pi\sqrt{(m/k)}$

Using Hooke's law:

$k = mg / x$

Substituting into the period formula:

$T = 2\pi\sqrt{(x/g)}$

Given:
$x = 1.5$ cm $= 0.015$ m
$g = 9.81$ m/s²

$T = 2\pi\sqrt{(0.015 / 9.81)}$
$T = 2\pi\sqrt{(0.00153)}$
$T = 2\pi(0.0391)$
$T = 0.246$ s

3. a) i) Write the mathematical expressions of Newton's laws of universal gravitation and gravitational field strength.

- Newton's law of gravitation:

$F = G (m_1m_2 / r^2)$

- Gravitational field strength:

$g = GM / R^2$

ii) Use the answers in 3 a) i) to show that the magnitude of the gravitational field at the earth's surface is given by GM_E / R_E^2, where M_E is the mass of the earth, R_E is the radius of the earth and G is the gravitational constant.

Using Newton's gravitational law:

$F = G (M_E m / R_E^2)$

Since force due to gravity is $F = mg$, equating both:

$mg = G (M_E m / R_E^2)$

Dividing by m:

$g = GM_E / R_E^2$

3. b) Prove that the radius R_0 of the orbit of the satellite is given by $R_0 = \sqrt{(GM_E T^2 / 4\pi^2)}$, where T is the period of revolution, G and M_E have the same meaning as in 3 a) ii).

Using Newton's law of gravitation:

$F = G (M_E m / R^2)$

For circular motion:

$F = m\omega^2 R$

Since $\omega = 2\pi/T$, substituting:

$G (M_E m / R^2) = m(4\pi^2 R / T^2)$

Dividing by m:

$G M_E / R^2 = 4\pi^2 R / T^2$

Rearranging:

$R^3 = G M_E T^2 / 4\pi^2$

Taking square root:

$R = \sqrt{(G M_E T^2 / 4\pi^2)}$

4. a) i) How does a man jumping from a certain height manage to increase the number of loops made in the air?

- By pulling in his arms and legs (reducing moment of inertia), angular velocity increases, allowing more loops.

ii) Why is it advisable to use a wrench with a long arm to tighten the bolt of a truck wheel?

- A longer arm increases the torque applied for the same force, making it easier to tighten the bolt.

4. b) Calculate the moment of inertia if the energy of 484 J was spent in increasing the speed of a flywheel from 60 rev/min to 360 rev/min.

Using rotational kinetic energy formula:

$KE = 1/2 I \omega^2$

Converting rpm to rad/s:

$\omega_1 = (2\pi \times 60) / 60 = 2\pi$ rad/s
$\omega_2 = (2\pi \times 360) / 60 = 12\pi$ rad/s

Energy equation:

$484 = 1/2\ I\ ((12\pi)^2 - (2\pi)^2)$

Solving for I:

$I = (484 \times 2) / (144\pi^2 - 4\pi^2)$
$I = 968 / 140\pi^2$
$I = 2.2$ kgm^2

8. a) i) Distinguish between an e.m.f. of a cell and potential difference.

- Electromotive force (e.m.f.) is the total energy supplied per unit charge by a source such as a battery or cell, including energy lost due to internal resistance.
- Potential difference is the energy transferred per unit charge between two points in a circuit and is measured across a component like a resistor.

8. a) ii) A cell of e.m.f. E and internal resistance r is supplying a current I across the external resistor R. Draw a circuit diagram to show how the e.m.f., E and potential difference, V are related.

- The circuit consists of a battery with e.m.f. E, internal resistance r, an external resistor R, and a current I flowing through the circuit.
- The voltage across R is given by $V = E - Ir$.
- A voltmeter is connected across R to measure the potential difference, and an ammeter is placed in series to measure the current I.

8. b) i) How is an increase in length affecting the resistivity and conductivity of a conductor?

- Resistivity is a material property and does not depend on length. However, resistance increases with length as per the formula $R = \rho L/A$.
- Conductivity is the inverse of resistivity and remains constant for a given material regardless of length.

8. b) ii) Sketch the characteristic graph to show how the current varies with voltage in ohmic conductors.

- The graph is a straight line passing through the origin, indicating that current (I) is directly proportional to voltage (V), following Ohm's law $V = IR$.

8. c) Study the circuit diagram in Figure 1 then answer the questions that follow:

i) Find the reading of the ammeters A, B, and C, assuming that they have no internal resistance.

Using Kirchhoff's current law at node X:

$I_A = I_B + I_C$

Using Ohm's law:

Voltage drop across 8Ω resistor:
$V = IR = I_A \times 8\Omega$

For loop AXYA:

$12 - 2I_A - 8I_A = 0$
$12 = 10I_A$
$I_A = 1.2$ A

For loop XYB:

$3 - 5I_B - 10I_B = 0$
$3 = 15I_B$
$I_B = 0.2$ A

Using Kirchhoff's current law:

$I_C = I_A - I_B$
$I_C = 1.2 - 0.2$
$I_C = 1.0$ A

ii) Determine the potential difference between X and Y.

$V_{XY} = I_A \times 8\Omega$
$V_{XY} = 1.2 \times 8$
$V_{XY} = 9.6$ V

9. a) i) How does intrinsic semiconductor differ from extrinsic semiconductor? Give two points.

- Intrinsic semiconductors are pure, while extrinsic semiconductors contain added impurities to enhance conductivity.
- Conductivity in intrinsic semiconductors depends only on temperature, while extrinsic semiconductors have controlled conductivity due to doping.

9. a) ii) Describe p-n junction diode characteristics and sketch a graph to show how the current through it varies with the potential difference (p.d) across it.

- In forward bias, current remains small until the threshold voltage (0.7V for silicon, 0.3V for germanium), then rises exponentially.
- In reverse bias, only a small leakage current flows until the breakdown voltage is reached.
- The graph has a steep rise in forward bias and a nearly flat reverse region with sudden increase at breakdown voltage.

9. b) Figure 2 is a junction-transistor voltage amplifier circuit diagram.

If $R_1 = 100\ \Omega$, $V_{CC} = 6.0$ V, $h_{FE} = 60$ and $V_{BE} = 0.6$ V, calculate:

i) the voltage across R_1.

Base current:

$I_B = (V_B - V_{BE}) / R_1$
$I_B = (6 - 0.6) / 100$
$I_B = 5.4 / 100$
$I_B = 0.054$ A

Voltage across R_1:

$V_{R_1} = I_B \times R_1$
$V_{R_1} = 0.054 \times 100$
$V_{R_1} = 5.4$ V

ii) the magnitude of I_B and I_C.

$I_B = 0.054$ A

Collector current:

$I_C = h_{FE} \times I_B$
$I_C = 60 \times 0.054$
$I_C = 3.24$ A

9. c) i) Identify two distinguishable characteristics of semiconductors.

- Semiconductors have a small energy gap between the valence and conduction bands.
- Their electrical conductivity increases with temperature due to increased carrier excitation.

ii) Analyze the effect of temperature in conduction of solids.

- In metals, increasing temperature increases lattice vibrations, reducing conductivity due to electron scattering.
- In semiconductors, increasing temperature excites more electrons into the conduction band, increasing conductivity.

10. a) i) What are the three characteristic features of an op-amp?

- Very high voltage gain, allowing small input signals to be amplified significantly.
- Very high input impedance, minimizing current draw from the input source.
- Very low output impedance, ensuring efficient signal transfer to connected components.

10. a) ii) With the aid of relevant diagrams, identify two types of op-amps.

- Inverting amplifier: The input signal is applied to the inverting terminal (-), and the non-inverting terminal (+) is grounded. The output is phase-inverted.
- Non-inverting amplifier: The input signal is applied to the non-inverting terminal (+), and feedback is provided to the inverting terminal (-), maintaining the same phase at the output.

10. b) i) Determine the output voltage in the circuit diagram shown in Figure 3.

This circuit represents an inverting amplifier, and its output voltage is given by:

$V_o = -(R_f / R_{in}) \times V_{in}$

where:
$R_f = 18\ k\Omega$, $R_{in} = 10\ k\Omega$, and $V_{in} = +4\ V$

$V_o = -(18\ k\Omega / 10\ k\Omega) \times 4\ V$
$V_o = -(1.8 \times 4)$
$V_o = -7.2\ V$

10. b) ii) Study the logic circuit in Figure 4 and then draw its truth table.

The circuit consists of AND and OR gates. The truth table can be derived by analyzing the outputs step by step based on input values A and B.

A	B	Q1 (A AND 1)	Q2 (B AND 1)	Q3 (Q1 OR Q2)	Q4 (Q3 AND 1)	Output
0	0	0	0	0	0	0
0	1	0	1	1	1	1
1	0	1	0	1	1	1

| 1 | 1 | 1 | 1 | 1 | 1 | 1 |

10. c) i) What is meant by bandwidth of a signal?

- Bandwidth is the range of frequencies a signal occupies or requires for proper transmission and processing. It is measured in hertz (Hz).

10. c) ii) An audio signal of 1 kHz is used to demodulate a carrier of 500 kHz. Determine the bandwidth required.

- The bandwidth required for amplitude modulation is given by:

Bandwidth = 2 × Audio frequency

Bandwidth = 2 × 1 kHz
Bandwidth = 2 kHz