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: 2001**

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) What do you understand by

(i) gravitational intensity
Gravitational intensity at a point is the gravitational force experienced per unit mass at that point. It is given by

$g = GM / r^2$

where G is the gravitational constant, M is the mass of the celestial body, and r is the distance from the center of the mass.

(ii) gravitational potential
Gravitational potential at a point is the work done in bringing a unit mass from infinity to that point in the gravitational field. It is given by

$V = - GM / r$

(iii) How are gravitational intensity and gravitational potential related?
Gravitational intensity g is the negative gradient of gravitational potential V:
$g = - dV / dr$

(b) Taking the earth to be a uniform sphere of radius 6400 km, and the value of g at the surface to be 9.8 m/s^2, calculate the total energy needed to raise a satellite of 2000 kg into orbit at an altitude of 8000 km.
Total energy required is the sum of kinetic and potential energy:
$E = GMm / 2r - GMm / R$

Given:
$M = 5.97 \times 10^{24}$ kg
$m = 2000$ kg
$R = 6400$ km $= 6.4 \times 10^6$ m
$r = 6400 + 8000 = 14400$ km $= 1.44 \times 10^7$ m
$G = 6.67 \times 10^{-11}$ Nm^2/kg^2

$E = (6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 2000) / (2 \times 1.44 \times 10^7) - (6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 2000) / 6.4 \times 10^6$

$E = (7.96 \times 10^{16}) / (2.88 \times 10^7) - (7.96 \times 10^{16}) / (6.4 \times 10^6)$
$E = 2.77 \times 10^9 - 1.24 \times 10^{10}$
$E = -9.62 \times 10^9$ J
Thus, the total energy needed is 9.62×10^9 J.

(c) (i) Explain the term "parking orbit" of a satellite.

A parking orbit is a stable orbit where a satellite moves at the same angular velocity as the Earth's rotation, remaining fixed relative to a point on Earth's surface. It is commonly used for communication and weather satellites.

(ii) Explain briefly how the satellite is sent into orbit when the intended altitude has been reached. What would happen if this procedure of putting a satellite in an orbit failed to come into effect?

A satellite is first launched vertically to clear the dense atmosphere and then tilted into a horizontal trajectory where a booster rocket provides the necessary velocity to maintain a stable orbit.
If the satellite fails to gain the required orbital velocity, it will fall back to Earth due to gravity. If the velocity is too high, it may escape Earth's gravitational pull and move into space.

2. (a) Write down the formula for the viscous drag force on a sphere falling in a fluid as stated by Stokes. Explain the symbols used.

The Stokes' law formula is:

$F = 6\pi\eta rv$
where
F = viscous drag force
η = coefficient of viscosity of the fluid
r = radius of the sphere
v = velocity of the sphere

(b) (i) When a sphere in a liquid starts to move from rest, what are the magnitudes and directions of the forces acting on it?

- Gravitational force (mg) acting downward.
- Buoyant force acting upward due to displacement of fluid.
- Viscous drag acting opposite to motion.

(ii) Why does the sphere in (i) above has an initial acceleration?

Initially, when the sphere is released, the net force acting on it is nonzero because the viscous drag is minimal at low speeds. This results in an initial acceleration given by Newton's second law:

$a = (mg - F_b - F_d) / m$

(iii) How do the forces change as the velocity of the sphere increases?
- The gravitational force remains constant.
- The buoyant force remains constant.
- The viscous drag increases as velocity increases.
- Eventually, the net force becomes zero, and the sphere moves at terminal velocity.

3. (a) (i) What is the difference between an isothermal and an adiabatic process?

An isothermal process occurs at constant temperature, where heat exchange with surroundings keeps temperature unchanged.
An adiabatic process occurs with no heat exchange; all work done results in temperature change.

(ii) Show that an adiabatic change follows an adiabatic equation.

For an adiabatic process:

PV^γ = constant

Using the first law of thermodynamics:

$dU = dQ - dW$

Since $dQ = 0$,

$dU = - PdV$

Using the relation for internal energy of an ideal gas,

$\gamma PV dV = - dU$

Integrating both sides leads to

PV^γ = constant

(b) (i) Distinguish between the specific heat capacity and the molar heat capacity. Give the units of each.

Specific heat capacity (C) is the heat required to raise the temperature of 1 kg of a substance by 1 K, measured in J/kgK.
Molar heat capacity (C_m) is the heat required to raise the temperature of 1 mole of a substance by 1 K, measured in J/molK.

(ii) Calculate the two principal molar heat capacities of oxygen and explain why the specific heat capacity of the gas at constant pressure is greater than that at constant volume.

Using the relation:
$C_p - C_v = R$

For oxygen (diatomic gas), R = 8.314 J/molK

The degrees of freedom for a diatomic gas:

$C_v = (5/2) R = (5/2) \times 8.314 = 20.785$ J/molK

$C_p = (7/2) R = (7/2) \times 8.314 = 29.099$ J/molK

C_p is greater than C_v because at constant pressure, heat is used to expand the gas as well as increase internal energy, whereas at constant volume, all heat contributes only to internal energy.

(c) (i) What is a reversible change? State the condition for a reversible change to occur.

A reversible change is a process that can be reversed without leaving any net change in the system and surroundings.
Condition: The system must be in thermodynamic equilibrium throughout the process.

(ii) A litre of air at 10^5 Pa pressure expands adiabatically and reversibly to twice its volume. Calculate the work done by the gas.

Work done in an adiabatic process is:

$W = (P_1V_1 - P_2V_2) / (\gamma - 1)$

Given:
$P_1 = 10^5$ Pa, $V_1 = 1$ L $= 10^{-3}$ m^3
$V_2 = 2 \times V_1 = 2 \times 10^{-3}$ m^3
$\gamma = 1.4$ for air

Using PV^γ = constant:

$P_2 = P_1 (V_1 / V_2)^\gamma$
$P_2 = 10^5 \times (10^{-3} / 2 \times 10^{-3})^{1.4}$
$P_2 = 10^5 \times (0.5)^{1.4}$
$P_2 \approx 3.78 \times 10^4$ Pa

Work done:

$W = (10^5 \times 10^{-3} - 3.78 \times 10^4 \times 2 \times 10^{-3}) / (1.4 - 1)$
$W = (100 - 75.6) / 0.4$
$W \approx 61$ J

The work done by the gas is approximately 61 J.

4. (a) (i) What do you understand by an ideal gas?

An ideal gas is a hypothetical gas that follows the ideal gas equation $PV = nRT$ at all temperatures and pressures, assuming no intermolecular forces and perfectly elastic collisions between molecules.

(ii) Derive the expression $P = (1/3) \rho c^2$ for an ideal gas where

P = pressure of the gas
ρ = density of the gas
c^2 = mean square speed

The kinetic theory of gases states that the pressure exerted by gas molecules on the walls of a container is due to collisions.

Consider a cubic container of side L containing N gas molecules of mass m moving with velocity components (v_x, v_y, v_z).

The change in momentum for a single collision along one wall is:

$\Delta p = 2 m v_x$

Time taken between successive collisions with the same wall is:

$t = 2L / v_x$

Force exerted by one molecule:

$F = \Delta p / t = (2 m v_x) / (2L / v_x) = (m v_x^2) / L$

Total force by N molecules:

$F_{total} = \Sigma (m v_x^2) / L$

Since molecules are moving in all directions equally, the mean square velocity components are:

$v_x^2 = v_y^2 = v_z^2 = (1/3) c^2$

where c^2 is the mean square speed.

Thus, total pressure:

$P = (1/3) (Nm/L^3) c^2 = (1/3) \rho c^2$

(b) The Doppler broadening of a spectral line is proportional to the root mean square speed (r.m.s) of the atoms emitting light. Which source has less Doppler broadening; a mercury lamp at 300 K or a krypton lamp at 77 K?

Doppler broadening depends on the thermal motion of emitting atoms, given by:

$c_{rms} = \sqrt{(3 k T / m)}$

Since krypton is at a lower temperature (77 K), its atoms move slower compared to mercury at 300 K, resulting in less Doppler broadening.

Thus, the krypton lamp at 77 K has less Doppler broadening than the mercury lamp at 300 K.

5. (a) (i) What is a Brewster angle?
Brewster's angle is the angle of incidence at which light reflected from a surface is completely polarized perpendicular to the plane of incidence. It is given by:

$\tan \theta_B = n_2 / n_1$

where n_1 and n_2 are the refractive indices of the two media.

(ii) Name one effect which could not be explained by Huygens' wave theory.

The photoelectric effect cannot be explained by Huygens' wave theory, as it requires a particle-like nature of light, which was explained by Einstein using quantum mechanics.

(b) (i) Why is it necessary to use satellites for long-distance TV transmission?

Satellites are necessary because the Earth's curvature obstructs direct line-of-sight transmission for long distances. Satellites act as repeaters, receiving and retransmitting signals over large areas.

(ii) Why does a thin film of oil on the surface of water appear colored?

Thin film interference occurs due to the varying thickness of the oil film. Light waves reflecting from the top and bottom surfaces of the film interfere constructively and destructively at different wavelengths, creating color patterns.

(c) In a Young's slit experiment, the distance of the screen from the two slits is 1.0 m. When light of wavelength 6000 Å is allowed to fall on the slits, the width of the fringes obtained on a screen is 2.0 mm.

Determine

(i) the distance between the slits

The fringe width is given by:

$\Delta y = \lambda D / d$

where
Δy = fringe width = 2.0 mm = 2.0×10^{-3} m
λ = 6000 Å = 6000×10^{-10} m = 6.0×10^{-7} m
D = 1.0 m

Rearranging for d:

$d = \lambda D / \Delta y$
$d = (6.0 \times 10^{-7} \times 1.0) / (2.0 \times 10^{-3})$
$d = 3.0 \times 10^{-4}$ m

The distance between the slits is 0.3 mm.

(ii) the width of the fringes if the wavelength of the incident light is 4800 Å

New fringe width:

$\Delta y' = (\lambda' D) / d$

where λ' = 4800 Å = 4.8×10^{-7} m

$\Delta y' = (4.8 \times 10^{-7} \times 1.0) / (3.0 \times 10^{-4})$
$\Delta y' = 1.6 \times 10^{-3}$ m

The fringe width is 1.6 mm.

(d) The wavelength of a particular line in the emission of a distant star is measured as 600.80 nm. The true wavelength is 600.00 nm.

(i) Is the star moving away from or towards the observer?

Using the Doppler shift formula:

$\Delta\lambda / \lambda = v / c$

where
$\Delta\lambda = \lambda_{observed} - \lambda_{actual}$ = 600.80 - 600.00 = 0.80 nm

λ_actual = 600.00 nm
$c = 3.0 \times 10^8$ m/s

Since the observed wavelength is longer than the actual wavelength, the star is moving away from the observer (redshift).

(ii) Calculate the speed of the star.

$v = (\Delta\lambda / \lambda)\, c$

$v = (0.80 / 600.00) \times (3.0 \times 10^8)$
$v = (1.33 \times 10^{-3}) \times (3.0 \times 10^8)$
$v = 4.0 \times 10^5$ m/s
The star is moving away at 400 km/s.

6. (a) (i) What is meant by 'specific charge' of an ion? Give the SI units of specific charge.

Specific charge of an ion is the ratio of its charge to its mass. It is given by:
specific charge = q / m
where q is the charge and m is the mass of the ion.
SI unit: Coulombs per kilogram (C/kg).

(ii) An accumulator battery of emf 50 V and internal resistance 2 Ω is charged on a 100 V d.c. source. What series resistance will be required to give a charging current of 2 A?

Using Kirchhoff's voltage law:

$V = E + Ir + IR$

where
V = 100 V
E = 50 V
I = 2 A
r = 2 Ω
R = series resistance

$100 = 50 + (2 \times 2) + (2 \times R)$
$100 = 50 + 4 + 2R$
$100 - 54 = 2R$
$R = 46 / 2$
$R = 23\ \Omega$
The required series resistance is 23 Ω.

(b) (i) State the laws of electrolysis.
Faraday's First Law: The mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed.
Faraday's Second Law: The mass of different substances deposited or liberated by the same quantity of electricity is proportional to their electrochemical equivalent.

(ii) If an electric current passes through a copper voltameter and a water voltameter in series, calculate the volume of hydrogen gas that will be liberated in the water voltameter at 25°C and 780 mmHg pressure whilst 5×10^{-5} kg of copper is deposited in the copper voltameter.

Using Faraday's laws,
$m_{Cu} / m_H = (E_{Cu} / E_H)$

where
mass of hydrogen deposited per Coulomb = 1.04×10^{-8} kgC^{-1}
mass of copper deposited per Coulomb = 3.3×10^{-7} kgC^{-1}

Charge passed:
Q = mass of copper / mass per Coulomb
$Q = (5 \times 10^{-5}) / (3.3 \times 10^{-7})$
Q = 0.1515 C
Mass of hydrogen deposited:

$m_H = Q \times (1.04 \times 10^{-8})$
$m_H = (0.1515) \times (1.04 \times 10^{-8})$
$m_H = 1.58 \times 10^{-9}$ kg

Using ideal gas equation to find volume:
PV = nRT

n = mass / molar mass = $(1.58 \times 10^{-9}) / (2.016 \times 10^{-3})$
$n = 7.83 \times 10^{-7}$ moles

V = nRT / P
P = 780 mmHg = 780×133.3 Pa
T = 25°C = 298 K
R = 8.314 J/molK

$V = (7.83 \times 10^{-7} \times 8.314 \times 298) / (780 \times 133.3)$
$V = (1.94 \times 10^{-3}) / (104\ 994)$
$V \approx 1.85 \times 10^{-8}\ m^3$
Volume of hydrogen gas liberated is 18.5 µL.

(c) (i) Briefly explain line spectra and how they are produced.
Line spectra are distinct lines of color or wavelengths emitted by an atom when electrons transition between energy levels. When an electron absorbs energy, it moves to a higher energy level. Upon returning to a lower level, it emits energy in the form of light, producing spectral lines unique to each element.
(ii) Draw an I-V characteristic for electric conduction in gases. Does it obey Ohm's law? Why?

The I-V characteristic for gases shows an initial low current, followed by a sharp increase after ionization. It does not obey Ohm's law because the conductivity depends on ionization levels, which increase with voltage.

(iii) Mention and explain the applications of line gaseous spectra.

1. Spectroscopy – Used to identify elements in stars and compounds based on unique spectral lines.
2. Neon and Fluorescent Lights– Gases emit characteristic spectra when excited by electricity.
3. Plasma Diagnostics – Helps study ionized gases in fusion reactors.
4. Chemical Analysis – Used in flame tests and forensic analysis.

7. (a) State the law of force acting on a conductor of length l carrying an electric current in a magnetic field.

The force F on a conductor of length l carrying current I in a magnetic field B is given by:
$F = B I l \sin \theta$
where θ is the angle between the conductor and the magnetic field.

(b) What is the magnetic field induction at the centre of a solenoid?
The magnetic field at the center of a solenoid is given by:

$B = \mu_0 n I$

where
μ_0 = permeability of free space ($4\pi \times 10^{-7}$ Tm/A)
n = number of turns per unit length
I = current in the solenoid

(c) It is desired to design a solenoid that will produce a magnetic field of 0.1 T at the centre. The radius of the solenoid is 5.0 cm, its length is 50 cm and it carries a current of 10 A. Calculate

(i) the number of turns per unit length that this solenoid could have

Using $B = \mu_0 n I$,

$0.1 = (4\pi \times 10^{-7})\, n\, (10)$

$n = (0.1) / ((4\pi \times 10^{-7}) \times 10)$
$n = (0.1) / (1.257 \times 10^{-5})$
$n = 7955$ turns per meter

(ii) the total length of the wire required

Total turns = $n \times$ length of solenoid

Total turns = 7955×0.50
Total turns = $3977.5 \approx 3980$ turns

Length of wire = number of turns × circumference of solenoid

$L = 3980 \times 2\pi (0.05)$
$L = 3980 \times 0.314$
$L \approx 1250$ m

Total length of wire required is approximately 1250 m.

(d) (i) State the Biot-Savart law.

The Biot-Savart law states that the magnetic field dB at a point due to an element of current-carrying conductor is given by:

$dB = (\mu_0 / 4\pi) (I\, dl \times \hat{r}) / r^2$

where
dB = small magnetic field
I = current
dl = small length element of the conductor
r = distance from the element
$\hat{r}$ = unit vector along r

(ii) In a hydrogen atom, an electron keeps moving around its nucleus with a constant speed of 2.18×10^6 m/s. Assuming the orbit to be circular of radius 5.3×10^{-11} m, determine the magnetic flux density B it produces at the site of a proton on the nucleus.

Magnetic field due to a moving charge:

$B = (\mu_0 / 4\pi) (q\, v) / r^2$

Given:
$\mu_0 = 4\pi \times 10^{-7}$ Tm/A

$q = 1.6 \times 10^{-19}$ C
$v = 2.18 \times 10^{6}$ m/s
$r = 5.3 \times 10^{-11}$ m

$B = (4\pi \times 10^{-7} / 4\pi) \times (1.6 \times 10^{-19} \times 2.18 \times 10^{6}) / (5.3 \times 10^{-11})^2$
$B = (10^{-7}) \times (3.49 \times 10^{-13}) / (2.81 \times 10^{-21})$
$B \approx 1.24$ T

(e) A capacitor of capacitance 10^{-6} F is used in a radio circuit. If the frequency of the circuit is 10^3 Hz and the current flowing in it is 2 mA r.m.s, calculate the voltage across the capacitor.

Reactance of the capacitor:

$X_C = 1 / (2\pi f C)$
$X_C = 1 / (2\pi \times 10^3 \times 10^{-6})$
$X_C = 159.15\ \Omega$

Voltage:
$V = I X_C$
$V = (2 \times 10^{-3}) \times (159.15)$
$V \approx 0.318$ V
8. (a) The circuit below is designed to switch on a light-emitting diode (LED) when darkness falls. The circuit uses a light-dependent resistor (LDR), which has a resistance greater than 1 MΩ in the dark but less than 1 kΩ when illuminated.

(i) Calculate the potential at the inverting input.
The inverting input is connected to a voltage divider consisting of a 40 kΩ resistor and a 20 kΩ resistor. The voltage at the inverting input is given by:

$V_{inverting} = (R_2 / (R_1 + R_2)) \times V_{supply}$
where
$R_1 = 40$ kΩ, $R_2 = 20$ kΩ, and $V_{supply} = 15$ V
$V_{inverting} = (20\ k\Omega / (40\ k\Omega + 20\ k\Omega)) \times 15$ V
$V_{inverting} = (20 / 60) \times 15$
$V_{inverting} = 5$ V

(ii) Calculate the approximate potential of the non-inverting input when the LDR is in the dark and when in the light.
The non-inverting input voltage is determined by the voltage divider formed by the LDR and the 10 kΩ resistor.

For LDR in darkness ($R_{LDR} = 1$ MΩ):
$V_{non\text{-}inverting\_dark} = (10\ k\Omega / (10\ k\Omega + 1\ M\Omega)) \times 15$ V

V_non-inverting_dark ≈ (10 / 1010) × 15
V_non-inverting_dark ≈ 0.15 V
For LDR in light (R_LDR = 1 kΩ):

V_non-inverting_light = (10 kΩ / (10 kΩ + 1 kΩ)) × 15 V
V_non-inverting_light = (10 / 11) × 15
V_non-inverting_light ≈ 13.6 V

(iii) Why does the LED light when darkness falls?
When it is dark, the resistance of the LDR increases, causing the non-inverting input voltage to drop below the inverting input voltage (5 V). Since the operational amplifier is configured as a comparator, the output goes high, turning on the transistor, which allows current to flow through the LED, making it light up.

(b) (i) Define a transistor and explain how it is made.
A transistor is a semiconductor device used to amplify or switch electronic signals. It consists of three layers of semiconductor material forming two p-n junctions. There are two main types:

- NPN transistor – A layer of p-type material between two n-type layers.
- PNP transistor – A layer of n-type material between two p-type layers.
  It is made by doping silicon or germanium with impurities to create regions of excess electrons (n-type) or holes (p-type).

(ii) Mention three uses of a transistor and the three different modes in which a transistor can be connected in the circuit by using the emitter (E), base (B), and collector (C).

Uses of a transistor:

- Amplification of signals in audio and radio circuits.
- Switching applications in digital electronics.
- Voltage regulation in power supply circuits.

Three connection modes:

- Common Emitter – Provides high gain and is commonly used in amplification.
- Common Base – Provides low input impedance and high output impedance, mainly used in RF circuits.
- Common Collector – Also called an emitter follower, used for impedance matching.

(c) (i) Develop truth tables showing the output X, Y, and Z for the given logic circuits.
For the first circuit:

Inputs A	B	X	Y	Z
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

For the second circuit:

Inputs A	B	X	Y	Z
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

The truth table is obtained by analyzing the behavior of AND, OR, and NOT gates in the circuit.

9. (a) (i) What are cathode rays?

Cathode rays are streams of high-speed electrons emitted from the negative electrode (cathode) in a vacuum tube when a high voltage is applied.

(ii) Mention six properties of cathode rays.

- Travel in straight lines in the absence of electric and magnetic fields.
- Carry a negative charge.
- Cause fluorescence when they strike certain materials.
- Produce heat when they strike a metal surface.
- Can be deflected by electric and magnetic fields.
- Possess momentum and can exert pressure on objects.

(b) (i) Define thermionic emission and explain why nowadays oxide-coated metal is preferred to tungsten as emitting material.

Thermionic emission is the process by which electrons are emitted from a heated metal surface due to thermal energy overcoming the work function.

Oxide-coated metals are preferred over tungsten because they have a lower work function, requiring less energy to emit electrons, making them more efficient.

(ii) A p.d. of 2 kV is maintained between a heated thermionic cathode and a collector electrode in a vacuum, the latter being more positive. Calculate the speed of the electrons striking the collector.

Using the energy conservation equation:

$eV = \frac{1}{2} m v^2$

Solving for v:

$v = \sqrt{(2eV / m)}$

Given:
$e = 1.6 \times 10^{-19}$ C
$V = 2000$ V
$m = 9.11 \times 10^{-31}$ kg

$v = \sqrt{(2 \times 1.6 \times 10^{-19} \times 2000 / 9.11 \times 10^{-31})}$
$v = \sqrt{(6.4 \times 10^{-16} / 9.11 \times 10^{-31})}$
$v = \sqrt{(7.02 \times 10^{14})}$
$v \approx 8.38 \times 10^{7}$ m/s

(iii) A beam of electrons enters into a field of potential 10^5 volts. Determine the velocity of the electrons accelerated through the potential.

Using the same formula:

$v = \sqrt{(2eV / m)}$

$V = 10^5$ V

$v = \sqrt{(2 \times 1.6 \times 10^{-19} \times 10^{5} / 9.11 \times 10^{-31})}$
$v = \sqrt{(3.2 \times 10^{-14} / 9.11 \times 10^{-31})}$
$v = \sqrt{(3.51 \times 10^{16})}$
$v \approx 1.87 \times 10^{8}$ m/s

(c) (i) Protons are made to rotate in a circular orbit of radius r at the moment they enter into a uniform magnetic field of flux density 0.8 T. If the charge-mass ratio of a proton is 1.0×10^8 C/kg, show that the number of revolutions per second of these protons does not depend on the radius (r) of the orbit and hence determine the frequency (f) of the proton in this field.

The centripetal force required for circular motion is provided by the magnetic force:

$q v B = m v^2 / r$

Simplifying:
$v / r = q B / m$

Since the angular velocity $\omega = v / r$,
$\omega = q B / m$

Frequency is given by:

$f = \omega / 2\pi = (q B) / (2\pi m)$

Since r does not appear, the frequency is independent of radius.

Substituting values:

$f = (1.0 \times 10^8 \times 0.8) / (2\pi)$
$f = (8 \times 10^7) / (6.28)$
$f \approx 1.27 \times 10^7$ Hz

(ii) In an experiment to determine the specific charge of an electron using Thomson's method, the stream of electrons from the cathode is accelerated through a p.d. of 1.5 kV and passes undeflected through both electric and magnetic fields which are perpendicular to one another to hit a fluorescent screen at the end of the tube.

If the electric field is provided by 2 parallel plates 2 cm apart joined to a p.d. of 400 V and the magnetic field provided by the Helmholtz's coil is 8.6×10^{-4} T, determine the specific charge of the electrons.

For undeflected motion:

$e/m = E^2 / (2V B^2)$

Electric field between plates:

$E = V/d = 400 / 0.02$
$E = 2 \times 10^4$ V/m

Substituting values:

$e/m = (2 \times 10^4)^2 / (2 \times 1.5 \times 10^3 \times (8.6 \times 10^{-4})^2)$
$e/m = (4 \times 10^8) / (2 \times 1.5 \times 10^3 \times 7.4 \times 10^{-7})$
$e/m = (4 \times 10^8) / (2.22 \times 10^{-3})$
$e/m \approx 1.8 \times 10^{11}$ C/kg

10. (a) (i) What is meant by quantization of energy?

Quantization of energy means that energy exists in discrete amounts or packets rather than being continuous. In atoms, electrons can only occupy specific energy levels, and transitions between them involve fixed energy quanta.

(ii) What is meant by wave-particle duality?

Wave-particle duality refers to the concept that particles, such as electrons and photons, exhibit both wave-like and particle-like properties. This is demonstrated by the double-slit experiment, where electrons produce an interference pattern, and the photoelectric effect, where light behaves as discrete photons.

(b) Define de-Broglie wavelength and find its value when the speed v is 10^5 m/s.

The de-Broglie wavelength is given by:

$\lambda = h / (m v)$

where $h = 6.63 \times 10^{-34}$ Js, $m = 9.11 \times 10^{-31}$ kg, and $v = 10^5$ m/s.

$\lambda = (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 10^5)$
$\lambda = (6.63 \times 10^{-34}) / (9.11 \times 10^{-26})$
$\lambda \approx 7.28 \times 10^{-9}$ m

(c) Figure 10 below shows the X-ray spectrum of an element. How can the following be explained?
(i) The line spectrum A
Line spectra are produced when electrons transition between specific energy levels in the atom, emitting X-rays of fixed wavelengths.

(ii) The continuous spectrum B
The continuous spectrum is caused by the deceleration of high-energy electrons as they interact with the target material, producing a broad range of X-ray wavelengths.

(iii) The wavelength cut-off C
The cut-off wavelength represents the minimum possible wavelength (or maximum energy) of the emitted X-rays, determined by the highest kinetic energy of incident electrons.

(d) What information was gained from Moseley's experiments on the wavelengths of the X-ray line spectra of elements?
Moseley's experiments showed that the frequency of X-ray spectral lines is proportional to the square of the atomic number (Z), leading to Moseley's law:
$\sqrt{f} = k (Z - b)$

This confirmed that atomic number is the fundamental property determining element identity, helping correct the periodic table.

(e) (i) What is the difference between fusion and fission?

Fusion: The process in which two light atomic nuclei combine to form a heavier nucleus, releasing energy.
Fission: The process in which a heavy nucleus splits into smaller nuclei, releasing energy.

(ii) Write down a nuclear reaction for the fission of ^{235}U into lanthanum and bromine. Calculate the total energy released by the fission of 1 kg of ^{235}U.

Fission reaction:

$^{235}U + {}^{1}n \rightarrow {}^{140}La + {}^{93}Br + 3\,{}^{1}n$ + Energy

Energy released per fission = 200 MeV

Total number of atoms in 1 kg of ^{235}U:

$N = (1000\ g) / (235\ g/mol) \times (6.022 \times 10^{23}\ atoms/mol)$
$N \approx 2.56 \times 10^{24}$ atoms

Total energy released:
$E = N \times 200\ MeV \times 1.6 \times 10^{-13}\ J/MeV$
$E = (2.56 \times 10^{24}) \times (3.2 \times 10^{-11})$
$E \approx 8.2 \times 10^{13}\ J$