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: 2014**

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) Distinguish random error from systematic error.

Random error: These errors occur due to unpredictable fluctuations in measurement conditions, such as slight variations in instrument readings.

Systematic error: These errors arise due to consistent and predictable factors, such as instrument calibration errors or observer bias.

1. (a)(ii) Give a practical example of each term in 1(a)(i) and briefly explain how they can be reduced or eliminated.

Example of random error: Measuring the time period of a pendulum multiple times and obtaining slightly different values due to reaction time differences.
Reduction: Taking multiple readings and averaging them.
Example of systematic error: Using a ruler with incorrect calibration, leading to a consistent overestimation of length.
Reduction: Regular calibration of instruments and using proper measuring techniques.

1. (b) Define the terms error and mistake.

Error: The deviation of a measured value from the true value due to limitations in measurement.
Mistake: A human error in observation, recording, or calculation, such as misreading a scale.

1. (b)(ii) An experiment was done to find the acceleration due to gravity by using the formula:

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

where all symbols carry their usual meaning. If the clock loses 3 seconds in 5 minutes, determine the error in measuring 'g', given that T = 2.22 sec, L = 121.6 cm, ΔT = 0.1 sec, and ΔL = 0.05 cm.

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

Substituting values:
$\Delta g / g = (0.05 / 121.6) + 2(0.1 / 2.22)$
$\Delta g / g = 0.000411 + 0.09009$
$\Delta g / g = 0.0905$

$g = (4\pi^2 \times 121.6) / (2.22)^2$
$g = (15793.47) / 4.9284$
$g = 3.204 \text{ m/s}^2$

$\Delta g = 3.204 \times 0.0905$
$\Delta g = 0.29$ m/s²
$g = 3.204 \pm 0.29$ m/s²

1. (c)(i) What is the importance of dimensional analysis in spite of its drawbacks?

Dimensional analysis helps in checking the correctness of equations, deriving formulas, and converting units. However, it does not provide numerical constants or work for non-physical equations.

1. (c)(ii) The following measurements were taken by a student for the length of a piece of rod: 21.02, 20.99, 20.92, 21.11, and 20.69 cm. Based on error analysis, find the true value of the length of a piece of rod and its associated error.

Mean length:

$L_{mean} = (21.02 + 20.99 + 20.92 + 21.11 + 20.69) / 5$
$L_{mean} = 104.73 / 5$
$L_{mean} = 20.95$ cm

Absolute error:
ΔL = max deviation from mean = $|21.11 - 20.95|$
$\Delta L = 0.16$ cm
True value = 20.95 ± 0.16 cm

2. (a) Outline the motions that add up to make projectile motion.
1. Uniform horizontal motion due to constant velocity.
2. Accelerated vertical motion due to gravitational force.

2. (b) In the first second of its flight, a rocket ejects 1/60 of its mass with a relative velocity of 2400 m/s.

2. (b)(i) Find its acceleration.
Using momentum conservation:
$\Delta v = (\Delta m / m) \times v_{relative}$

$\Delta v = (1/60) \times 2400$
$\Delta v = 40$ m/s

Acceleration:
$a = \Delta v / \Delta t$
$a = 40 / 1$
$a = 40$ m/s²

2. (b)(ii) What is the final velocity if the ratio of initial to final mass of the rocket is 4 at a time of 60 seconds?

Using rocket equation:
$v_{final} = v_{exhaust} \ln(m_{initial} / m_{final})$

$v_{final} = 2400 \ln(4)$
$v_{final} = 2400 \times 1.386$
$v_{final} = 3326.4$ m/s

2. (c) A ball is thrown upwards with an initial velocity of 33 m/s from a point 65° on the side of a hill which slopes upward uniformly at an angle of 28°.
2. (c)(i) At what distance up the slope does the ball strike?

Resolving initial velocity components along and perpendicular to the slope:
$u_x = 33 \cos(65 - 28)$
$u_x = 33 \cos(37)$
$u_x = 33 \times 0.7986$
$u_x = 26.36$ m/s

$u_y = 33 \sin(65 - 28)$
$u_y = 33 \sin(37)$
$u_y = 33 \times 0.6018$
$u_y = 19.87$ m/s

Using time of flight formula:
$t = 2 u_y / g$
$t = (2 \times 19.87) / 9.81$
$t = 39.74 / 9.81$
$t = 4.05$ s

Using range formula along slope:
$R = u_x \times t$
$R = 26.36 \times 4.05$
$R = 106.72$ m

2. (c)(ii) Calculate the time of flight of the ball.
$t = (2 \times 19.87) / 9.81$
$t = 39.74 / 9.81$
$t = 4.05$ s

3. (a)(i) State the principle of conservation of linear momentum.
The total linear momentum of a system remains constant if no external force acts on it.

3. (a)(ii) Give two examples of the principle stated in 3(a)(i).
1. A gun recoiling backward when a bullet is fired.
2. A rocket propelling forward by ejecting gas backward.

3. (b)(i) A cannon of mass 1300 kg fires a 72 kg ball in a horizontal direction with a muzzle speed of 55 m/s. If the cannon is mounted so that it can recoil freely calculate the recoil velocity of the cannon relative to the earth.

Using momentum conservation:
$m_{cannon} v_{cannon} = m_{ball} v_{ball}$
$1300 v_{cannon} = 72 \times 55$
$v_{cannon} = (72 \times 55) / 1300$
$v_{cannon} = 3960 / 1300$
$v_{cannon} = 3.05$ m/s

3. (b)(ii) Horizontal velocity of the ball relative to the earth.
Since the cannon recoils at 3.05 m/s, the velocity of the ball relative to the Earth is:
$v_{ball\_relative} = 55 - 3.05$
$v_{ball\_relative} = 51.95$ m/s

3. (c)(i) Define the term radial acceleration.
Radial acceleration is the acceleration directed towards the center of a circular path, given by $a_r = v^2 / r$.

3. (c)(ii) An insect is released from rest at the top of the smooth bowling ball such that it slides over the ball. Prove that it will lose its footing with the ball at an angle of about 48° with the vertical.

At any point, the normal force N provides the required radial acceleration:
$N + mg \cos\theta = mv^2 / r$
At the point of losing contact, N = 0, so:
$mg \cos\theta = mv^2 / r$

Using energy conservation:
$mgh = 1/2\ m v^2$
Since $h = r(1 - \cos\theta)$:
$mg\ r(1 - \cos\theta) = 1/2\ m v^2$

Solving for v^2:
$v^2 = 2 g r (1 - \cos\theta)$
Substituting in the normal force equation:
$mg \cos\theta = m (2 g (1 - \cos\theta)) / r$
Canceling m and rearranging:

$\cos\theta = 2 (1 - \cos\theta)$
$\cos\theta + 2 \cos\theta = 2$

$3 \cos\theta = 2$
$\cos\theta = 2/3$
$\theta = \cos^{-1}(2/3)$
$\theta = 48.2°$

4. (a)(i) State where the magnitude of acceleration is greatest in a simple harmonic motion (S.H.M.).
The magnitude of acceleration is greatest at the maximum displacement (amplitude) in simple harmonic motion.

4. (a)(ii) Sketch a graph of acceleration against displacement for a simple harmonic motion.
The graph is a straight line passing through the origin with a negative slope, indicating that acceleration is proportional to displacement but acts in the opposite direction.

4. (b) A vertical spring fixed at one end has a mass of 0.2 kg and is attached at the other end.
4. (b)(i) Determine the extension of the spring.
Using Hooke's Law at equilibrium:

$mg = kx$
Rearranging for x:
$x = mg / k$
Substituting values:
$x = (0.2 \times 9.81) / k$
$x = 1.962 / k$
Since k is not provided, the answer remains in terms of k.

4. (b)(ii) Determine the energy stored in the spring.
Energy stored in a stretched spring is given by:
$E = 1/2\ k x^2$
Substituting x from (i):
$E = 1/2\ k (1.962 / k)^2$

$E = 1/2 \times k \times (3.85 / k)$
$E = 1.925 / k$
Since k is not given, the energy remains in terms of k.

4. (c) The displacement of a particle from the equilibrium position moving with simple harmonic motion is given by $x = 0.05 \sin(6\pi t)$, where t is in seconds.

4. (c)(i) Calculate the amplitude of oscillations.
The amplitude is the maximum displacement:

$A = 0.05$ m

4. (c)(ii) Calculate the period of oscillations.
Comparing with standard equation $x = A \sin(\omega t)$,
$\omega = 6\pi$ rad/s

Period is given by:
$T = 2\pi / \omega$
$T = 2\pi / 6\pi$
$T = 1/3$ s

4. (c)(iii) Calculate the maximum acceleration of the particle.
Acceleration in S.H.M. is given by:
$a_{max} = A\omega^2$
Substituting values:
$a_{max} = (0.05)(6\pi)^2$

$a_{max} = (0.05) \times (36\pi^2)$
$a_{max} = (0.05) \times (355.3)$
$a_{max} = 17.76$ m/s²

5. (a)(i) Define the universal gravitational constant.
The universal gravitational constant, G, is the proportionality constant in Newton's law of universal gravitation. It is given by:
$G = 6.674 \times 10^{-11}$ N m²/kg²

5. (a)(ii) How is gravitational potential related to gravitational field strength?
Gravitational potential (V) is the work done per unit mass to bring a mass from infinity to a point in a gravitational field. Gravitational field strength (g) is the negative gradient of gravitational potential:
$g = - dV / dr$

5. (b)(i) Write down an expression for the acceleration due to gravity (g) of a body of mass m which is at a distance r from the center of the Earth.
Using Newton's law of gravitation:
$F = G M m / r^2$
From Newton's second law:
$F = m g$
Equating the two equations:
$m g = G M m / r^2$
Cancelling m:
$g = G M / r^2$

5. (b)(ii) If the Earth were made of lead of relative density 11.3, what would be the value of acceleration due to gravity on the surface of the Earth?
Density (ρ) is related to mass and volume:

$M = \rho \times V$
Since $V = 4/3 \pi R^3$,
$M = \rho \times (4/3 \pi R^3)$
Substituting into $g = G M / R^2$:
$g = G (\rho \times 4/3 \pi R^3) / R^2$
$g = (4/3) \pi G \rho R$

Given that standard Earth's density is approximately 5.51 g/cm³ and standard g = 9.81 m/s², the ratio of new g to old g is:

$g_{new} / g_{old} = (\rho_{new} / \rho_{old})$
$g_{new} = (11.3 / 5.51) \times 9.81$
$g_{new} = 2.05 \times 9.81$
$g_{new} = 20.1$ m/s²

5. (c)(i) Why the value of acceleration due to gravity (g) changes due to the change in latitude? Give two reasons.
1. The Earth is not a perfect sphere; it bulges at the equator, increasing the radius and reducing g.
2. The rotation of the Earth causes a centrifugal force at the equator, reducing the effective value of g.

5. (c)(ii) A rocket is fired from the Earth towards the Sun. At what point on its path is the gravitational force on the rocket zero?
The gravitational force is zero at the point where the gravitational pulls from Earth and Sun balance each other.

Using:
$G M_e / d^2 = G M_s / (D - d)^2$
Solving for d, where:
M_e = mass of Earth
M_s = mass of Sun
D = distance between Earth and Sun

Substituting values:
$d = D / \text{sqrt}(M_s / M_e)$
Using $M_s / M_e \approx 3.3 \times 10^5$,
$d = 1.5 \times 10^{11} / \text{sqrt}(3.3 \times 10^5)$
$d = 1.5 \times 10^{11} / 575$
$d = 2.6 \times 10^8$ m

6. (a)(i) Define torque and give its S.I. unit.

Torque (τ) is the turning effect of a force about a point, given by:
$\tau = r \times F$
where:
r = perpendicular distance from axis
F = force applied
SI unit: Newton meter (N·m)
6. (a)(ii) A disc of moment of inertia 2.5×10^{-2} kgm² is rotating freely about an axis through its center at 20 rev/min. If some wax of mass 0.048 kg is dropped gently on the disc 0.05 m from its axis, what will be the new revolution per minute of the disc?

Using conservation of angular momentum:
$I_1 \omega_1 = I_2 \omega_2$
New moment of inertia:
$I_2 = I_1 + m r^2$
$I_2 = (2.5 \times 10^{-2}) + (0.048 \times 0.05^2)$
$I_2 = (2.5 \times 10^{-2}) + (0.048 \times 0.0025)$
$I_2 = 2.5 \times 10^{-2} + 1.2 \times 10^{-4}$
$I_2 = 2.512 \times 10^{-2}$ kgm²

Initial angular velocity:
$\omega_1 = 20$ rev/min $= (20 \times 2\pi) / 60$
$\omega_1 = 2.094$ rad/s
Using conservation:

$(2.5 \times 10^{-2}) \times 2.094 = (2.512 \times 10^{-2}) \times \omega_2$
$\omega_2 = (2.5 \times 10^{-2} \times 2.094) / (2.512 \times 10^{-2})$
$\omega_2 = 2.082$ rad/s
Converting back to rev/min:
$n_2 = (\omega_2 \times 60) / (2\pi)$
$n_2 = (2.082 \times 60) / (2\pi)$
$n_2 = 19.9$ rev/min

6. (b) Explain briefly why

6. (b)(i) A high diver can turn more somersaults before striking the water.
A high diver can turn more somersaults because when they tuck their body in, the moment of inertia decreases. Since angular momentum is conserved, a decrease in moment of inertia results in an increase in angular velocity, allowing the diver to spin faster.

6. (b)(ii) A dancer on skates can spin faster by folding her arms.

When the dancer folds her arms, she reduces her moment of inertia. Due to the conservation of angular momentum, the decrease in moment of inertia results in an increase in angular velocity, making her spin faster.

6. (c) A heavy flywheel of moment of inertia 0.4 kgm^2 is mounted on a horizontal axle of 0.01 m. If a force of 60 N is applied tangentially to the axle:

6. (c)(i) Calculate the angular velocity of the flywheel after 5 seconds from rest.
Torque is given by:

$\tau = r \times F$
Substituting values:
$\tau = 0.01 \times 60$
$\tau = 0.6$ Nm

Using the relation:
$\tau = I \alpha$
Solving for α:

$\alpha = \tau / I$
$\alpha = 0.6 / 0.4$
$\alpha = 1.5$ rad/s^2

Using angular motion equation:
$\omega = \omega_0 + \alpha t$
Since the flywheel starts from rest, $\omega_0 = 0$:

$\omega = 0 + (1.5 \times 5)$
$\omega = 7.5$ rad/s

6. (c)(ii) List down two assumptions taken to arrive at your answer in 6(c)(i).

1. No external resistive forces such as friction act on the flywheel.
2. The force applied remains constant throughout the motion.

7. (a)(i) Give two ways in which the internal energy of the system can be changed.

1. By heating or cooling the system, which increases or decreases the kinetic energy of the particles.
2. By doing work on the system, such as compressing a gas, which increases internal energy.

7. (a)(ii) List down two simple applications of the First law of thermodynamics in our daily life.

1. Cooking food: Heat energy is transferred to the food, increasing its internal energy.

2. Refrigerators: Work is done to transfer heat from inside the fridge to the surrounding environment.

7. (b) One mole of a gas expands from volume V_1 to a volume V_2. If the gas obeys the Van der Waal's equation:

$$(p + a / v^2) (v - b) = RT$$

derive the formula for work done in this process.

Work done in an expansion process is given by:

$$W = \int p \, dv$$

Using the given equation:

$$p = (RT / (v - b)) - (a / v^2)$$

Substituting this into the work integral:

$$W = \int [(RT / (v - b)) - (a / v^2)] \, dv$$

Splitting the integral:

$$W = \int (RT / (v - b)) \, dv - \int (a / v^2) \, dv$$

Evaluating each term separately:

$$\int (RT / (v - b)) \, dv = RT \ln (v - b)$$

$$\int (a / v^2) \, dv = a / v$$

Applying limits from V_1 to V_2:

$$W = RT \ln ((V_2 - b) / (V_1 - b)) - a (1/V_2 - 1/V_1)$$

7. (c) A heat engine works at two temperatures of 27°C and 227°C. Calculate the

7. (c)(i) Efficiency of the engine.

Efficiency of a Carnot engine is given by:

$$\eta = 1 - T_c / T_h$$

where:
T_c = 27°C = 27 + 273 = 300 K
T_h = 227°C = 227 + 273 = 500 K

η = 1 - (300 / 500)
η = 1 - 0.6
η = 0.4

Efficiency is 40%.

7. (c)(ii) Temperature which will increase the efficiency by 10% if the room temperature is kept at 27°C.

New efficiency η' = 40% + 10% = 50% = 0.5

Using the Carnot efficiency formula:

0.5 = 1 - (300 / T_h')

Rearranging:

T_h' = 300 / (1 - 0.5)
T_h' = 300 / 0.5
T_h' = 600 K

New temperature is 600 - 273 = 327°C.

8. (a)(i) Define thermal convection.

Thermal convection is the transfer of heat through the movement of fluid due to temperature-induced density differences.

8. (a)(ii) Prove that at a very small temperature difference, $\Delta T = T_6 - T_s$, Newton's law of cooling obeys Stefan's law, whereby T_6 is the temperature of the body and T_s is the temperature of the surrounding.

Newton's law of cooling states:

$dT / dt = - k (T_6 - T_s)$

Stefan's law states:

$P = \sigma A (T_6^4 - T_s^4)$

For a small temperature difference:

$T_6 = T_s + \Delta T$

Expanding using binomial approximation:

$T_6^4 - T_s^4 \approx 4T_s^3 \Delta T$

$P = \sigma A 4T_s^3 \Delta T$

Since power loss P is proportional to the rate of cooling:

$dT / dt = - k \Delta T$

which is Newton's law of cooling.

8. (b)(i) What is meant by temperature of inversion?

Temperature of inversion is the temperature at which the thermoelectric emf of a thermocouple reverses direction when one junction is heated.

8. (b)(ii) A thermometer was wrongly calibrated as it reads the melting point of ice as -10°C and reading a temperature of 60°C in place of 50°C. What would be the temperature of boiling point of water on this scale?

Using linear transformation:

T_actual = m T_measured + c

Two calibration points:

0 = m (-10) + c
50 = m (60) + c

Solving for m and c:

c = 10
m = 50 / 70
m = 5 / 7

For boiling point at 100°C:

T_measured = (5 / 7) x 100 + 10
T_measured = 71.4 + 10

$T_{measured} = 81.4°C$

9. (a)(i) What is meant by alternating current (a.c.)?

Alternating current (a.c.) is an electric current that periodically reverses direction.

9. (a)(ii) What is the effective value of A.C.?

The effective value (RMS value) of an AC voltage or current is the value that produces the same heating effect as an equivalent DC value. It is given by:

$I_{rms} = I_{peak} / \sqrt{2}$

9. (b)(i) A 60 volt, 10 watt lamp is to be run on 100 volt, 60 Hz A.C. mains. Calculate the inductance of a choke coil required.

Using power formula:

$P = V^2 / R$

$R = V^2 / P$
$R = (60)^2 / 10$
$R = 3600 / 10$
$R = 360\ \Omega$

Impedance of the coil:

$Z = V / I$

$I = P / V$
$I = 10 / 60$
$I = 1/6$ A

$Z = 100 / (1/6)$
$Z = 600\ \Omega$

Inductive reactance:

$X_L = \sqrt{(Z^2 - R^2)}$
$X_L = \sqrt{(600^2 - 360^2)}$
$X_L = \sqrt{(360000 - 129600)}$
$X_L = \sqrt{230400}$
$X_L = 480\ \Omega$

Inductance:

$X_L = 2\pi f L$

$L = X_L / (2\pi f)$
$L = 480 / (2\pi \times 60)$
$L = 480 / 376.99$
$L = 1.27$ H

9. (b)(ii) If a resistor is used in (b)(i) above instead of choke, what will be the value of its resistance?

$R = Z = 600\ \Omega$

9. (c)(i) Find the power input to the circuit.

Total impedance:

$X_L = 2\pi f L$
$X_L = 2\pi \times 300 \times 1.5$
$X_L = 2827.43\ \Omega$

$X_C = 1 / (2\pi f C)$
$X_C = 1 / (2\pi \times 300 \times 30 \times 10^{-6})$
$X_C = 17.68\ \Omega$

Net reactance:

$X = X_L - X_C$
$X = 2827.43 - 17.68$
$X = 2809.75\ \Omega$

Total impedance:

$Z = \sqrt{(R^2 + X^2)}$
$Z = \sqrt{(70^2 + 2809.75^2)}$
$Z = \sqrt{7892700}$
$Z = 2810\ \Omega$

Current:

$I = V / Z$
$I = 230 / 2810$

$I = 0.082$ A

Power:

$P = I^2 R$
$P = (0.082)^2 \times 70$
$P = 0.472$ W

9. (c)(ii) At the frequency $\omega_0 = 1 / \sqrt{(LC)}$, how does the circuit respond?

At this frequency, the circuit is in resonance, meaning that the inductive reactance and capacitive reactance cancel each other, and only resistance determines the impedance.

10. (a)(i) Define current density.

Current density (J) is the electric current per unit cross-sectional area of a conductor. It is given by:

$J = I / A$

where:
J = current density (A/m^2)
I = current (A)
A = cross-sectional area (m^2)

10. (a)(ii) Define conductivity.

Conductivity (σ) is the measure of a material's ability to conduct electric current. It is the reciprocal of resistivity (ρ) and is given by:

$\sigma = 1 / \rho$

where:
σ = conductivity (S/m)
ρ = resistivity (Ωm)

10. (b)(i) Under what condition is Ohm's law true?

Ohm's law is valid when the temperature and physical properties of a conductor remain constant, ensuring that the current is directly proportional to the voltage applied.

10. (b)(ii) Why does the voltage across the terminals of a cell or battery fall when it is delivering a current?

The voltage across the terminals of a cell decreases when it supplies current due to its internal resistance. The terminal voltage V is given by:

$V = E - Ir$

where:
E = emf of the cell (V)
I = current (A)
r = internal resistance (Ω)

As the current increases, the voltage drop Ir increases, reducing the terminal voltage.

10. (c)(i) Define temperature coefficient of resistance.

The temperature coefficient of resistance (α) is the fractional change in resistance per degree change in temperature. It is given by:

$R = R_0(1 + \alpha\Delta T)$

where:
R = resistance at temperature T
R_0 = resistance at reference temperature
α = temperature coefficient of resistance ($°C^{-1}$)
ΔT = temperature change (°C)

10. (c)(ii) A heating coil of Nichrome wire with cross-sectional area of 0.1 mm^2 operates on a 12V supply and has a power of 36W when immersed in water at 373K. Calculate the length of the wire.

Given:
$P = 36$ W
$V = 12$ V
$A = 0.1\ mm^2 = 0.1 \times 10^{-6}\ m^2$
ρ (Nichrome) $= 1.10 \times 10^{-6}\ \Omega m$

Using power formula:

$P = V^2 / R$

Solving for R:

$R = V^2 / P$

$R = (12)^2 / 36$
$R = 144 / 36$
$R = 4\ \Omega$

Using resistance formula:

$R = \rho L / A$

Solving for L:

$L = R A / \rho$

Substituting values:

$L = (4 \times 0.1 \times 10^{-6}) / (1.10 \times 10^{-6})$
$L = (4 \times 0.1) / 1.10$
$L = 0.4 / 1.10$
$L = 0.364$ m

The length of the Nichrome wire is 0.364 meters.

11. (a)(i) What is meant by the following electronic circuits:

Logic gates: These are digital circuits that perform logical operations based on binary inputs, such as AND, OR, and NOT operations.

11. (a)(ii) Integrated circuits: Integrated circuits (ICs) are miniaturized electronic circuits that combine multiple components such as transistors, resistors, and capacitors onto a single semiconductor chip.

11. (b) Draw a truth table for the circuit in Figure 1 including the states at C, D, E, F, and G.

The circuit consists of NOT gates, AND gates, and an OR gate. The truth table is constructed by analyzing the logic at each gate.

A	B	C = NOT A	D = NOT B	E = C AND B	F = A AND D	G = E OR F
0	0	1	1	0	0	0
0	1	1	0	1	0	1
1	0	0	1	0	1	1
1	1	0	0	0	0	0

11. (c)(i) What type of a single gate would provide exactly the same function as the circuit in Figure 2?

The circuit in Figure 2 functions as an XOR (Exclusive OR) gate.

11. (c)(ii) Draw the diagram of a symbol representing a single gate in 11(c)(i).

The XOR gate is represented by its standard logic symbol.

12. (a)(i) What is a light-emitting diode (LED)?

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current passes through it in the forward direction.

12. (a)(ii) Give three advantages of LED lamps in radio and other electronic systems over filament lamps.

1. Higher efficiency: LEDs convert more electrical energy into light with less heat production.
2. Longer lifespan: LEDs last significantly longer than filament bulbs.
3. Faster switching: LEDs can turn on and off instantly, making them ideal for digital applications.

12. (b)(i) What is the basic difference between good conductors and semiconductors?

Good conductors have a high density of free electrons, allowing easy flow of current, while semiconductors have fewer free electrons and their conductivity depends on temperature and doping.

12. (b)(ii) Two silicon diodes, each of forward bias voltage of 0.7V, are connected in a circuit as shown.

Calculate the value of I_1 and I_2.

Applying Kirchhoff's Voltage Law:

For the upper loop:

$20V - 0.7V - (3.3k\Omega \times I_2) = 0$

$I_2 = (20 - 0.7) / 3300$
$I_2 = 19.3 / 3300$
$I_2 = 5.85$ mA

For the lower loop:

$20V - 0.7V - (5.6k\Omega \times I_1) = 0$

$I_1 = (20 - 0.7) / 5600$
$I_1 = 19.3 / 5600$
$I_1 = 3.45$ mA

12. (c)(i) Mention two types of transistors.

1. Bipolar Junction Transistor (BJT)
2. Field Effect Transistor (FET)

12. (c)(ii) Which among the transistors mentioned in (c)(i) above responds quickly to electrical signals? Give reason for your answer.

Field Effect Transistors (FETs) respond faster because they rely on an electric field to control the current flow, resulting in faster switching times and lower power consumption.

13. (a)(i) Give the meaning of the following terms:

Bandwidth: The range of frequencies within a given signal that allows transmission of data without significant loss of quality.

13. (a)(ii) Amplitude modulated carrier wave: A waveform in which the amplitude of a high-frequency carrier signal is varied in proportion to the amplitude of a lower-frequency information signal.

13. (b)(i) What is the purpose of amplifiers in a phone link?

Amplifiers boost the strength of the transmitted signal to compensate for losses due to distance, ensuring clear communication.

13. (b)(ii) Sketch the frequency spectrum for 1500 m radio waves modulated by a 4 kHz audio signal.

The spectrum consists of a central carrier frequency at 200 kHz with two sidebands at 196 kHz (lower) and 204 kHz (upper).

13. (c)(i) List down two advantages of digital signals over analogue signals.

1. Less noise interference: Digital signals maintain integrity better than analogue signals.
2. Easier storage and processing: Digital signals can be compressed and manipulated efficiently.

13. (c)(ii) A carrier of frequency 800 kHz is amplitude modulated by frequencies ranging from 1 kHz to 10 kHz. What frequency range does each sideband cover?

Upper sideband range:

$f_{upper} = f_c + f_{m(max)}$
$f_{upper} = 800 + 10$
$f_{upper} = 810$ kHz

Lower sideband range:

$f_{lower} = f_c - f_{m(max)}$
$f_{lower} = 800 - 10$
$f_{lower} = 790$ kHz

Total bandwidth:

$BW = 2 \times f_{m(max)}$
$BW = 2 \times 10$
$BW = 20$ kHz

Each sideband covers a range of 10 kHz.

14. (a)(i) Describe the sources and effects of air pollution on the environment.

Sources:
1. Vehicle emissions
2. Industrial smoke
3. Burning fossil fuels

Effects:
1. Respiratory diseases
2. Climate change
3. Acid rain

14. (a)(ii) Describe the sources and effects of radiation pollution on the environment.

Sources:
1. Nuclear power plants
2. Medical radiation (X-rays)
3. Radioactive waste disposal

Effects:
1. DNA damage and cancer risks

2. Contamination of soil and water
3. Genetic mutations in living organisms

14. (b)(i) Briefly explain the influence of rainfall and water on plant growth and development.

1. Adequate rainfall promotes soil hydration, supporting root absorption of nutrients.
2. Excessive rainfall can lead to soil erosion and waterlogging, reducing oxygen supply to roots.

14. (b)(ii) Briefly explain the influence of wind on plant growth and development.

1. Moderate wind helps in pollination and seed dispersal.
2. Strong winds can damage plant structures, leading to reduced growth.