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: 2022**

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) The period of oscillation of a simple pendulum is given by the relation $T = 2\pi\sqrt{(L/g)}$. Deduce the formula of fractional error in g.

Taking logarithm on both sides:

$\ln T = \ln (2\pi) + (1/2) \ln L - (1/2) \ln g$

Differentiating both sides:

$\Delta T/T = (1/2) (\Delta L/L) - (1/2) (\Delta g/g)$

Rearranging for fractional error in g:

$\Delta g/g = 2 (\Delta L/L - \Delta T/T)$

ii) Which quantity in 1 a) i) should be measured most accurately? Give reason for your answer.

- The period (T) should be measured most accurately because errors in T contribute twice as much to the error in g compared to errors in L.
- Small timing errors can significantly affect the accuracy of g.

1. 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:

Initial energy = Final energy

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

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) Why bodies on the earth's surface do not move towards each other? Explain basing on Newton's law of universal gravitation.

- According to Newton's law of gravitation, the force between two objects is given by $F = Gm_1m_2/r^2$.
- For small objects on earth, their masses are too small, making the force of attraction between them negligible.
- The gravitational pull of the earth is much stronger, keeping objects attracted to the earth instead of towards each other.

2. a) ii) Use the law in a) i) to derive Kepler's third law.

Equating centripetal force to gravitational force for planetary motion:

$m v^2 / r = G M m / r^2$

Since $v = 2\pi r / T$, squaring both sides:

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

Rearranging:

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

This is Kepler's third law, stating that the square of the period of a planet is proportional to the cube of its orbital radius.

2. b) Show that the moon would depart forever if its speed were increased by approximately 41% where by M_E and M_M are the mass of the earth and moon respectively.

Using the escape velocity formula:

$v_e = \sqrt{(2GM/r)}$

If the moon's speed increases by 41%, the new velocity is

$v_{new} = 1.41\ v_o$

For the moon to escape,

$1.41\ v_o \geq \sqrt{(2GM_E / r)}$

Since $v_o = \sqrt{(GM_E / r)}$, we get

$1.41\sqrt{(GM\_E / r)} \geq \sqrt{(2GM\_E / r)}$

Squaring both sides:

$1.988\ GM\_E / r \geq 2GM\_E / r$

Since $1.988 \approx 2$, this means that the moon will escape from earth's gravitational pull.

3. a) i) Briefly explain the importance of energy interchange in simple harmonic motion.

- In simple harmonic motion, energy continuously interchanges between kinetic energy and potential energy.
- At maximum displacement, potential energy is maximum while kinetic energy is zero.
- At equilibrium, kinetic energy is maximum while potential energy is zero.
- This continuous interchange keeps the motion oscillating.

3. a) ii) What would happen when the negative sign in the equation, $a = -\omega^2 y$ as applied in simple harmonic motion (S.H.M) is omitted?

- The negative sign indicates that acceleration is directed opposite to displacement, restoring the system to equilibrium.
- If omitted, acceleration would act in the same direction as displacement, leading to unbounded motion instead of oscillation.

3. b) An object of mass 2 kg executes S.H.M with a frequency of 2 Hz and amplitude of 2.5 cm. Calculate its maximum velocity and maximum potential energy.

Maximum velocity:

$v\_max = \omega A$

$\omega = 2\pi f = 2\pi \times 2 = 4\pi$ rad/s

$A = 2.5$ cm $= 0.025$ m

$v\_max = 4\pi \times 0.025$
$v\_max = 0.314$ m/s

Maximum potential energy:

$PE\_max = 1/2\ k\ A^2$

$k = m\ \omega^2 = 2 \times (4\pi)^2$

$k = 2 \times 16\pi^2$
$k = 32\pi^2$

$PE_{max} = 1/2 \times 32\pi^2 \times (0.025)^2$
$PE_{max} = 0.031$ J

4. a) i) Why an aircraft twist its wings as it prepared to land?

- Twisting the wings changes the angle of attack, increasing lift while reducing speed.
- This allows the aircraft to land safely without stalling.

4. a) ii) What would be the effect on the horizontal range for a given projection of angle θ if its initial velocity is doubled?

- The range of a projectile is given by $R = (u^2 \sin 2\theta) / g$.
- If the velocity is doubled,

$R' = (4u^2 \sin 2\theta) / g$
$R' = 4R$

- The range becomes four times the original range.

5. a) i) Why lake water at very cold regions does not freeze completely into ice even if the temperature on it is far below the freezing point? Explain with the aid of a relevant diagram.

- Water at the surface freezes first because it is exposed to cold air.
- Ice is a poor conductor of heat, so deeper water remains in liquid form.
- Convection currents in the lake circulate warmer water, preventing complete freezing.

5. a) ii) What is the biological significance of the behavior observed in 5 a) i)?

- It allows aquatic life to survive under ice in winter.
- The liquid water beneath provides a stable environment for organisms.

5. b) One litre of pure water at 25°C is poured into an electric kettle of negligible heat capacity rated 2.5 kW. If the kettle is switched on, calculate the time taken to raise the temperature of water to 100°C.

Using $Q = mc\Delta T$

$Q = 1 \times 4200 \times (100 - 25)$
$Q = 4200 \times 75$
$Q = 315000$ J

Power = energy / time

t = 315000 / 2500
t = 126 s

6. a) An ideal gas of volume 0.05 m^3 initially at 27°C and pressure 1.0×10^5 Pa, is heated at constant pressure until its volume increases to 0.06 m^3. Calculate the external work done by the gas.

$W = P \Delta V$

$W = (1.0 \times 10^5) \times (0.06 - 0.05)$
$W = (1.0 \times 10^5) \times 0.01$
$W = 1000$ J

7. a) i) Identify two principles on which the wind turbine operates to generate electrical energy.

- Conservation of energy: Wind energy is converted into mechanical energy, which then generates electricity.
- Aerodynamic lift: Blades are designed to maximize lift and rotational motion.

7. a) ii) Why renewable energy sources are usually regarded as environmentally friendly? Explain giving two examples.

- They do not produce greenhouse gases.
- Examples: Solar and wind energy produce no air pollution.

7. b) i) What is the influence of oxygen and carbon dioxide gases to plant growth?

- Oxygen is required for respiration.
- Carbon dioxide is used in photosynthesis.

7. b) ii) Briefly explain the effect of rainfall on the renewal of soil air.

- Rainwater infiltrates the soil, displacing trapped air.
- As water drains, fresh air refills the soil pores, renewing soil air.

8. a) i) How does a fuse protect electrical installations?

- A fuse is a thin wire that melts when excessive current flows through it.
- It breaks the circuit and prevents damage to electrical appliances and wiring due to overheating or short circuits.

8. a) ii) Why do the bulbs in a house become dim when a high-power heater is connected to the main supply?

- The heater draws a large current, causing a voltage drop in the wiring.
- The reduced voltage available for the bulbs results in dimming.

8. b) i) A current of 0.5 A passes through a light bulb rated 40 W. If the charge on an electron is 1.6×10^{-19} C, calculate the number of electrons passed through the filament bulb.

The number of electrons per second is given by:

$n = I / e$

where
$I = 0.5$ A
$e = 1.6 \times 10^{-19}$ C

$n = (0.5) / (1.6 \times 10^{-19})$
$n = 3.125 \times 10^{18}$ electrons per second

8. b) ii) Figure 2 is a circuit diagram with resistors of 3 kΩ, 1 kΩ, and 2 kΩ connected to a cell of 24 V. Use Kirchhoff's voltage law to determine the voltage between points 'a' and 'b'.

Total resistance in series:

$R_{total} = 2\ k\Omega + 1\ k\Omega + 3\ k\Omega = 6\ k\Omega$

Current:

$I = V / R_{total}$
$I = 24\ V / 6\ k\Omega$
$I = 4$ mA

Voltage drop across 2 kΩ resistor:

$V_{ab} = I \times 2\ k\Omega$
$V_{ab} = (4 \times 10^{-3}) \times (2000)$
$V_{ab} = 8$ V

8. c) Study the circuit diagram in Figure 3 and then answer the questions that follow:

i) The value of E such that a current of 0.5 A exists in an 8 Ω resistor with a sense from 'a' to 'b'.

Using Ohm's Law:

V = IR
E = (0.5 A) × (8 Ω)
E = 4 V

ii) The potential difference Va - Vb.

Va - Vb = E - voltage drop across 8 Ω resistor
Va - Vb = 7 - 4
Va - Vb = 3 V

9. a) i) What is meant by a semiconductor based on energy band theory of solids?

- A semiconductor has a small energy gap (~1 eV) between the valence band and conduction band.
- At room temperature, some electrons gain energy to cross this gap, allowing limited conduction.

9. a) ii) Give three distinctions between intrinsic and extrinsic semiconductors.

- Intrinsic semiconductors are pure, while extrinsic semiconductors have impurities added.
- Conductivity in intrinsic semiconductors depends only on temperature, while in extrinsic semiconductors, it depends on doping concentration.
- Intrinsic semiconductors have equal electron and hole concentrations, while extrinsic semiconductors have more electrons (n-type) or more holes (p-type).

9. b) i) Which property of a semiconductor diode permits it to be used as a rectifier?

- The unidirectional conductivity of a diode allows current to flow only in forward bias and blocks it in reverse bias.

9. b) ii) In a common base connection, the emitter current Ie = 1 mA and collector current Ic = 0.95 mA. If this transistor is connected in common emitter with a base current of 0.05 mA, calculate the collector current.

Using current gain:

$\beta = Ic / Ib$

Rearranging:

$Ic = \beta Ib$

Since $\beta = \alpha / (1 - \alpha)$, where $\alpha = Ic / Ie$:

$\alpha = 0.95 / 1 = 0.95$

$\beta = 0.95 / (1 - 0.95)$
$\beta = 19$

Now, calculating collector current:

$Ic = 19 \times 0.05$
$Ic = 0.95$ mA

9. c) i) Distinguish between breakdown voltage and knee voltage as applied to P-N junction.

- Breakdown voltage is the reverse voltage at which a diode conducts heavily due to avalanche or Zener breakdown.
- Knee voltage is the minimum forward voltage required for significant current to flow in a diode.

9. c) ii) Why does the conductivity of an intrinsic semiconductor increase with the increase in temperature while that of metals decreases?

- In semiconductors, higher temperature excites more electrons from the valence band to the conduction band, increasing conductivity.
- In metals, higher temperature increases lattice vibrations, scattering electrons and reducing conductivity.

10. a) i) Why are NAND (or NOR) gates known as digital building blocks?

- Any Boolean function can be implemented using only NAND or NOR gates.
- They are universal gates, capable of constructing all other logic gates.

10. a) ii) Draw the logic symbol and give the name of the gate obtained from the combination of the gates shown in Figure 4.

- The given logic diagram represents an OR gate followed by a NOT gate, forming a NOR gate.

10. b) i) Why is the current gain in a common base transistor amplifier always less than one?

- In a common base configuration, the collector current is slightly less than the emitter current due to recombination at the base.
- Since current gain $\alpha = Ic/Ie$ and $Ic < Ie$, α is always less than 1.

10. b) ii) Identify three main properties of an operational amplifier.

- Very high voltage gain
- Very high input impedance
- Very low output impedance

10. c) i) Give two advantages of digital circuits over analog circuits.

- Digital circuits are less affected by noise and distortion.
- Digital circuits can store and process data easily using logic gates.

10. c) ii) With the aid of an illustrative diagram, state the condition necessary for a transistor to behave as an open switch.

- A transistor behaves as an open switch when the base-emitter voltage is below the threshold level, preventing current flow from collector to emitter.
- In an NPN transistor, the switch is open when Vbe < 0.7V (for silicon).