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: 2015**

Instructions

1. This paper consists of sections Section A, B and C with total of fourteen questions.
2. Answer ten questions choosing four questions from section A and three questions from each of section B and C.

1. a) i) what is meant by random errors?

- random errors are unpredictable variations that occur during measurements due to uncontrollable factors such as environmental fluctuations, instrument precision limitations, or observer inconsistencies.

ii) briefly explain two causes of random errors in measurements.
- human error: inconsistent reading or interpretation of instrument scales by the observer.
- environmental changes: fluctuations in temperature, pressure, or humidity affecting instrument readings.

b) the period t of oscillation of a body is said to be 1.5 ± 0.002s while its amplitude a is 0.3 ± 0.005m and the radius of gyration k is 0.28 ± 0.005m. if the acceleration due to gravity g was found to be related to t, a, and k by the equation

$g = 4\pi^2 (a^2 + k^2) / t^2$
find the
i) numerical value of g, in four decimal places.
substituting the given values:
$g = (4 \times 3.1416^2 \times (0.3^2 + 0.28^2)) / 1.5^2$
$g = (4 \times 9.8696 \times (0.09 + 0.0784)) / 2.25$
$g = (4 \times 9.8696 \times 0.1684) / 2.25$
$g = (6.6456) / 2.25$
$g = 9.2152$ m/s²

ii) percentage error in g.

percentage error = (sum of percentage errors in measured quantities)

percentage error in $a^2 = (2 \times 0.005 / 0.3) \times 100 = 3.33\%$
percentage error in $k^2 = (2 \times 0.005 / 0.28) \times 100 = 3.57\%$
percentage error in $t^2 = (2 \times 0.002 / 1.5) \times 100 = 0.267\%$
total percentage error in $g = 3.33\% + 3.57\% + 0.267\%$
$= 7.167\%$

c) i) state the law of dimensional analysis.

- the law of dimensional analysis states that an equation is dimensionally consistent if both sides of the equation have the same fundamental units.

ii) the largest mass, m, of a stone that can be moved by the flowing river depends on the velocity of flow v, the density ρ of water, and the acceleration due to gravity g. show that the mass, m, varies to the sixth power of the velocity of flow.

assuming the relationship:

$m = k v^a \rho^b g^c$
dimensional analysis:

$[m] = [v^a] [\rho^b] [g^c]$
$[kg] = [(m/s)^a] [(kg/m^3)^b] [(m/s^2)^c]$
$[m] = m^a s^{-a} kg^b m^{-3b} m^c s^{-2c}$
equating the powers of fundamental dimensions:

for kg: $1 = b$
for m: $0 = a - 3b + c$
for s: $0 = -a - 2c$
solving for a and c:
$b = 1$
$0 = a - 3(1) + c$
$0 = a - 3 + c$
$c = 3 - a$
$0 = -a - 2c$
substituting $c = 3 - a$:
$0 = -a - 2(3 - a)$
$0 = -a - 6 + 2a$
$0 = a - 6$
$a = 6$
thus, $m \propto v^6$.

2. a) i) define the term trajectory.
- trajectory is the path followed by a projectile under the influence of external forces, typically gravity and air resistance.

ii) briefly explain why the horizontal component of the initial velocity of a projectile always remains constant.
- in the absence of air resistance, no external force acts in the horizontal direction after projection, causing the horizontal velocity to remain constant.

b) i) list down two limitations of projectile motion.

- neglecting air resistance can lead to discrepancies between theoretical and actual results.
- assuming uniform acceleration due to gravity ignores variations caused by altitude and latitude.

ii) a body projected from the ground at an angle of 60° is required to pass just above the two vertical walls each of height 7m. if the velocity of projection is 100m/s, calculate the distance between the two walls.
using the vertical motion equation:
$h = u^2 \sin^2\theta / 2g$

$7 = (100^2 \times \sin^2 60) / (2 \times 10)$
$7 = (10000 \times 0.75) / 20$
$7 = 7500 / 20$
$7 = 375m$

the horizontal distance traveled during this time is given by:
$x = u \cos\theta \times t$
$t = 2u \sin\theta / g$
$t = (2 \times 100 \times \sin 60) / 10$
$t = (200 \times 0.866) / 10$
$t = 173.2 / 10$
$t = 17.32s$
thus,

$x = 100 \cos 60 \times 17.32$
$x = 100 \times 0.5 \times 17.32$
$x = 866m$
distance between the two walls = 866m.
c) a fireman standing at a horizontal distance of 38m from the edge of the burning storey building aimed to raise streams of water at an angle of 60° into the first floor through an open window which is 20m above the ground level. if water strikes on this floor 2m away from the window, determine:

i) time of flight.
$t = 2u \sin\theta / g$
$t = (2 \times u \times \sin 60) / 10$
$t = (2 \times u \times 0.866) / 10$

ii) what speed must the water leave the nozzle at the fire hose?

using the equation:
$h = u^2 \sin^2\theta / 2g$
$20 = (u^2 \times \sin^2 60) / (2 \times 10)$
$u^2 \times 0.75 = 400$
$u^2 = 400 / 0.75$
$u = \sqrt{(533.3)}$
$u = 23.1$ m/s

3. (a)(i) Mention three effects of looping the loop.

1. The normal reaction force varies depending on the position of the object in the loop.
2. The object experiences different speeds at different points in the loop due to gravitational effects.
3. The object must have a minimum speed at the highest point to maintain circular motion without falling.

3. (a)(ii) Why there must be a force acting on a particle moving with uniform speed in a circular path? Write down an expression for its magnitude.
A force is required to keep the particle moving in a circular path because, according to Newton's first law of motion, an object in motion will continue in a straight line unless acted upon by an external force. This force is called the centripetal force and is responsible for continuously changing the direction of the velocity of the particle.

The magnitude of the centripetal force is given by:
$F = m \times v^2 / r$
where:
m = mass of the object
v = velocity of the object
r = radius of the circular path

3. (b)(i) What provides the centripetal force on the car?
The centripetal force on the car is provided by the friction between the tires and the road surface.

3. (b)(ii) Why is it necessary to reduce its speed?
Reducing the speed is necessary to prevent skidding or losing control when negotiating a sharp bend. A higher speed requires a greater centripetal force, and if the friction is not sufficient to provide this force, the car may slide out of the turn.

3. (c)(i) A ball of mass 0.5 kg is attached to the end of a cord whose length is 1.5 m then whirled in a horizontal circle. If the cord can withstand a maximum tension of 50 N, calculate the maximum speed the ball can have before the cord breaks.
The maximum tension in the cord provides the centripetal force required for circular motion:
$T = m \times v^2 / r$
Rearranging for v:
v = sqrt(T x r / m)
Substituting the given values:

v = sqrt(50 x 1.5 / 0.5)
v = sqrt(150)
v = 12.25 m/s

3. (c)(ii) Tension in the cord if the ball speed is 5 m/s.
Using the same centripetal force equation:
$T = m \times v^2 / r$
Substituting the values:
$T = (0.5 \times 5^2) / 1.5$
T = (0.5 x 25) / 1.5
T = 12.5 / 1.5
T = 8.33 N

4. (a)(i) Briefly explain why the motion of a simple pendulum is not strictly simple harmonic.
The motion of a simple pendulum is only approximately simple harmonic for small angles of displacement. At larger angles, the restoring force is not directly proportional to the displacement, as the equation of motion includes a sine function, making the motion non-linear.

4. (a)(ii) Why the velocity and acceleration of a body executing simple harmonic motion (S.H.M.) are out of phase?
In simple harmonic motion, the velocity and acceleration are out of phase because velocity is maximum at the equilibrium position while acceleration is zero there. Conversely, acceleration is maximum at extreme positions where velocity is zero. This phase difference is exactly 90 degrees.

4. (b)(i) A body of mass 0.30 kg executes simple harmonic motion with a period of 2.5 sec and amplitude of 4.0×10^{-2} m. Determine the maximum velocity of the body.

The maximum velocity in S.H.M. is given by:

$v_{max} = A \times \omega$
where:
A = amplitude = 4.0×10^{-2} m
ω = angular frequency = $2\pi / T$

Substituting the values:
$\omega = 2\pi / 2.5$
$\omega = 2.513$ rad/s
$v_{max} = (4.0 \times 10^{-2}) \times 2.513$
$v_{max} = 0.101$ m/s

4. (b)(ii) Maximum acceleration of the body.

The maximum acceleration in S.H.M. is given by:
$a_{max} = A \times \omega^2$
Substituting the values:
$a_{max} = (4.0 \times 10^{-2}) \times (2.513)^2$
$a_{max} = (4.0 \times 10^{-2}) \times 6.31$
$a_{max} = 0.252$ m/s²

4. (b)(iii) Energy associated with the motion.
The total energy in S.H.M. is given by:
$E = 1/2 \times m \times \omega^2 \times A^2$
Substituting the values:

$E = 1/2 \times (0.30) \times (2.513)^2 \times (4.0 \times 10^{-2})^2$
$E = 1/2 \times 0.30 \times 6.31 \times 1.6 \times 10^{-3}$

$E = 0.0015$ J

4. (c) A particle of mass 0.25 kg vibrates with a period of 2.0 sec. If its greatest displacement is 0.4 m, what is its maximum kinetic energy?

Maximum kinetic energy is given by:
$KE_{max} = 1/2 \times m \times \omega^2 \times A^2$
where:
$m = 0.25$ kg
$A = 0.4$ m
$\omega = 2\pi / T = 2\pi / 2 = 3.142$ rad/s

Substituting:
$KE_{max} = 1/2 \times 0.25 \times (3.142)^2 \times (0.4)^2$
$KE_{max} = 1/2 \times 0.25 \times 9.87 \times 0.16$
$KE_{max} = 0.197$ J

5. (a)(i) Define moment of inertia of a body.
Moment of inertia of a body is the measure of its resistance to rotational motion about a given axis. It depends on the mass distribution of the body relative to the axis of rotation and is given by:
$I = \Sigma m \times r^2$

where:
m = mass of each particle
r = perpendicular distance from the axis of rotation

5. (a)(ii) Briefly explain why there is no unique value for the moment of inertia of a given body.
The moment of inertia of a given body depends on the axis about which it is measured. Since a body can rotate about different axes, the moment of inertia varies based on the chosen axis of rotation and the mass distribution relative to that axis.

5. (b)(i) State the principle of conservation of angular momentum.
The principle of conservation of angular momentum states that if no external torque acts on a system, the total angular momentum of the system remains constant. Mathematically,

$L = I \times \omega$
where:
L = angular momentum
I = moment of inertia
ω = angular velocity
If I changes, ω adjusts to conserve L.

5. (b)(ii) A horizontal disc rotating freely about a vertical axis makes 45 revolutions per minute. A small piece of putty of mass 2.0×10^{-2} kg falls vertically onto the disc and sticks to it at a distance of 5.0×10^{-2} m from the axis. If the number of revolutions per minute is thereby reduced to 36, calculate the moment of inertia of the disc.
Using conservation of angular momentum:

$I_1\omega_1 = (I_1 + I_2)\omega_2$

where:
I_1 = moment of inertia of the disc
I_2 = moment of inertia of the putty
ω_1 = initial angular velocity
ω_2 = final angular velocity

Angular velocity is given by:
$\omega = 2\pi N / 60$
Initial angular velocity:
$\omega_1 = (2\pi \times 45) / 60$
$\omega_1 = 4.712$ rad/s
Final angular velocity:

$\omega_2 = (2\pi \times 36) / 60$
$\omega_2 = 3.769$ rad/s
Moment of inertia of the putty:

$I_2 = m \times r^2$
$I_2 = (2.0 \times 10^{-2}) \times (5.0 \times 10^{-2})^2$
$I_2 = 5.0 \times 10^{-5}$ kg m²
Using conservation equation:
$I_1 \times 4.712 = (I_1 + 5.0 \times 10^{-5}) \times 3.769$

Expanding and solving for I_1:

$I_1 \times 4.712 = I_1 \times 3.769 + (5.0 \times 10^{-5}) \times 3.769$
$I_1 \times (4.712 - 3.769) = (5.0 \times 10^{-5}) \times 3.769$
$I_1 \times 0.943 = 1.885 \times 10^{-4}$
$I_1 = 2.0 \times 10^{-4}$ kg m²

5. (c)(i) Define the term tangential velocity.
Tangential velocity is the linear velocity of a point on a rotating object measured in the direction tangent to its circular path. It is given by:

$v = r \times \omega$

where:
r = radius
ω = angular velocity

5. (c)(ii) Explain why the astronaut appears to be weightless when travelling in the space vehicle.
An astronaut in a space vehicle experiences weightlessness because both the astronaut and the vehicle are in free fall around the Earth. Since there is no normal reaction force acting on the astronaut, they experience an apparent absence of weight.

6. (a)(i) State Newton's law of gravitation.
Newton's law of gravitation states that every particle of matter in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Mathematically,
$F = G \times (m_1 \times m_2) / r^2$

where:
G = gravitational constant (6.674×10^{-11} N m^2/kg^2)
m_1, m_2 = masses of the two objects
r = distance between the masses

6. (a)(ii) Use the law stated in (a)(i) to derive Kepler's third law.
For a satellite orbiting a planet in a circular orbit, the gravitational force provides the necessary centripetal force:

$G \times (M \times m) / r^2 = m \times v^2 / r$
Since $v = 2\pi r / T$, substituting in the equation:
$G \times M / r^2 = (4\pi^2 r^2) / (T^2 r)$
$G \times M = (4\pi^2 r^3) / T^2$

Rearranging for T^2:
$T^2 = (4\pi^2 / G M) \times r^3$
This is Kepler's third law, which states that the square of the orbital period of a planet is proportional to the cube of its average distance from the Sun.

6. (b)(i) Briefly explain why Newton's equation of universal gravitation does not hold for bodies falling near the surface of the Earth.
Newton's equation considers point masses or large distances between bodies. Near the Earth's surface, the gravitational force depends on altitude and Earth's density distribution, making the simple inverse-square law approximation slightly inaccurate.

6. (b)(ii) Show that the total energy of a satellite in a circular orbit equals half its potential energy.

Total energy of a satellite is the sum of its kinetic and potential energy.

Kinetic energy:
$KE = 1/2 \times m \times v^2$
Potential energy:
$PE = - G \times M \times m / r$
Using centripetal force equation:
$G \times M \times m / r^2 = m \times v^2 / r$
Solving for v^2:
$v^2 = G \times M / r$
Substituting into KE equation:
$KE = 1/2 \times m \times (G \times M / r)$
$KE = G \times M \times m / (2r)$

Total energy:
$E = KE + PE$
$E = (G \times M \times m) / (2r) - (G \times M \times m) / r$
$E = - (G \times M \times m) / (2r)$

Since $PE = - G \times M \times m / r$,
$E = PE / 2$

6. (c)(i) What would be the length of a day if the rate of rotation of the Earth were such that the acceleration due to gravity g = 0 at the equator?
At the equator, the apparent weight is reduced due to centrifugal force. For weightlessness, centrifugal acceleration must equal gravitational acceleration.
Centrifugal acceleration:
$a_c = \omega^2 r$
Equating with g:
$\omega^2 r = g$
$\omega = \text{sqrt}(g / r)$
$\omega = 2\pi / T$
$T = 2\pi / \text{sqrt}(g / r)$

Substituting $g = 9.81\ m/s^2$, $r = 6.37 \times 10^6$ m:
$T = 2\pi / \text{sqrt}(9.81 / 6.37 \times 10^6)$
$T = 2\pi / \text{sqrt}(1.54 \times 10^{-6})$
$T = 2\pi / (1.24 \times 10^{-3})$
T = 5064 s
T = 1.41 hours

6. (c)(ii) Calculate the height above the Earth's surface for a satellite in a parking orbit.
For a geostationary satellite, T = 24 hours = 86400 s.
Using Kepler's law:
$r^3 = (G \times M \times T^2) / (4\pi^2)$

Substituting known values:
$r^3 = (6.674 \times 10^{-11} \times 5.972 \times 10^{24} \times 86400^2) / (4\pi^2)$
$r^3 = 7.54 \times 10^{22}$
$r = 4.23 \times 10^7$ m
Height above Earth's surface:

$h = r - R$
$h = 4.23 \times 10^7 - 6.37 \times 10^6$
$h = 3.59 \times 10^7$ m
$h = 35,900$ km

7. (a)(i) What is meant by a thermometric property?
A thermometric property is a physical quantity that changes in a predictable manner with temperature and can be used to measure temperature.

7. (a)(ii) Mention three qualities that make a particular property suitable for use in a practical thermometer.

1. The property must change uniformly with temperature.
2. The property must be easy to measure accurately.
3. The property must have a wide range of values over different temperatures.

7. (b)(i) Calculate the value of unknown room temperature on the scales of resistance thermometer and constant volume gas thermometer.

For the resistance thermometer, temperature is determined using:
$\theta = (R - R_0) / (R_{100} - R_0) \times 100$
where:
$R = 64992\ \Omega$ (resistance at unknown temperature)
$R_0 = 63000\ \Omega$ (resistance at 0°C)
$R_{100} = 75000\ \Omega$ (resistance at 100°C)
Substituting values:

$\theta = (64992 - 63000) / (75000 - 63000) \times 100$
$\theta = (1992 / 12000) \times 100$
$\theta = 16.6$°C
For the constant volume gas thermometer, temperature is determined using:

$\theta = (P - P_0) / (P_{100} - P_0) \times 100$
where:
$P = 8.51 \times 10^6\ Nm^{-2}$
$P_0 = 8.00 \times 10^6\ Nm^{-2}$
$P_{100} = 1.10 \times 10^7\ Nm^{-2}$
Substituting values:

$\theta = (8.51 \times 10^6 - 8.00 \times 10^6) / (1.10 \times 10^7 - 8.00 \times 10^6) \times 100$
$\theta = (0.51 \times 10^6) / (3.00 \times 10^6) \times 100$
$\theta = 17°C$

7. (b)(ii) Why do the answers in (b)(i) above differ slightly?

The answers differ slightly due to differences in calibration methods, variations in sensitivity of the thermometers, and possible experimental errors such as pressure variations in the gas thermometer.

8. (a)(i) Define coefficient of thermal conductivity.
The coefficient of thermal conductivity is a measure of a material's ability to conduct heat. It is the quantity of heat transmitted per unit time through a unit area of the material per unit temperature gradient.

8. (a)(ii) Write down two characteristics of a perfectly lagged bar.

1. There is no heat loss along its length, meaning heat flows only in one direction.
2. The temperature distribution is uniform along any cross-section of the bar.

8. (b)(i) Calculate the electrical power supplied to an immersion heater.
Given:
Area = $5.0\ m^2$
Temperature difference $\Delta T = 350\ K - 290\ K = 60\ K$
Thickness of insulation d = 50 mm = 0.05 m
Thermal conductivity $k = 4.0 \times 10^{-2}\ Wm^{-1}K^{-1}$

Heat transfer rate:
$Q = (k \times A \times \Delta T) / d$
Substituting values:
$Q = (4.0 \times 10^{-2} \times 5.0 \times 60) / 0.05$
$Q = (12) / 0.05$
$Q = 240\ W$

8. (b)(ii) If the heater were switched off, how long would it take for the temperature of hot water to fall by 1K?
Using heat capacity formula:
$Q = mc\Delta T$
where:
m = mass of water = density x volume = 1000 x 0.8 = 800 kg
c = specific heat capacity of water = 4200 J/kgK

Substituting values:
$Q = 800 \times 4200 \times 1$
$Q = 3.36 \times 10^6\ J$

Time required:
t = Q / Power loss
$t = 3.36 \times 10^6 / 240$
t = 14000 s
t = 3.89 hours

8. (c) The element of an electric fire with an output of 1000 W is a cylinder of 250 mm long and 15 mm in diameter. If it behaves as a black body, estimate its temperature.
Using Stefan-Boltzmann law:
$P = \sigma A T^4$
where:
P = 1000 W
$\sigma = 5.67 \times 10^{-8}$ W/m²K⁴
$A = \pi d L$

Substituting values:
$A = \pi \times 0.015 \times 0.25$
$A = 1.178 \times 10^{-2}$ m²
Solving for T:
$T^4 = P / (\sigma A)$
$T^4 = 1000 / (5.67 \times 10^{-8} \times 1.178 \times 10^{-2})$
$T^4 = 1.51 \times 10^{12}$
T = 3800 K
9. (a)(i) What is meant by internal resistance of a cell?
Internal resistance of a cell is the resistance within the cell that opposes the flow of current, causing a voltage drop inside the cell.

9. (a)(ii) What is meant by drift velocity?

Drift velocity is the average velocity of charge carriers in a conductor due to an applied electric field.

9. (b)(i) What is a potentiometer?
A potentiometer is an instrument used to measure the potential difference between two points without drawing current from the circuit.

9. (b)(ii) Mention two advantages and two disadvantages of a potentiometer.
Advantages:
1. High accuracy as it does not draw current from the circuit.
2. Can measure very small potential differences precisely.

Disadvantages:
1. Requires a long wire, making it bulky.
2. Needs a stable power supply for accurate measurements.

9. (c)(i) State Kirchhoff's laws of electric network.

1. Kirchhoff's Current Law (KCL): The sum of currents entering a junction is equal to the sum of currents leaving the junction.
2. Kirchhoff's Voltage Law (KVL): The sum of the voltage drops in a closed loop is equal to the sum of the voltage sources.

9. (c)(ii) Find the value of the current I in the circuit shown in Figure 1.

Total resistance:

Series:

$R_{series} = 4\Omega + 12\Omega = 16\Omega$

Parallel:

$1 / R_{eq} = 1 / 16 + 1 / 1 + 1 / 5 + 1 / 20$

$1 / R_{eq} = 0.0625 + 1 + 0.2 + 0.05$

$1 / R_{eq} = 1.3125$

$R_{eq} = 0.7619\ \Omega$

Total resistance:

$R_{total} = R_{eq} + 2\Omega = 0.7619 + 2$

$R_{total} = 2.7619\ \Omega$

Using Ohm's law:

$I = V / R$

$I = 12 / 2.7619$

$I = 4.34$ A

10. (a) Distinguish between ohmic and non-ohmic conductor. Give one example in each case.

Ohmic conductor: Obeys Ohm's law, meaning current is directly proportional to voltage. Example: Copper wire.

Non-ohmic conductor: Does not obey Ohm's law, meaning resistance changes with voltage. Example: Diode.

10. (b) Sketch the diagram showing the variation of current with potential difference across the following:

(i) Filament electric bulb - nonlinear curve due to temperature increase.

(ii) Gas-filled diode - sharp increase in current beyond threshold voltage.

10. (c)(i) What length of the wire is required to make a coil with a resistance of 0.5Ω?

Using:

$R = \rho L / A$

Solving for L:

$L = R A / \rho$

where:

$A = \pi (d/2)^2 = \pi (0.0001 / 2)^2$
$A = 7.85 \times 10^{-9}\ m^2$
$L = (0.5 \times 7.85 \times 10^{-9}) / (1.69 \times 10^{-8})$
$L = 0.232\ m$

10. (c)(ii) If on passing a current of 2.4 A the temperature of the coil rises by 10°C, what error would arise in taking the potential drop as 1.0V?
Change in resistance:
$\Delta R = R_0 \alpha \Delta T$
$\Delta R = 0.5 \times (4.3 \times 10^{-3}) \times 10$
$\Delta R = 0.0215\ \Omega$
New resistance:
$R_{new} = 0.5 + 0.0215$
$R_{new} = 0.5215\ \Omega$
New voltage:

$V = I \times R_{new}$
$V = 2.4 \times 0.5215$
$V = 1.2516\ V$

Error:
Error = 1.2516 - 1.0
Error = 0.2516 V

12. (a)(i) List three properties of operational amplifiers.

1. Very high input impedance to prevent loading of the previous stage.
2. Very low output impedance to drive the next stage effectively.
3. Very high open-loop gain, allowing amplification of small signals.

12. (a)(ii) What is meant by the term negative feedback? Give four advantages of using it in an op-amp or any type of voltage amplifier.
Negative feedback is a process where a portion of the output signal is fed back to the input in opposition to the original signal. This stabilizes the gain and improves performance.

Advantages:
1. Increases the bandwidth of the amplifier.
2. Reduces distortion and noise in the output signal.
3. Improves the stability of the amplifier.
4. Reduces sensitivity to variations in component values.

12. (b)(i) Define closed-loop gain.

Closed-loop gain is the gain of an amplifier when negative feedback is applied, controlling the overall amplification of the circuit.

12. (b)(ii) Derive an expression of the closed-loop gain for an inverting op-amp voltage amplifier with an input resistor R_1 and a feedback resistor R_2.
For an inverting op-amp, the closed-loop gain is given by:
$V_0 / V_i = - R_2 / R_1$
where:
V_0 = output voltage
V_i = input voltage
R_1 = input resistor
R_2 = feedback resistor

Using Kirchhoff's Current Law at the inverting terminal:
$I_1 = I_2$
$V_i / R_1 = - V_0 / R_2$
Rearranging for gain:
$V_0 / V_i = - R_2 / R_1$

12. (c) Calculate the value of output potential V_0 in Figure 2 if the input potential V_i is +2.0V.

Given:
$R_1 = 15\ k\Omega$
$R_2 = 30\ k\Omega$
$V_i = +2.0V$

Using the inverting amplifier gain formula:

$V_0 = - (R_2 / R_1) \times V_i$
$V_0 = - (30\ k\Omega / 15\ k\Omega) \times 2.0V$
$V_0 = - (2 \times 2.0)$
$V_0 = -4.0V$
13. (a)(i) Give one advantage of frequency modulation (FM) as compared to amplitude modulation (AM).
FM has better noise immunity, making it less susceptible to interference compared to AM.

13. (a)(ii) Briefly explain the importance of bandwidth of an amplitude modulated (AM) signal.

The bandwidth determines the amount of information that can be transmitted. A larger bandwidth allows better audio quality but requires more spectrum space, while a smaller bandwidth limits the audio frequency range.

13. (b)(i) State the function of a modulator in radios.

A modulator combines the audio signal with a high-frequency carrier signal to enable efficient transmission over long distances.

13. (b)(ii) Sketch a block diagram to show the general plan of any communication system.
The general plan includes:
1. Information Source
2. Transmitter
3. Channel
4. Receiver
5. Destination

13. (c)(i) The amplitude modulated (AM) broadcast band ranges from 450 to 1200 kHz. If each station modulates with audio frequencies up to 5.5 kHz, determine the bandwidth needed for each station.

Bandwidth per station:
BW = 2 x Maximum Audio Frequency
BW = 2 x 5.5 kHz
BW = 11 kHz

13. (c)(ii) Total bandwidth available.
Total bandwidth = Upper Frequency - Lower Frequency
BW_total = 1200 kHz - 450 kHz
BW_total = 750 kHz

14. (a)(i) What is the origin of an earthquake?
An earthquake originates from the sudden release of energy in the Earth's crust due to tectonic movements, volcanic activity, or human-induced explosions.

14. (a)(ii) List down three sources of Earth’s magnetism.

1. Motion of molten iron in the Earth's outer core.
2. Induced magnetism from solar radiation.
3. Magnetic minerals in the Earth's crust.

14. (b) A large explosion at the Earth’s surface creates compressional (P) and shear (S) waves moving with a speed of 6.0 km/s and 3.5 km/s respectively. If both waves arrive at the seismological station with 30 seconds interval, calculate the distance measured between the seismological station and the site of explosion.
Given:
P-wave speed = 6.0 km/s
S-wave speed = 3.5 km/s
Time difference = 30 s

Let the distance be d:
Time taken by P-wave:

$t_1 = d / 6.0$
Time taken by S-wave:

$t_2 = d / 3.5$
Time difference equation:
$t_2 - t_1 = 30$
$(d / 3.5) - (d / 6.0) = 30$
Taking LCM (3.5 x 6.0 = 21):
$(6d - 3.5d) / 21 = 30$
$2.5d / 21 = 30$
$d = (30 \times 21) / 2.5$
d = 252 km

14. (c) Explain three techniques applicable for improving soil environment for the best plant growth.

1. Soil Aeration. Increases oxygen availability in the soil, improving root respiration and nutrient uptake.
2. Soil Mulching. Helps retain moisture, reduce temperature fluctuations, and prevent erosion.
3. Crop Rotation. Enhances soil fertility by reducing nutrient depletion and controlling pests and diseases.