**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: 2024**

**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) Use dimensional analysis to find the numerical values of length and mass given that the velocity of light, acceleration due to gravity, and normal atmospheric pressure are $3\times10^8$ m/s, 10 m/s², and $10^5$ N/m² respectively.

Using dimensional analysis:

- Velocity of light, $c = 3 \times 10^8$ m/s
  Dimension: $[L T^{-1}]$
- Acceleration due to gravity, $g = 10$ m/s²
  Dimension: $[L T^{-2}]$

- Atmospheric pressure, $P = 10^5$ N/m²
  Since pressure = Force/Area and Force = mass × acceleration,
  Dimension: $[M L^{-1} T^{-2}]$

Now, solving for length [L] and mass [M]:
- Taking g as a reference for length: $L = c^2/g$
  Substituting values:
  $L = (3 \times 10^8)^2 / (10) = 9 \times 10^{15}$ m

- Using pressure to find mass:
  $M = P L^2 / g$
  Substituting values:
  $M = (10^5 \times (9 \times 10^{15})^2) / (10)$
  $= 8.1 \times 10^{32}$ kg

Thus, the numerical values of length and mass are approximately $9 \times 10^{15}$ m and $8.1 \times 10^{32}$ kg, respectively.

1. b) Give reasons for the following phenomena:

i) A racing car travels faster around banked curved tracks than if it were flat.

On a banked track, the normal reaction of the road has a component that provides additional centripetal force. This reduces the reliance on friction alone, allowing the car to maintain higher speeds without skidding. On a flat track, friction is the only source of centripetal force, limiting speed before slipping occurs.

ii) An ice skater pulls both arms and legs toward the axis of rotation and sometimes throws out the arms and one leg.

This is due to the conservation of angular momentum. When the skater pulls in the arms and legs, the moment of inertia decreases, causing the angular velocity to increase, making them spin faster. Conversely, extending limbs increases the moment of inertia and decreases rotational speed.

2. a) i) Provide three examples that illustrate the application of the law of conservation of linear momentum.

1. A bullet fired from a gun: The bullet moves forward while the gun recoils backward with equal momentum.
2. A rocket propulsion system: A rocket expels exhaust gases downward, resulting in an upward thrust due to conservation of momentum.
3. Two ice skaters pushing each other apart: If they push each other while stationary, they move in opposite directions with equal but opposite momentum.

2. a) ii) A rocket projected vertically expels exhaust gases at $5 \times 10^4$ m/s. If its mass is $3.5 \times 10^6$ kg and fuel is consumed at a rate of $1.3 \times 10^2$ kg/s, find its thrust acceleration.

Thrust force is given by:

F = rate of change of mass × velocity of expelled gases

$F = (1.3 \times 10^2) \times (5 \times 10^4)$

$F = 6.5 \times 10^6$ N

Using Newton's second law:

Acceleration, a = F / m

$a = (6.5 \times 10^6) / (3.5 \times 10^6)$

$a = 1.86$ m/s²

2. b) An object with a frictionless surface of 1 m is inclined at an angle of 40° to the horizontal. How fast will it be going if it moves in a positive direction down the plane?

Using conservation of energy:

Potential energy at the top converts to kinetic energy at the bottom.

Initial potential energy:

PE = mgh, where $h = L \sin \theta$

Final kinetic energy:

$KE = 1/2\ mv^2$

Equating:

$mgh = 1/2\ mv^2$

$gL \sin \theta = 1/2\ v^2$

$(10 \times 1 \times \sin 40°) = 1/2\ v^2$

$v^2 = 12.86$

$v = 3.59$ m/s

Thus, the object moves at 3.59 m/s down the plane.

3. a) The motion of a simple pendulum will be simple harmonic only if its amplitude of oscillation is small. Use a formula to stipulate this statement.

For a simple pendulum, the restoring force is given by:

$F = -mg \sin\theta$
For small angles, $\sin\theta \approx \theta$ (in radians), so:
$F \approx -mg\theta$
Since $\theta = x/L$, where x is the displacement and L is the length of the pendulum, we get:
$F \approx -mg(x/L)$
Rearranging:
$a = F/m = -(g/L)\, x$

This is of the form $a = -\omega^2 x$, which is the equation of simple harmonic motion, where:
$\omega = \text{sqrt}(g/L)$
Thus, the motion of the pendulum is simple harmonic for small oscillations.

3. b) i) Identify two distinctive examples of bodies executing Simple Harmonic Motion (SHM).
1. A mass-spring system oscillating in the absence of damping.
2. A simple pendulum swinging with small amplitude.

3. b) ii) Use mathematical expressions to show that the total energy of a body executing SHM is independent of time.
Total energy in SHM is given by:
$E = KE + PE$
Kinetic energy:
$KE = 1/2\, m\omega^2 (A^2 - x^2)$
Potential energy:
$PE = 1/2\, m\omega^2 x^2$

Total energy:
$E = (1/2\, m\omega^2 A^2 - 1/2\, m\omega^2 x^2) + 1/2\, m\omega^2 x^2$
$E = 1/2\, m\omega^2 A^2$
Since A (amplitude) and $\omega$ (angular frequency) are constant, total energy remains constant over time.

4. a) i) Assess the motion of a solid sphere dropped from an artificial satellite orbiting the earth in a circular orbit towards the earth's surface.

When the sphere is released, it initially has the same orbital velocity as the satellite. Due to the absence of an immediate force along its velocity direction, it continues moving forward while gradually descending under gravity. Its trajectory follows a curved path until atmospheric drag significantly affects its motion, eventually causing it to fall towards the earth.

4. a) ii) Why are space rockets usually launched from west to east?

1. The earth rotates from west to east, providing an additional velocity boost to rockets launched in that direction.
2. This reduces the fuel required to achieve orbital velocity.

4. b) i) Derive an expression for the total energy needed to place a satellite in orbit.

Total energy in orbit is given by:
E = KE + PE

Kinetic energy:
$KE = 1/2\ m\ v^2$

Potential energy:
PE = - GMm/r

For circular orbits, using centripetal force:
$GMm/r^2 = mv^2/r$
Thus, $v^2 = GM/r$

Substituting into kinetic energy:
KE = 1/2 m (GM/r) = GMm/2r
Total energy:

E = GMm/2r - GMm/r
E = -GMm/2r

4. b) ii) Compute the numerical value of total energy for a satellite of mass 1000 kg moving in a circular orbit of radius 7000 km.

Using:
E = -GMm/2r
$G = 6.674 \times 10^{-11}\ Nm^2/kg^2$, $M = 5.972 \times 10^{24}$ kg, $r = 7000 \times 10^3$ m, m = 1000 kg
$E = - (6.674 \times 10^{-11} \times 5.972 \times 10^{24} \times 1000) / (2 \times 7 \times 10^6)$
$E = - 2.85 \times 10^{10}$ J

5. a) i) Give two daily life activities that utilize the mechanism of heat transfer by convection.

1. Boiling water in a pot: Hot water rises while cooler water sinks, creating convection currents.
2. Air conditioning: Warm air rises and cool air sinks, allowing heat to be transferred through convection.

5. a) ii) What are the two necessary conditions for Newton's law of cooling to be valid?

1. The temperature difference between the body and the surroundings should be small.
2. The heat transfer should occur in a medium where convection and conduction are the dominant modes of heat loss.

5. b) A metal box cools in 5 minutes from 65°C to 45°C. If the temperature of the surrounding is 10°C, determine its temperature within the next 5 minutes.

Newton's law of cooling states:
$dT/dt = -k(T - T_a)$
Using the formula:
$T_2 - T_a / T_1 - T_a = e^{(-kt)}$
Given:
$T_1 = 65°C$, $T_2 = 45°C$, $T_a = 10°C$, $t = 5$ min

Substituting:
(45 - 10) / (65 - 10) = e^(-5k)
35 / 55 = e^(-5k)
e^(-5k) = 0.636

Taking the natural logarithm:

-5k = ln(0.636)
k = 0.113

Now, calculating temperature after another 5 minutes:

$T - T_a = (T_2 - T_a)\ e^{(-5k)}$
T - 10 = 35 × e^(-0.565)
T - 10 = 35 × 0.568
T = 29.88°C
Thus, the temperature after the next 5 minutes is 29.88°C.

6. a) i) Why do birds often swell their feathers during winter?
Birds fluff their feathers to trap a layer of air, which acts as insulation. This reduces heat loss and helps them maintain body temperature.

6. a) ii) Why do animals curl into nearly a ball shape when they feel cold?
By curling into a ball, animals reduce their exposed surface area, minimizing heat loss to the surroundings and conserving body heat.

6. b) A layer of ice 10 cm thick is formed on a pond. If the air temperature is -10°C, how long will it take for the thickness of ice to increase by 1 mm?
Heat transfer through conduction is given by:
$Q = (k\ A\ \Delta T\ t) / d$

Where:

- k = thermal conductivity of ice = 2.2 W/mK
- A = 1 $m^2$ (assuming unit area)
- $\Delta T$ = temperature difference = 10°C
- d = 10 cm = 0.1 m
- Latent heat of fusion of ice = $3.34 \times 10^5$ J/kg
- Density of ice = 920 kg/$m^3$

Mass of ice formed:
$m = \text{volume} \times \text{density} = (0.001 \times 1) \times 920 = 0.92$ kg
Heat required:
$Q = m L = 0.92 \times 3.34 \times 10^5$
$Q = 3.07 \times 10^5$ J

Using conduction equation:
$3.07 \times 10^5 = (2.2 \times 1 \times 10 \times t) / 0.1$
Solving for t:
$t = (3.07 \times 10^5 \times 0.1) / (2.2 \times 10)$
t = 1395.45 s

Converting to minutes:
t = 23.26 minutes
Thus, it takes 23.26 minutes for the ice thickness to increase by 1 mm.

7. a) i) What are the four advantages of tidal energy?

1. Renewable and sustainable energy source.
2. Predictable and reliable, unlike wind or solar.
3. Low environmental impact compared to fossil fuels.
4. Long lifespan of tidal power plants with minimal maintenance.

7. a) ii) Which characteristic property of seismic waves is used to locate discontinuities in the earth's crust?
Seismic waves change velocity and direction when passing through different layers. The property used is wave refraction and reflection, which helps in detecting underground discontinuities.

7. b) Give two causes and two effects of thermal pollution.

Causes:
1. Discharge of hot water from industries and power plants into water bodies.
2. Deforestation, which reduces shade and increases surface water temperature.

Effects:
1. Decreased oxygen levels in water, harming aquatic life.

2. Disruption of ecosystems, leading to loss of biodiversity.

8. a) i) What are the four functions of a pure capacitor in a circuit?

1. Stores electrical energy in the form of an electric field.
2. Blocks direct current while allowing alternating current to pass.
3. Smoothens voltage fluctuations in power supply circuits.
4. Used in timing and tuning circuits, such as filters and oscillators.

8. a) ii) Show that the resonance frequency of an LC circuit is given by the expression $f = 1 / (2\pi\sqrt{(LC)})$.

At resonance, the inductive reactance and capacitive reactance are equal:

$XL = XC$

Since inductive reactance $XL = 2\pi fL$ and capacitive reactance $XC = 1 / (2\pi fC)$, equating them:

$2\pi fL = 1 / (2\pi fC)$

Rearranging for f:

$f^2 = 1 / (4\pi^2LC)$
$f = 1 / (2\pi\sqrt{(LC)})$

8. b) A capacitor of 0.4 μF, a coil of inductance 0.4 H, a resistor of 10 Ω, and a lamp are connected in series with an alternating voltage of 0.01 V (r.m.s). If its frequency is varied from low to high while the magnitude of alternating voltage is kept constant:

i) Use a relevant circuit diagram to sketch the graphs showing the variation of impedance and current with frequency and briefly explain how the brightness of the lamp will vary.

- At low frequency, the capacitive reactance is high, and the inductive reactance is low, causing high impedance and low current, making the lamp dim.
- At resonance, inductive and capacitive reactances cancel out, leading to the lowest impedance and highest current, making the lamp brightest.
- At very high frequency, inductive reactance dominates, increasing impedance and reducing current, making the lamp dim again.

ii) Calculate the voltage across the capacitor at resonance, neglecting the lamp resistance.

At resonance, voltage across the capacitor is given by:

$Vc = I\ XC$

Impedance at resonance:

$Z = R = 10\ \Omega$ (since $X_L = X_C$)

Current:

$I = V / Z = 0.01 / 10 = 0.001$ A

Capacitive reactance:

$X_C = 1 / (2\pi fC)$
$f = 1 / (2\pi\sqrt{(LC)})$
$= 1 / (2\pi\sqrt{(0.4 \times 0.4 \times 10^{-6})})$
$= 1 / (2\pi\sqrt{(1.6 \times 10^{-7})})$
$= 1 / (2\pi \times 4 \times 10^{-4})$
$= 1 / (8\pi \times 10^{-4})$
$= 3980\ \Omega$

Voltage across capacitor:

$V_c = I \times X_C$
$= 0.001 \times 3980$
$= 3.98$ V

9. a) i) How does amplitude modulation (AM) differ from frequency modulation (FM)?

1. In AM, the amplitude of the carrier wave varies according to the message signal, while in FM, the frequency varies.
2. AM is more susceptible to noise, while FM provides better sound quality.
3. AM signals require less bandwidth, whereas FM requires more bandwidth.
4. AM transmitters are cheaper, but FM transmitters offer better performance.

9. a) ii) Elaborate two basic functions of a receiver as used in a communication system.

1. Detects and amplifies the received signal.
2. Demodulates the signal to extract the original information.

9. b) Figure 1 is an op-amp circuit with negative feedback made through a capacitor C.

i) State the practical use of the circuit shown in Figure 1.

The circuit is an integrator, which is used in signal processing, waveform generation, and analog computing to integrate input signals over time.

ii) If $R = 2\ k\Omega$, $C = 2\ \mu F$, and $f = 50$ Hz, determine the maximum voltage of the circuit at time t = 2 seconds given that $V_i = 0.55 \sin \omega t$ and $V_o = -1 / (RC) \int V_i\, dt$.

Angular frequency:

$\omega = 2\pi f = 2\pi \times 50 = 314$ rad/s

Input voltage:

$V_i = 0.55 \sin(314t)$

Integrating:

$V_o = -(1 / (RC)) \int 0.55 \sin(314t)\, dt$
$= -(1 / (2000 \times 2 \times 10^{-6})) \int 0.55 \sin(314t)\, dt$
$= -(1 / 0.004) \times (-0.55 / 314) \cos(314t)$
$= (0.55 / (0.004 \times 314)) \cos(314t)$
$= 0.55 / 1.256$
$= 0.438 \cos(314t)$

At t = 2 s:

$V_o = 0.438 \cos(314 \times 2)$
$= 0.438 \cos(628)$

Since $\cos(628) \approx 1$,

$V_o \approx 0.438$ V

9. c) i) Why are television transmission towers made high?

1. To increase the coverage area by minimizing obstructions.
2. To reduce signal attenuation and improve reception.
3. To allow signals to reach distant receivers without interference.

9. c) ii) Describe the methods of transmission and reception of radio signals.

1. Transmission: The modulated signal is amplified and transmitted via an antenna as electromagnetic waves.

2. Reception: The antenna captures the transmitted waves, demodulates the signal, and converts it back to sound or data for output.

10. a) i) Apply Boolean Algebra to analyze the logic circuit diagram shown in Figure 2 and create its truth table.

- The circuit consists of an OR gate and an AND gate.
- The OR gate produces the output C' = A + B.
- The AND gate takes inputs A and (A + B), giving the final output:

  C = A . (A + B)
  Expanding using Boolean algebra:
  C = A.A + A.B
  C = A + A.B
  Using the absorption rule:
  C = A

Truth Table

| A | B | A + B | C = A |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 |

10. a) ii) Why is the NOT gate known as an inverter?

- The NOT gate inverts the input signal, meaning:
  - If the input is 1, the output is 0.
  - If the input is 0, the output is 1.
- It reverses or complements the input, hence called an inverter.

10. b) i) How do metals differ from semiconductors in terms of energy band and conductivity?

- Energy Band Difference:
  - Metals: Have overlapping conduction and valence bands, allowing free electron movement.
  - Semiconductors: Have a small band gap (~1 eV), allowing controlled conduction.

- Conductivity Difference:
  - Metals: Highly conductive due to free electrons.

- Semiconductors: Conductivity depends on temperature and doping; intrinsic semiconductors have fewer free electrons compared to metals.

10. b) ii) Identify any two factors to be considered when designing a voltage amplifier.

- Gain Stability:
  - The amplifier should provide a consistent voltage gain without excessive variations due to temperature or component tolerances.

- Bandwidth:
  - The frequency range over which the amplifier operates efficiently should match the application requirements.

10. c) Figure 3 is a silicon common-emitter amplifier circuit with base-emitter voltage $V_{BE} = 0.7$ V.

If the current amplification factor, β, is 50, calculate the base current $I_B$ and the voltage $V_{CE}$ in the circuit.

Step 1: Calculate Base Current $I_B$
Using the relationship:
$I_C = \beta I_B$

- Collector resistor $R_L = 3$ kΩ
- Supply voltage $V_{CC} = 6$ V
- Voltage across collector resistor: $V_{RL} = V_{CC} - V_{CE}$

Assuming the transistor is in active mode,
$V_{CE} \approx V_{CC} / 2$ (for good amplification), so
$V_{CE} \approx 3$ V

Thus,
$V_{RL} = 6 - 3 = 3$ V

Collector current:
$I_C = V_{RL} / R_L$
$I_C = 3 \text{ V} / 3000\ \Omega$
$I_C = 1$ mA

Base current:
$I_B = I_C / \beta$
$I_B = 1 \text{ mA} / 50$
$I_B = 0.02 \text{ mA} = 20\ \mu\text{A}$

Step 2: Calculate Voltage $V_{CE}$

$V_{CE} = V_{CC} - I_C R_L$

$V_{CE} = 6 - (1 \times 10^{-3} \times 3000)$

$V_{CE} = 6 - 3$

$V_{CE} = 3$ V

Thus,

- Base current $I_B = 20\ \mu A$
- Voltage $V_{CE} = 3$ V