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: 2020**

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) i) Apply the method of dimension to derive an expression for the acceleration of a particle moving in a uniform circular motion.

Centripetal acceleration is given by:

$a = v^2 / r$

Since $v = r\omega$, substituting gives:
$a = r\omega^2$

Dimensional formula of ω (angular velocity):
$\omega = \theta/t = [M^0L^0T^{-1}]$

Since r has the dimension of length:

$a = [L][T^{-2}] = [L\ T^{-2}]$

This matches the dimension of acceleration, proving its correctness.

1. a) ii) Check the correctness of the equation, $\gamma = (hrg / 2\cos\theta)$, where h, r, g, and γ are the angle of contact, density of the liquid, reading on the tube, acceleration due to gravity, surface tension, and the height of the liquid respectively.

Dimensional analysis:

$\gamma = (hrg / 2\cos\theta)$

γ (surface tension) has the dimension of force per unit length:

$[M\ T^{-2}]$

Checking the right-hand side:

h (height) = [L]
r (length) = [L]
g (acceleration) = $[L\ T^{-2}]$

Thus, $hrg = [L] \times [L] \times [L\ T^{-2}] = [L^3\ T^{-2}]$

Since γ should have the dimension of force per unit length $[M\ T^{-2}]$, the equation is dimensionally incorrect.

b) Calculate the tension in the cable which delivers the power of 23 kW when pulling a fully loaded elevator at a constant speed of 0.75 m/s.

Power is given by:

$P = T\ v$

Rearranging for T:

$T = P / v$

$T = (23000\ W) / (0.75\ m/s)$

$T = 30666.67\ N$

2. a) i) Why the outer rail of a curved railway track is raised over the inner?

- Raising the outer rail helps create a centripetal force that prevents the train from derailing at high speeds.
- It allows the train to navigate curves smoothly by reducing lateral forces.

2. a) ii) Based on Newton's laws of motion, explain how a helicopter gets its lifting force.

- The rotor blades push air downward, generating an equal and opposite reaction force (Newton's third law).
- This reaction force provides the lift needed to counteract gravity.

2. b) Determine the internal energy produced by a bullet of mass 10 g traveling horizontally at a speed of 1.0×10^3 m/s which embeds itself in a block of wood of mass 9.9×10^2 g suspended freely by two strings.

Using kinetic energy formula:

$KE = 1/2\ m\ v^2$

$m = 10\ g = 0.01\ kg$
$v = 1000\ m/s$

$KE = 1/2 \times 0.01 \times (1000)^2$
$KE = 5000\ J$

The entire kinetic energy converts into internal energy, so the internal energy produced is 5000 J.

3. a) Find the gravitational potential at a point on the earth's surface if the values of universal gravitational constant, mass, and radius of the earth are 6.7×10^{-11} Nm^2kg^{-2}, 6.0×10^{24} kg, and 6.4×10^6 m respectively.

Gravitational potential is given by:

$V = - GM / R$

Substituting values:

$V = - (6.7 \times 10^{-11} \times 6.0 \times 10^{24}) / 6.4 \times 10^6$
$V = -6.28 \times 10^7$ J/kg

3. b) A communication satellite occupies an orbit such that its period of revolution about the earth is 24 hours.

i) What is the physical significance of this period?

- The satellite is in a geostationary orbit, meaning it remains fixed relative to a point on Earth, making it ideal for telecommunications and weather monitoring.

ii) Establish an expression for the radius, R, of the orbit stating clearly the meaning of symbols used.

Using Kepler's third law:

$T^2 = (4\pi^2 R^3) / GM$

Rearranging for R:

$R = [(GMT^2) / 4\pi^2]^{(1/3)}$

where:
G = gravitational constant
M = mass of the Earth
T = orbital period

4. a) An object falling freely from a given height, H, hits an inclined plane at h from the ground. If the direction of velocity of the object as a result of the impact becomes horizontal, what would be the value of h/H at the time it reaches the ground?

Using energy conservation:

$mgh = 1/2\ m\ v^2$

$h/H = 1/2$

4. b) A ball is kicked with an initial velocity of 8.0 m/s such that it just passes over the barrier which is 2.2 m high. Neglecting air resistance, calculate:

i) the horizontal velocity of the ball.

Horizontal velocity remains constant:

$v_x = 8.0$ m/s

ii) the total time of flight.

Using equation of motion:

$h = 1/2\ g\ t^2$

$2.2 = (1/2 \times 9.81 \times t^2)$

$t^2 = 0.448\ s^2$
$t = 0.67$ s

5. a) Give the evidence for the validity of the first law of thermodynamics.

- Energy is conserved in all thermodynamic processes, as seen in heat engines and refrigeration cycles.

5. b) i) Based on Wien's displacement law, what would happen on a black body when constantly heated?

- The peak wavelength of emitted radiation shifts toward shorter wavelengths, making the object appear bluer.

ii) Estimate the rise in temperature of the gas if 60 Joule is supplied to 2 moles of helium gas placed inside an insulated container of a fixed volume.

Using formula:
$Q = n\ Cv\ \Delta T$

For helium, $Cv = 3R/2 = 12.5$ J/mol·K
$\Delta T = Q / (n\ Cv)$
$\Delta T = 60 / (2 \times 12.5)$
$\Delta T = 2.4$ K

6. a) i) Why is it preferred to purchase a cooking utensil of low specific heat capacity?

- A low specific heat capacity allows the utensil to heat up quickly, reducing cooking time.

ii) How does a fish survive in a pond during an extreme winter season even if the pond is deep frozen on the surface?

- Water at 4°C is denser and remains at the bottom, allowing fish to survive in a liquid state.

6. b) The ice on a pond is 10 mm thick. If the temperature above and below its surface are 263 K and 273 K respectively, calculate the rate of heat transfer through the ice.

Using Fourier's law:

$Q = (k\ A\ \Delta T) / d$

where k = 2.2 W/mK for ice,

$Q = (2.2 \times A \times 10) / 0.01$
$Q = 220\ A\ W$

7. a) For each of the following cases elaborate:

i) two solutions for thermal pollution.

- cooling towers and artificial lakes
  - industries can use cooling towers to dissipate excess heat into the atmosphere before releasing water back into natural water bodies.
  - artificial cooling lakes can be created to store heated water, allowing it to cool before being discharged.

- regulating industrial processes
  - using energy-efficient methods such as heat exchangers can minimize excessive heat release into the environment.
  - implementing strict regulations on the temperature of discharged industrial water can reduce thermal pollution.

ii) three disadvantages of tidal energy.

- high installation cost
  - tidal energy plants require expensive infrastructure, including dams and turbines, making them costly to build.

- environmental impact

- tidal barrages can disrupt marine ecosystems by altering tidal patterns and affecting fish migration.

- limited locations
  - tidal energy is only viable in specific coastal regions with sufficient tidal range, limiting its widespread use.

7. b) what are the three constituents of our ozone layer of the earth?

- ozone (o_3)
  - the primary component of the ozone layer, responsible for absorbing harmful ultraviolet (uv) radiation from the sun.

- oxygen (o_2)
  - plays a role in the continuous formation and destruction of ozone molecules through photochemical reactions.

- nitrogen and trace gases
  - small amounts of nitrogen, water vapor, and chlorine compounds influence ozone chemistry and depletion.

8. a) i) how does a step-up transformer differ from a step-down transformer?

- step-up transformer
  - increases the voltage while decreasing the current.
  - the secondary coil has more turns than the primary coil.

- step-down transformer
  - decreases the voltage while increasing the current.
  - the secondary coil has fewer turns than the primary coil.

ii) why is the transmission of electricity always done at the highest possible voltage?

- reduces power loss
  - power loss in transmission lines is given by $p = i^2r$, meaning lower current reduces losses.
- improves efficiency
  - high voltage allows for long-distance transmission with minimal energy dissipation.

8. b) i) an accumulator of e.m.f. 50 v and internal resistance 2 ω is charged on a 100 v dc source. what resistance will be required to give a charging current of 2 a?

using ohm's law:

$v = ir$

external resistance r_ext:

$r_{ext} = (v_{source} - v_{accumulator}) / i$

$r_{ext} = (100 - 50) / 2$
$r_{ext} = 50 / 2$
$r_{ext} = 25\ \omega$

ii) figure 1 shows a circuit for measuring the resistance of a wire q which is kept at constant temperature. identify the device labeled m_1 and m_2, and state its functions.

- m_1: ammeter
  - measures the current flowing through the wire.

- m_2: voltmeter
  - measures the potential difference across the wire q.

8. c) i) why are alloys used for making standard resistance coils?

- high resistivity
  - alloys such as constantan and manganin have higher resistivity than pure metals, allowing for precise resistance values.

- low temperature coefficient
  - their resistance changes very little with temperature, making them ideal for standard resistance applications.

ii) a coil of a wire has a resistance of 10.8 ω at 20°c and 14.1 ω at 100°c. determine the temperature coefficient of resistance and hence its resistance at 0°c.

temperature coefficient of resistance is given by:

$\alpha = (r_2 - r_1) / [r_1 (t_2 - t_1)]$

substituting values:

$\alpha = (14.1 - 10.8) / [10.8 \times (100 - 20)]$
$\alpha = 3.3 / (10.8 \times 80)$
$\alpha = 3.3 / 864$
$\alpha = 0.00382$ per °c

resistance at 0°c:

$r_0 = r_1 / (1 + \alpha t_1)$

$r_0 = 10.8 / (1 + 0.00382 \times 20)$
$r_0 = 10.8 / 1.0764$
$r_0 = 10.04\ \omega$

9. a) i) state the function of a digital circuit

- a digital circuit processes binary signals (0s and 1s) to perform logical and arithmetic operations in electronic devices.
- it is the foundation of modern computing and communication systems.

ii) state the function of an integrated circuit

- an integrated circuit (ic) is a miniaturized electronic circuit that combines multiple components like transistors, resistors, and capacitors into a single chip.
- it improves performance, reduces size, and increases reliability in electronic devices.

9. b) i) identify three basic logic gates that make up all digital circuits

- and gate
- or gate
- not gate

ii) construct the truth table from the logic gates shown in figure 2

a	b	not a	not b	and (a, not b)	and (not a, b)	or (and1, and2)
0	0	1	1	0	0	0
0	1	1	0	0	1	1
1	0	0	1	1	0	1
1	1	0	0	0	0	0

9. c) i) what does the circuit symbol in figure 3 represent?
- it represents an XOR (exclusive or) gate, which outputs high (1) when the inputs are different.

ii) sketch the output waveform q

- the output waveform follows the xor logic, where it is high when the inputs x and y differ and low when they are the same.

10. a) i) what are the four important properties of semiconductors?

- electrical conductivity lies between conductors and insulators.
- conductivity increases with temperature due to increased carrier excitation.
- doping modifies conductivity, creating n-type or p-type semiconductors.
- semiconductors exhibit rectification, allowing current flow in one direction.

ii) if the resistivity of n-type germanium is 0.01 ω m at room temperature, find the donor concentration given that the mobility of electrons is 0.39 m^2/volt sec.

using the formula:

$\sigma = nq\mu$

where:
σ = conductivity = 1 / resistivity = 1 / 0.01 = 100 s/m
n = donor concentration
q = charge of an electron = 1.6×10^{-19} c
μ = mobility of electrons = 0.39 $m^2/v \cdot s$

$n = \sigma / (q\mu)$
$n = 100 / (1.6 \times 10^{-19} \times 0.39)$
$n = 1.6 \times 10^{21}$ electrons/m^3

10. b) i) what will be the output voltage when l is connected to m in figure 4?

- when l is connected to m, the transistor is in saturation mode, making vo approximately 0v.

ii) how the circuit can be used as a switching circuit?

- the transistor acts as a switch where a small input voltage at the base controls a large current from collector to emitter.
- when base voltage is high, the transistor conducts, turning the switch "on"; when base voltage is low, it remains "off".

10. c) briefly explain the transfer characteristic of an operational amplifier.

- the transfer characteristic of an op-amp describes the relationship between input voltage and output voltage.
- in an ideal op-amp, the output saturates at either the positive or negative supply voltage when the input voltage exceeds the threshold.
- the transition region determines the amplification behavior, often expressed as vo = a(v+ - v-).