THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2013**

Instructions

1. This paper consists of section A, B and C with total of nine questions.

2. Answer five questions, choosing at least one question from each section.

3. Each question carries twenty marks.

1. (a) (i) Write down the Poiseuille's equation for a viscous fluid flowing through a tube defining all the symbols.

Poiseuille's equation is given by

$Q = (\pi r^4 \Delta P) / (8\eta L)$

where Q is the volumetric flow rate, r is the radius of the tube, ΔP is the pressure difference, η is the viscosity of the fluid, and L is the length of the tube.

(ii) What assumptions are used to develop the equation in (a)(i) above.

- The fluid is incompressible and Newtonian.
- The flow is laminar and steady.
- There is no turbulence in the flow.
- The tube is rigid and cylindrical with constant cross-section.
- The velocity is zero at the walls due to no-slip condition.
- The flow is driven purely by pressure difference.

(iii) What is meant by Newtonian fluid?

A Newtonian fluid is a fluid whose viscosity remains constant regardless of the shear rate or applied stress. Examples include water and air.

(b) A submarine model is situated in a part of a tube with diameter 5.1 cm where water moves at 2.4 m/s. Determine the:

(i) velocity of flow in the water supply pipe of diameter 25.4 cm.

Using the equation of continuity

$A_1V_1 = A_2V_2$

$\pi(0.051/2)^2 \times 2.4 = \pi(0.254/2)^2 \times V_2$

Solving for V_2

$V_2 = (\pi(0.051/2)^2 \times 2.4) / (\pi(0.254/2)^2)$

$V_2 \approx 0.24$ m/s

(ii) pressure difference between the narrow and the wide tube.

Using Bernoulli's equation

$P_1 + 0.5\rho V_1^2 = P_2 + 0.5\rho V_2^2$

$\Delta P = 0.5\rho(V_2^2 - V_1^2)$

Substituting values with $\rho = 1000$ kg/m³

$\Delta P = 0.5 \times 1000 \times (0.24^2 - 2.4^2)$

$\Delta P \approx -2870$ Pa

(c) (i) Define compressibility of a gas in terms of the elasticity of gases.

Compressibility is the measure of how much a gas volume decreases under pressure, mathematically defined as $\beta = (1/V)(dV/dP)$, where V is volume and P is pressure.

(ii) The bulk modulus of elasticity for lead is 8×10^9 N/m². Find the density of lead if the pressure applied is 2×10^8 N/m².

Using the bulk modulus relation

$B = \Delta P / (\Delta V/V)$

Rearranging for density ρ

$\rho = B / g\Delta V$
$\rho = (8 \times 10^9) / (9.81 \times (2 \times 10^8 / 8 \times 10^9))$
$\rho \approx 1140$ kg/m³

2. (a)
(i) Define the terms: proportional limit, elastic limit, yield point and elasticity.
Proportional limit: The maximum stress within which stress is proportional to strain.
Elastic limit: The maximum stress beyond which permanent deformation occurs.
Yield point: The point where a material begins to deform plastically.
Elasticity: The ability of a material to return to its original shape after removing applied force.
(ii) Use a sketch graph to show how the extension of the wire varies with the applied force and mark the elastic limit and yield point on it. Explain how the magnitude of the Young's modulus is obtained from the graph.
(The graph should be stress-strain with a linear portion up to the elastic limit, followed by a curve at the yield point.)
Young's modulus is obtained from the slope of the initial linear region using
E = stress / strain = $(F/A) / (\Delta L/L)$.

(b) A block of metal weighing 20 N with a volume of 8×10^{-4} m³ is completely immersed in oil of density 700 kg/m³ then attached to one end of a vertical wire of length 4.0 m and diameter 0.6 mm whose other end is fixed. If the length of the wire is increased by 1.0 mm, find the:
(i) young's modulus of the wire.
Buoyant force
$F_b = \rho g V$
$= 700 \times 9.81 \times 8 \times 10^{-4}$
$= 5.5$ N
Effective weight
$W_{eff} = 20 - 5.5$
$= 14.5$ N
Using Young's modulus formula
$E = (F L) / (A \Delta L)$
$A = \pi d^2/4 = \pi(0.6 \times 10^{-3})^2/4$
$= 2.83 \times 10^{-7}$ m²
$E = (14.5 \times 4.0) / (2.83 \times 10^{-7} \times 1.0 \times 10^{-3})$
$E \approx 2.04 \times 10^{11}$ N/m²
(ii) energy stored in the wire.
$U = 0.5 (F \Delta L)$
$U = 0.5 \times 14.5 \times 1.0 \times 10^{-3}$
$U \approx 7.25 \times 10^{-3}$ J

(c) A rubber cord of a Y-shaped object has a cross-sectional area of 4×10^{-6} m² and relaxation length of 100 mm. If the arms of the catapult are 70 mm apart, calculate the:
(i) tension in the rubber.

$L = \text{sqrt}((100)^2 + (70)^2) = 122.1$ mm
Strain = (122.1 - 100) / 100
= 0.221
Tension = Y × strain × A
Assuming $Y = 3 \times 10^6$ N/m²
$T = 3 \times 10^6 \times 0.221 \times 4 \times 10^{-6}$
$T \approx 2.65$ N
(ii) force required to stretch it when the rubber cord is pulled back until its length doubles.
New length = 2 × 100 = 200 mm
Strain = (200 - 100) / 100
= 1
F = Y × strain × A
$F = 3 \times 10^6 \times 1 \times 4 \times 10^{-6}$
$F \approx 12$ N

3. (a) (i) Briefly give comments on the following observations:
Polyatomic and diatomic gases have larger molar heat capacities than monatomic gases.
This is because polyatomic and diatomic gases have additional degrees of freedom for rotation and vibration, requiring more energy per mole.
(ii) Cubical container is used for the derivation of pressure of an ideal gas.
A cube simplifies analysis as molecules collide perpendicularly with walls, making it easier to derive pressure using kinetic theory.

(b) (i) What is meant by a gas constant.
Gas constant (R) is a proportionality constant in the ideal gas equation PV = nRT, representing the energy per mole per Kelvin.
(ii) Helium gas occupies a volume of 4×10^2 m³ at a pressure of 2×10^3 Pa and temperature of 300 K. Calculate the mass of helium and the r.m.s speed of its molecules.
Using PV = nRT
n = PV / RT
$= (2 \times 10^3 \times 4 \times 10^2) / (8.314 \times 300)$
$n \approx 322.1$ moles
Mass of helium = n × molar mass
= 322.1 × 4
= 1288.4 g = 1.288 kg
RMS speed
$v_{rms} = \text{sqrt}(3RT/M)$
$= \text{sqrt}(3 \times 8.314 \times 300 / (4 \times 10^{-3}))$
$v_{rms} \approx 1257$ m/s

(c) (i) When a gas expands adiabatically it does work on its surroundings although there is no heat input to the gas. Explain where this energy is coming from.

The energy comes from the internal energy of the gas, leading to a drop in temperature as work is done on the surroundings.

(ii) An ideal gas at 17°C and 750 mmHg is compressed isothermally until its volume is reduced to ¾ of its initial value. If it then allowed to expand adiabatically to a volume of 20% greater than its original value, calculate the final temperature and pressure of the gas.

Given:

Initial temperature, $T_1 = 17°C = 17 + 273 = 290$ K

Initial pressure, $P_1 = 750$ mmHg $= 750 \times 133.322$ Pa $= 99991.5$ Pa

Initial volume, $V_1 = 1$ (assume for ratio calculations)

Step 1: Isothermal Compression

Final volume after compression, $V_2 = 3/4 \times V_1 = 0.75 V_1$

Since the process is isothermal, we use

$P_1V_1 = P_2V_2$

$P_2 = P_1 \times (V_1/V_2)$

$P_2 = 99991.5 \times (1/0.75)$

$P_2 = 133322$ Pa

Step 2: Adiabatic Expansion

Final volume after expansion, $V_3 = 1.2 \times V_1$

For an adiabatic process, the temperature follows

$T_3 = T_1 \times (V_2/V_3)^{(\gamma - 1)}$

For a diatomic gas (air-like behavior), $\gamma = 1.4$

$T_3 = 290 \times (0.75/1.2)^{(1.4 - 1)}$

$T_3 = 290 \times (0.625)^{0.4}$

$T_3 \approx 240.3$ K

For pressure, we use

$P_3 = P_2 \times (V_2/V_3)^{\gamma}$

$P_3 = 133322 \times (0.75/1.2)^{1.4}$

$P_3 = 133322 \times (0.625)^{1.4}$

$P_3 \approx 69045.3$ Pa

Final temperature after expansion: 240.3 K

Final pressure after expansion: 69045.3 Pa

4.(a)(i) How does the first law of thermodynamics change under isothermal and adiabatic processes?

For an isothermal process, temperature remains constant, so the internal energy does not change ($\Delta U = 0$). The first law simplifies to

$Q = W$

For an adiabatic process, no heat is exchanged ($Q = 0$), so the first law simplifies to

$\Delta U = -W$

(b)(i) Show that the specific heat capacities of an ideal gas are related by the relation
$Cp = Cv + nR$
From the first law of thermodynamics,
$dQ = dU + PdV$
For constant volume, $dV = 0$, so
$dQ = dU$
Thus, heat capacity at constant volume is
$Cv = dU/dT$
For an ideal gas,
$dU = nCv\ dT$
For constant pressure, the heat added is
$dQ = dU + PdV$
Since for an ideal gas, $PdV = nR\ dT$,
$Cp\ dT = Cv\ dT + nR\ dT$
Dividing throughout by dT,
$Cp = Cv + nR$

(ii) Explain the meaning of all the symbols used in the equation (b)(i) above.
Cp = heat capacity at constant pressure
Cv = heat capacity at constant volume
n = number of moles of the gas
R = universal gas constant

(c)One mole of an ideal monatomic gas is heated at constant volume from the temperature of 300 K to 600 K. Calculate the:
(i) amount of heat added
For a monatomic ideal gas,
$Cv = (3/2)R$
Using $Q = nCv\Delta T$
$Q = (1) \times (3/2 \times 8.314) \times (600 - 300)$
$Q = (1.5 \times 8.314 \times 300)$
$Q \approx 3741$ J

(ii) work done by the gas
For a constant volume process, work done
$W = P\Delta V = 0$

(iii) change in its internal energy
$\Delta U = nCv\Delta T$
$\Delta U = 3741$ J

(d)

The piston of a bicycle pump at room temperature of 290 K is slowly moved in until the volume of air enclosed is one-fifth of the total volume of the pump. The outlet is then sealed and the piston suddenly drawn out to full extension. If no air passes the piston, find the temperature of the air in the pump immediately after withdrawing the piston, assuming that air is an ideal gas with cryoscopic constant, $\gamma = 1.4$.

Using the adiabatic relation

$T2 = T1 (V2/V1)^{(\gamma-1)}$

$T2 = 290 \times (1/5)^{(0.4)}$

$T2 \approx 165$ K

5. (a)

(i) What is meant by crossed polaroids?

Crossed polaroids are two polaroid filters placed perpendicular to each other, blocking all light transmission when perfectly aligned at 90°.

(ii) Briefly describe the appearance of fringes produced by monochromatic light.

Monochromatic light passing through a diffraction or interference setup produces bright and dark fringes. The bright fringes correspond to constructive interference, while dark fringes correspond to destructive interference.

(b)(i) Give two differences between diffracting grating spectra and prism spectra.

- A diffraction grating spectrum is formed due to interference of waves, whereas a prism spectrum is due to dispersion.
- A diffraction grating produces well-defined spectral lines, while a prism spectrum is continuous and more spread out.

(ii) A diffraction grating used at normal incidence gives a yellow line, $\lambda = 5750$ Å in a certain spectral order superimposed on a blue line, $\lambda = 4600$ Å of the next higher order. If the angle of diffraction is 30°, what is the spacing between the grating lines?

Using the grating equation

$n\lambda = d \sin\theta$

For yellow light,

$n(5750 \times 10^{-10}) = d \sin(30°)$

For blue light in the next order,

$(n+1)(4600 \times 10^{-10}) = d \sin(30°)$

Solving for d,

$d \approx 1.15 \times 10^{-6}$ m

(c)

(i) State Huygens principle of wave construction.

Every point on a wavefront acts as a secondary source of spherical wavelets, and the new wavefront is formed by the envelope of these wavelets.

(ii) A thin wedge of air of small angle is enclosed by two thin glass plates. When the plates are illuminated by a parallel beam of monochromatic light of wavelength 589 nm, the distance apart of the fringes is 0.8 mm. Calculate the angle of the wedge.

Using

$\theta = \lambda / (2d)$

$\theta = (589 \times 10^{-9}) / (2 \times 0.8 \times 10^{-3})$

$\theta \approx 3.68 \times 10^{-4}$ radians

6.(a)

(i) Explain why it is better to use a small current for a long time to plate a metal with a given thickness of silver than using a larger current for a short time.

A small current ensures uniform deposition, reducing roughness and preventing overheating, which can cause uneven plating.

(ii) Give four differences between the passage of electricity through metals and ionized solution.

- In metals, conduction is due to free electrons, while in ionized solutions, conduction is due to ions.
- Metals have a high electrical conductivity, while ionized solutions have lower conductivity.
- Metals do not undergo chemical change, while ionized solutions undergo electrolysis.
- Metals have a fixed resistance, while resistance in ionized solutions depends on ion concentration.

(b)

(i) Define electric discharge and give one example.

Electric discharge is the flow of electric current through a gas. An example is lightning.

(ii) A milliammeter connected in series with a hydrogen discharge tube indicates a current of 1.0×10^{-3} A. If the number of electrons passing the cross-section of the tube at a particular point is 4.0×10^{15} per second, find the number of protons that pass the same cross-section per second.

Charge per electron = 1.602×10^{-19} C

Current I = nq

$1.0 \times 10^{-3} = (4.0 \times 10^{15}) \times (1.602 \times 10^{-19}) + (Np \times 1.602 \times 10^{-19})$

Solving for Np,

$Np \approx 2.24 \times 10^{12}$

(c)

A silver and copper voltammeter are connected in parallel across a 6 V battery of negligible internal resistance. In half an hour 1.0 g of copper and 2.0 g of silver are deposited. Calculate the rate at which the energy is supplied by the battery.

Energy supplied per second,

P = VI

Using Faraday's law,

m = (ZIt)

I = m / (Zt)

For copper,

$Z\_Cu = 3.3 \times 10^{-7}$ kg/C
$I\_Cu = (1.0) / (3.3 \times 10^{-7} \times 1800)$
$I\_Cu \approx 1.68$ A
For silver,
$Z\_Ag = 1.118 \times 10^{-6}$ kg/C
$I\_Ag = (2.0) / (1.118 \times 10^{-6} \times 1800)$
$I\_Ag \approx 0.99$ A
Total current, $I = I\_Cu + I\_Ag = 2.67$ A
Power supplied by battery,
$P = 6 \times 2.67$
$P \approx 16.02$ W

7. (a)(i) State Lenz's law of electromagnetic induction.
Lenz's law states that the direction of an induced current is always such that it opposes the change in magnetic flux that caused it. This means that if a changing magnetic field induces a current in a loop, the induced current produces its own magnetic field that counteracts the original change.

(ii) An aircraft is flying horizontally at 200 m/s through the region where the vertical component of the earth magnetic field is 4.0×10^{-5} T. If the aircraft has a wing span of 40 m, what will be the potential difference (p.d) produced between the wing tips?
The induced potential difference (emf) in a moving conductor is given by
$\varepsilon = B\, l\, v$
where
$B = 4.0 \times 10^{-5}$ T (magnetic field),
$l = 40$ m (wing span),
$v = 200$ m/s (velocity of aircraft).

Substituting the values:
$\varepsilon = (4.0 \times 10^{-5}) \times (40) \times (200)$
$\varepsilon = 0.32$ V

(b)(i) A toroid of inner radius 25 cm and an outer radius of 28 cm has 4500 turns of wound around it which passes a current of 12 A. What will be the induction of the magnetic flux, outside the toroid.
The magnetic field outside a toroid is zero because the circular symmetry of the toroidal coil confines the magnetic field within itself.

(ii) inside the core of the toroid.
The magnetic field inside the toroid is given by Ampere's Law:
$\oint B\, dl = \mu_0 N I$
where
$B (2\pi r) = \mu_0 N I$
Solving for B,
$B = (\mu_0 N I) / (2\pi r)$

where
$\mu_0 = 4\pi \times 10^{-7}$ Tm/A (permeability of free space),
N = 4500 (number of turns),
I = 12 A (current),
r = (0.25 + 0.28) / 2 = 0.265 m (average radius).

Substituting the values:
$B = (4\pi \times 10^{-7} \times 4500 \times 12) / (2\pi \times 0.265)$
$B = (2.16 \times 10^{-2}) / (0.53)$
$B \approx 0.102$ T

(iii) in an empty space surrounding the toroid.
The magnetic field outside a toroid is zero, as the field lines remain confined within the toroidal structure.

(c)(i) Derive an expression for impedance of a series R - C circuit.
In an AC circuit containing a resistor R and a capacitor C in series, the total impedance Z is given by
$Z = \sqrt{(R^2 + Xc^2)}$
where
$Xc = 1/(\omega C) = 1/(2\pi fC)$
Thus,
$Z = \sqrt{(R^2 + (1/(2\pi fC))^2)}$

(ii) An alternating current (a.c) of 0.2 A r.m.s and frequency of 100/2π Hz flow in a circuit containing a series arrangement of a resistor R of resistance 20 Ω, an inductor L of 0.15 H and a capacitor C of capacitance 500 μF. Calculate the resultant potential difference (p.d) and the impedance of the circuit.
First, calculate angular frequency:
$\omega = 2\pi f$
$= 2\pi \times (100/2\pi)$
= 100 rad/s

Inductive reactance:
$X_L = \omega L$
$= 100 \times 0.15$
= 15 Ω

Capacitive reactance:
$X_C = 1 / (\omega C)$
$= 1 / (100 \times 500 \times 10^{-6})$
= 1 / 0.05
= 20 Ω

Impedance of the circuit:
$Z = \sqrt{(R^2 + (X_L - X_C)^2)}$

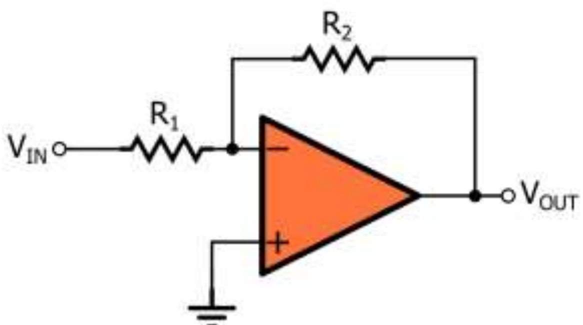
$= \sqrt{(20^2 + (15 - 20)^2)}$
$= \sqrt{(400 + 25)}$
$= \sqrt{425}$
$Z \approx 20.6\ \Omega$

Potential difference:
$V = IZ$
$= 0.2 \times 20.6$
$V \approx 4.12$ V

8. (a)(i) What is meant by transistor action?
Transistor action refers to the ability of a small input current at the base of a transistor to control a much larger current flowing between the collector and the emitter. This amplification property makes transistors essential in electronic circuits for switching and signal amplification.

(ii) Briefly explain why the collector of a transistor is made wider than the emitter and base?
- The collector is made wider to handle more power dissipation and prevent overheating.
- The wider collector reduces recombination, ensuring efficient charge carrier flow.
- A larger collector area improves heat dissipation and prevents breakdown due to excessive current.

(b)(i) Draw a well labeled circuit diagram of an inverting amplifier.



A well-labeled diagram of an operational amplifier in inverting mode should be drawn, showing the input resistor, feedback resistor, and output voltage.

(ii) Derive the closed-loop gain A of an inverting amplifier. If the input resistor is equal to the feedback resistor, what would be the value of the gain A.
Given,
Vin / Rin = -Vout / Rf

Rearranging for gain A:
A = Vout / Vin = -Rf / Rin
For Rf = Rin:
A = -Rin / Rin
A = -1

For an inverting amplifier, the gain A is given by
A = - (Rf / Rin)
If Rf = Rin, then
A = -1
(c)(i) Mention one application of LED. What type of a semiconductor is it?
Application: Used as indicator lights in electronic circuits.
Type: A direct bandgap semiconductor.

(ii) Write down two advantages of digital circuits over the analogue circuits.
1. Digital circuits are less affected by noise and provide higher accuracy.
2. Digital circuits allow easier data storage and processing in computers.

(iii) Truth table

A	B	C	D = A + B (OR)	F = D · C (AND)
0	0	0	0	0
0	0	1	0	0
0	1	0	1	0
0	1	1	1	1
1	0	0	1	0
1	0	1	1	1
1	1	0	1	0
1	1	1	1	1

9. (a)(i) Distinguish between white spectrum and line spectrum.
White spectrum contains all visible wavelengths forming a continuous spectrum, whereas line spectrum consists of discrete lines corresponding to specific wavelengths emitted or absorbed by atoms.

(ii) If the energy necessary to cause the ejection of an electron by photoelectric effect from the N - shell and K - shell of an atom is 10 eV and 20 eV respectively, calculate the maximum wavelength of radiation for each level.
Using the equation
$E = hc/\lambda$

For N-shell:
$\lambda = hc / E$
$= (6.626 \times 10^{-34} \times 3.0 \times 10^{8}) / (10 \times 1.602 \times 10^{-19})$
$= (1.9878 \times 10^{-25}) / (1.602 \times 10^{-18})$
$= 1.24 \times 10^{-7}$ m or 124 nm
For K-shell:
$\lambda = hc / E$
$= (6.626 \times 10^{-34} \times 3.0 \times 10^{8}) / (20 \times 1.602 \times 10^{-19})$
$= (1.9878 \times 10^{-25}) / (3.204 \times 10^{-18})$
$= 6.2 \times 10^{-8}$ m or 62 nm

(b)(i) What is the significance of the binding energy per nucleon?
Binding energy per nucleon indicates the stability of a nucleus. A higher value means the nucleus is more stable and requires more energy to be broken apart.

(ii) The nucleus of iron, $^{57}_{26}Fe$ with a mass of 56.935 a.m.u emits a γ - ray radiation of 14.4×10^3 eV. Calculate its recoil energy.
Using the recoil energy equation:
$E_{recoil} = (E_\gamma)^2 / (2Mc^2)$

Given:
$E_\gamma = 14.4 \times 10^3$ eV $= 14.4 \times 10^3 \times 1.602 \times 10^{-19}$ J
$M = 56.935$ a.m.u $\times 1.66 \times 10^{-27}$ kg/a.m.u
$c = 3.0 \times 10^8$ m/s

Substituting values:
$M = 56.935 \times 1.66 \times 10^{-27}$
$= 9.45 \times 10^{-26}$ kg

$E_{recoil} = ((14.4 \times 10^3 \times 1.602 \times 10^{-19})^2) / (2 \times 9.45 \times 10^{-26} \times (3.0 \times 10^8)^2)$
$= (3.32 \times 10^{-28}) / (5.67 \times 10^{-19})$
$\approx 5.86 \times 10^{-10}$ J

(c) Given that Rydberg's constant is approximately 1.1×10^7 m^{-1}. Calculate the corresponding range of frequency for emitted radiation in the:

(i) Lyman series
Using the Rydberg equation:
$1/\lambda = RZ^2 (1/n_1^2 - 1/n_2^2)$
For Lyman series, $n_1 = 1$, $n_2 \rightarrow \infty$, $Z = 1$ for hydrogen

$1/\lambda = 1.1 \times 10^7 (1 - 0)$
$\lambda = 1 / (1.1 \times 10^7)$
$\lambda = 9.09 \times 10^{-8}$ m

Using $f = c / \lambda$:
$f = (3.0 \times 10^8) / (9.09 \times 10^{-8})$
$f \approx 3.3 \times 10^{15}$ Hz

(ii) Balmer series
For Balmer series, $n_1 = 2$, $n_2 \rightarrow \infty$

$1/\lambda = 1.1 \times 10^7 (1/2^2 - 0)$
$1/\lambda = 1.1 \times 10^7 \times 1/4$

$\lambda = 4 / (1.1 \times 10^7)$
$\lambda = 3.64 \times 10^{-7}$ m

Using $f = c / \lambda$:
$f = (3.0 \times 10^8) / (3.64 \times 10^{-7})$
$f \approx 8.24 \times 10^{14}$ Hz

10. (a)(i) Describe a simple test which could confirm the emission of β - particles and γ - radiation.
A Geiger-Müller counter detects β-particles, showing increased count rate when placed near the source. To confirm γ-radiation, place a lead sheet; β-particles will be blocked while γ-radiation still registers on the counter.

(ii) What will happen to the nucleus of the new isotope after the emission of γ-radiation?
The nucleus remains the same element but moves to a lower energy state.

(iii) Find the decay constant of the isotope.
Decay constant is given by:
$\lambda = \ln(2) / T_{1/2}$

$T_{1/2}$ = 135 days = 135 × 24 × 3600 s
$\lambda = (0.693) / (135 \times 24 \times 3600)$
$\lambda \approx 5.95 \times 10^{-7}\ s^{-1}$

(b)(i) Briefly explain why the β - particles emitted from a radioactive source differ from the electrons obtained by thermionic emission?
Beta particles originate from the nucleus due to neutron decay, whereas thermionic electrons come from the atomic shell when heated. Beta particles have higher energy and speed than thermionic electrons.

(ii) The mass of a particular radioisotope in a sample is initially 6.4×10^{-3} kg. After 42 days the isotope was separated from the sample and found to have a mass of 1.0×10^{-3} kg. Calculate the half-life of the isotope.
Using the decay equation:
$N = N_0 (1/2)^{(t/T_{1/2})}$

$1.0 \times 10^{-3} = 6.4 \times 10^{-3} (1/2)^{(42/T_{1/2})}$
$(1/2)^{(42/T_{1/2})} = 1.0 / 6.4$
$(1/2)^{(42/T_{1/2})} = 0.15625$

Taking log on both sides:
$\log(0.15625) = (42/T_{1/2}) \log(0.5)$
$-0.8062 = (42/T_{1/2}) \times (-0.301)$

$T_{1/2} = 42 \times 0.301 / 0.8062$

$T_{1/2} \approx 15.7$ days

(c)(i) Define the activity of a nuclide.
Activity is the rate at which a radioactive sample undergoes decay, measured in becquerels (Bq) or curies (Ci).

(ii) A radioactive sample whose disintegration product is non-radioactive has an activity of 5×10^{11} curie at a certain time. At this time an α - particle detector showed a count rate of 32 s^{-1} but after 10 days the count rate dropped to 8 s^{-1}. Calculate the half-life and the number of nuclei which will remain after 100 days.

Using the decay formula:
$A = A_0 (1/2)^{(t/T_{1/2})}$
$8 = 32 (1/2)^{(10/T_{1/2})}$
$(1/2)^{(10/T_{1/2})} = 8/32$
$(1/2)^{(10/T_{1/2})} = 0.25$

Taking log on both sides:
$\log(0.25) = (10/T_{1/2}) \log(0.5)$
$-0.6021 = (10/T_{1/2}) \times (-0.301)$

$T_{1/2} = 10 \times 0.301 / 0.6021$
$T_{1/2} \approx 5$ days

Number of nuclei remaining after 100 days:
$N = N_0 (1/2)^{(100/5)}$
$N = N_0 (1/2)^{20}$
$N = N_0 \times 9.54 \times 10^{-7}$