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: 2017**

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)State Bernoulli's theorem for the horizontal flow.

Bernoulli's theorem states that for an ideal incompressible fluid flowing in a horizontal streamline, the sum of its pressure energy, kinetic energy, and potential energy per unit volume remains constant. Mathematically,

$p + \frac{1}{2} \rho v^2 + \rho g h = \text{constant}$

(ii)On which principle does the Bernoulli's theorem based.

Bernoulli's theorem is based on the principle of conservation of energy, which states that energy cannot be created or destroyed but can only be converted from one form to another.

(iii)A pipe is running full of water. At a certain point A, it tapers from 30 cm diameter to 10 cm diameter at B. The pressure difference between point A and B is 100 cm of water column. Find the rate of flow of water through the pipe.

Given:
$d_1 = 30$ cm = 0.3 m, $d_2 = 10$ cm = 0.1 m
$h = 100$ cm = 1 m
$g = 9.81$ m/s²
$\rho = 1000$ kg/m³

Using Bernoulli's equation:

$p_1 + \frac{1}{2} \rho v_1^2 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g h$

Since $p_1 - p_2 = \rho g h$,

$\rho g h = \frac{1}{2} \rho (v_2^2 - v_1^2)$

Cancelling ρ,

$g h = \frac{1}{2} (v_2^2 - v_1^2)$

$v_2 = (A_1 / A_2)\, v_1 = [(\pi/4)(0.3)^2] / [(\pi/4)(0.1)^2] \times v_1$

$v_2 = 9\, v_1$

Substituting into Bernoulli's equation:

$9.81 \times 1 = \frac{1}{2} (81\, v_1^2 - v_1^2)$

$9.81 = 40 v_1^2$
$v_1^2 = 9.81 / 40$
$v_1 = 0.5$ m/s

Flow rate:

$Q = A_1 v_1$
$Q = (\pi/4) (0.3)^2 \times 0.5$
$Q = 0.035$ m³/s

(b)(i)What is the terminal velocity?

Terminal velocity is the constant velocity attained by a freely falling object when the downward gravitational force is balanced by the upward drag and buoyant forces, preventing further acceleration.

(ii)Derive an expression for the terminal velocity of a spherical body falling freely through a viscous fluid.

For a sphere of radius r, mass m, and density ρ, moving through a fluid of viscosity η and density σ, the forces acting are:

- Gravitational force, $F_g = mg = (4/3)\pi r^3 \rho g$
- Buoyant force, $F_b = (4/3)\pi r^3 \sigma g$
- Viscous force, $F_v = 6\pi\eta r v$

At terminal velocity v_t, forces balance:

$F_g - F_b = F_v$

$(4/3)\pi r^3 \rho g - (4/3)\pi r^3 \sigma g = 6\pi\eta r v_t$

$(4/3)\pi r^3 g(\rho - \sigma) = 6\pi\eta r v_t$

Solving for v_t:

$v_t = (2r^2 g (\rho - \sigma)) / (9\eta)$

(c)Two capillaries of the same length and radii in the ratio of 1:2 are connected in series and the liquid is the same under streamline conditions. If the pressure across the two extreme ends of the combination is 1 m of water, what is the pressure difference across the first capillary?

Using Poiseuille's law for flow resistance:

$R \propto 1/r^4$

For two capillaries of radii r and 2r, their resistances are:

$R_1 = k / r^4$
$R_2 = k / (2r)^4 = k / 16r^4$

Total resistance in series:

$R_{total} = R_1 + R_2 = k / r^4 + k / 16r^4 = (16k + k) / 16r^4$

$R_{total} = 17k / 16r^4$

Using $\Delta P = Q R$,

$\Delta P_1 / \Delta P_{total} = R_1 / R_{total}$

$\Delta P_1 / 1 \text{ m} = (k / r^4) / (17k / 16r^4)$

$\Delta P_1 = (16 / 17) \text{ m}$

$\Delta P_1 = 0.94$ m of water

2.(a)A cyclist and a railway train are approaching each other with a speed of 10 m/s and 20 m/s respectively. If the engine driver sounds a warning siren at a frequency of 480 Hz, calculate the frequency of the note heard by the cyclist:

(i)Before the train has passed.

Using Doppler effect formula:

$f' = f (v + v_0) / (v - v_s)$

where
f = 480 Hz,
v = 343 m/s,
v_0 = 10 m/s (cyclist),
v_s = 20 m/s (train).

Substituting:

$f' = (480) (343 + 10) / (343 - 20)$

$f' = (480 \times 353) / (323)$

f' ≈ 524.3 Hz

(ii)After the train has passed.

$f' = f (v - v_0) / (v + v_s)$

f' = (480) (343 - 10) / (343 + 20)

f' = (480 × 333) / (363)

f' ≈ 440.3 Hz

(b)The equation $y = a \sin(\omega t - kx)$ represents a plane wave travelling in a medium along the x-direction, y being the displacement at the point x at time t. Deduce whether the wave is travelling in the positive x-direction or the negative x-direction.

Since the wave equation is in the form $y = a \sin(\omega t - kx)$, the negative sign indicates the wave is travelling in the positive x-direction.

(c)(i)A 40 cm long wire is in unison with a tuning fork of frequency 256 Hz, when it is submerged in water. By how much the length of the wire should be increased in air to maintain the same frequency?

For a string, frequency is given by:

$f = (1/2L) \sqrt{(T/\mu)}$

Since tension and mass per unit length remain constant,

$L_{air} / L_{water} = v_{air} / v_{water}$

$L_{air} = L_{water} \times (v_{air} / v_{water})$

$L_{air} = (0.4) \times (343 / 1482)$

$L_{air} = 0.4 \times 0.2315$

$L_{air} \approx 0.0926$ m or 9.26 cm

Thus, to maintain the same frequency in air, the wire should be increased by 9.26 cm.

3.(a)A grating with 300 lines per millimeter is illuminated normally with parallel beams of monochromatic light. A second order principal maximum is observed at 18.9° to the straight-through direction. Find the wavelength of the light.

Given:
Grating lines per mm = 300 lines/mm = 3×10^5 lines/m
Order of maximum, n = 2
Diffraction angle, $\theta = 18.9°$

Using the diffraction grating equation:

$n\lambda = d \sin\theta$

where d = 1 / (number of lines per meter)

$d = 1 / (3 \times 10^5)$
$d = 3.33 \times 10^{-6}$ m

Substituting values:

$2\lambda = (3.33 \times 10^{-6}) \sin 18.9°$

$2\lambda = (3.33 \times 10^{-6}) \times (0.324)$

$2\lambda = 1.08 \times 10^{-6}$

$\lambda = (1.08 \times 10^{-6}) / 2$

$\lambda = 5.4 \times 10^{-7}$ m or 540 nm

(b)A white light falls on a slit of width 'd'; for what value of 'd' will be the first minimum of light falling at the angle of 30° when the wavelength of light is 6500 nm?

Using single slit diffraction condition for the first minimum:

$d \sin\theta = m\lambda$

For first minimum, m = 1

$d = \lambda / \sin\theta$

Given:
$\lambda = 6500$ nm $= 6.5 \times 10^{-7}$ m
$\theta = 30°$

$d = (6.5 \times 10^{-7}) / \sin 30°$

$d = (6.5 \times 10^{-7}) / 0.5$

$d = 1.3 \times 10^{-6}$ m or 1.3 µm

4.(a)A steel rod of length 0.60 m and cross-sectional area 2.5×10^{-6} m² at a temperature of 100°C is clamped so that when it cools it is unable to contract. Find the tension in the rod when it has cooled to 20°C.

Given:
$L = 0.60$ m
$A = 2.5 \times 10^{-6}$ m²
$\Delta T = 100 - 20 = 80$°C
Coefficient of linear expansion, $\alpha = 1.2 \times 10^{-5}$ /°C
Young's modulus for steel, $Y = 2 \times 10^{11}$ N/m²

Using the thermal stress formula:

$F = Y A \alpha \Delta T$

$F = (2 \times 10^{11}) \times (2.5 \times 10^{-6}) \times (1.2 \times 10^{-5}) \times (80)$

$F = (2 \times 10^{11}) \times (2.4 \times 10^{-9})$

$F = 4.8 \times 10^{2}$ N

(b)A spring of 60 cm long is stretched by 2 cm for the application of a load of 200 g. What will be the length when a load of 500 g is applied?

Using Hooke's law:

$\Delta L \propto$ Load

$\Delta L_2 / \Delta L_1 = m_2 / m_1$

$\Delta L_2 = \Delta L_1 \times (m_2 / m_1)$

$\Delta L_2 = (2 \text{ cm}) \times (500 / 200)$

$\Delta L_2 = (2 \text{ cm}) \times (2.5)$

$\Delta L_2 = 5$ cm

Total length = original length + extension

$L_2 = 60 + 5$

$L_2 = 65$ cm

(c)Calculate the percentage increase in length of a wire of diameter 2.2 mm stretched by a load of 100 kg. (Young's modulus of wire is 1.2×10^{11} N/m²).

Given:
Diameter of the wire, $d = 2.2$ mm $= 2.2 \times 10^{-3}$ m
Radius, $r = d/2 = (2.2 \times 10^{-3}) / 2 = 1.1 \times 10^{-3}$ m
Cross-sectional area, $A = \pi r^2 = \pi(1.1 \times 10^{-3})^2$
$A = \pi \times (1.21 \times 10^{-6})$
$A \approx 3.8 \times 10^{-6}$ m²

Load applied, $F = mg = (100$ kg $\times 9.81$ m/s²$)$
$F = 981$ N

Young's modulus, $Y = 1.2 \times 10^{11}$ N/m²

Using the formula for elongation:

$\Delta L / L = F / (Y A)$

Substituting values:

$\Delta L / L = (981) / [(1.2 \times 10^{11}) \times (3.8 \times 10^{-6})]$

$\Delta L / L = 981 / (4.56 \times 10^{5})$

$\Delta L / L = 2.15 \times 10^{-3}$

To express this as a percentage:

Percentage increase in length = $(\Delta L / L) \times 100$

Percentage increase = $(2.15 \times 10^{-3}) \times 100$

Percentage increase $\approx 0.215\%$

Thus, the percentage increase in length of the wire is 0.215%.

5.(a)Briefly explain the following observations as applied to strengths of materials:

(i)Bridges are declared unsafe after long use.

Bridges experience continuous stress due to vehicles, wind, and temperature changes. Over time, these stresses cause fatigue in the material, leading to the formation of microcracks. If not maintained, these cracks grow, weakening the structure and eventually leading to failure.

(ii)Iron is more elastic than rubber.

Elasticity is the ability of a material to return to its original shape after deformation. Iron has a much higher Young's modulus compared to rubber, meaning it deforms less under applied force and recovers its shape more efficiently, making it more elastic in an engineering sense.

(b)A composite wire of diameter 1 cm consists of copper and steel wires of lengths 2.2 m and 2 m respectively. The total extension of the wire when stretched by a force is 1.2 mm. Calculate the force, given that Young's modulus for copper is 1.1×10^{11} Pa and for steel is 2×10^{11} Pa.

Given:
$L_1 = 2.2$ m, $L_2 = 2$ m
$Y_1 = 1.1 \times 10^{11}$ Pa, $Y_2 = 2 \times 10^{11}$ Pa
$A = \pi(0.01/2)^2 = 7.85 \times 10^{-6}$ m²
$\Delta L = 1.2$ mm $= 1.2 \times 10^{-3}$ m

Using the total extension formula:

$$\Delta L = (FL_1 / Y_1A) + (FL_2 / Y_2A)$$

Substituting values:

$$1.2 \times 10^{-3} = [(F \times 2.2) / (1.1 \times 10^{11} \times 7.85 \times 10^{-6})] + [(F \times 2.0) / (2 \times 10^{11} \times 7.85 \times 10^{-6})]$$

Solving for F:

$F \approx 4576$ N

(c)What do you understand by the following terms?
(i)A perfectly plastic material
A material that undergoes permanent deformation without any increase in stress once it has reached its yield point.

(ii)The ultimate tensile strength
The maximum stress a material can withstand before failure.

(iii)An elastic limit
The maximum stress that a material can sustain without undergoing permanent deformation.

(iv)Poisson's ratio
The ratio of lateral strain to axial strain in a material subjected to stress.

(d)Two rods of different materials but of equal cross-sections and lengths 1.0 m each are joined to make a rod of length 2.0 m. The metal of one rod has a coefficient of linear thermal expansion of 10^{-5}/°C and Young's modulus 3×10^{10} N/m². The other rod has values 2×10^{-5}/°C and 10^{10} N/m² respectively. How much pressure must be applied to the ends of the composite rod to prevent its expansion when the temperature is raised by 100°C?

Using:

$P = (Y_1\alpha_1 + Y_2\alpha_2)\ \Delta T / (Y_1 + Y_2)$

$P = [(3 \times 10^{10} \times 10^{-5}) + (10^{10} \times 2 \times 10^{-5})] \times 100 / (3 \times 10^{10} + 10^{10})$

$P = [(3 \times 10^{5}) + (2 \times 10^{5})] \times 100 / (4 \times 10^{10})$

$P = 5 \times 10^{7} / 4 \times 10^{10}$

$P = 1.25 \times 10^{6}$ Pa

6.(a)(i)Define tensile stress and tensile strain.

Tensile stress is the force per unit cross-sectional area exerted on a material when it is stretched. Mathematically,

Tensile stress = Force / Area = F / A

Tensile strain is the ratio of the change in length to the original length of a material under tensile stress. Mathematically,

Tensile strain = Change in length / Original length = ΔL / L

(ii)Calculate the work done in a stretching copper wire of 100 cm long and 0.03 cm² cross-sectional area when a load of 120 N is applied.

Given:
L = 100 cm = 1 m
A = 0.03 cm² = 3×10^{-6} m²

$F = 120$ N
Young's modulus for copper, $Y = 1.1 \times 10^{11}$ N/m²

Using the formula:

$$\Delta L = (F L) / (Y A)$$

$$\Delta L = (120 \times 1) / (1.1 \times 10^{11} \times 3 \times 10^{-6})$$

$$\Delta L = 120 / (3.3 \times 10^{5})$$

$$\Delta L = 3.64 \times 10^{-4} \text{ m}$$

Work done is given by:

$$W = \tfrac{1}{2} F \Delta L$$

$$W = \tfrac{1}{2} \times 120 \times 3.64 \times 10^{-4}$$

$$W = 0.0219 \text{ J}$$

(b)(i)Mention any two factors on which modulus of elasticity of a material depends.

1. Temperature: As temperature increases, the modulus of elasticity usually decreases.
2. Composition of the material: Different materials have different atomic structures affecting their elasticity.

(ii)A 45 kg traffic light is suspended with two steel wires of equal lengths and radii of 0.5 cm. If the wires make an angle of 15° with the horizontal, what is the fractional increase in their length due to the weight of the light?

Given:
$m = 45$ kg
$g = 9.81$ m/s²
$R = 0.5 \text{ cm} = 5 \times 10^{-3}$ m
$A = \pi(5 \times 10^{-3})^2 = 7.85 \times 10^{-6}$ m²
$Y = 2 \times 10^{11}$ N/m²

The force in each wire:

$$T = (mg) / (2 \sin 15°)$$

$$T = (45 \times 9.81) / (2 \times 0.2588)$$

$T = 220.725 / 0.5176$

$T = 426.4$ N

Using $\Delta L / L = (T) / (Y A)$

$\Delta L / L = (426.4) / (2 \times 10^{11} \times 7.85 \times 10^{-6})$

$\Delta L / L = 2.72 \times 10^{-6}$

(c)(i)Define free surface energy in relation to the liquid surface.

Free surface energy is the work done in increasing the surface area of a liquid by a unit amount due to intermolecular forces acting at the surface.

(ii)Explain what will happen if two bubbles of unequal radii are joined by a tube without bursting.

The smaller bubble has higher internal pressure due to the relation $P = 2T / R$. When connected by a tube, air flows from the smaller to the larger bubble, causing the smaller one to shrink and eventually collapse while the larger one expands.

(iii)A spherical drop of mercury of radius 5 mm falls on the ground and breaks into 1000 droplets. Calculate the work done in breaking the drop.

Given:
$R = 5$ mm $= 5 \times 10^{-3}$ m
Number of small droplets, $n = 1000$
Surface tension, $T = 0.472$ N/m

Volume before and after breaking remains the same:

$(4/3)\pi R^3 = 1000 \times (4/3)\pi r^3$

$R^3 = 1000 r^3$

$r = R / 10 = 5 \times 10^{-3} / 10 = 5 \times 10^{-4}$ m

Total surface area before:

$A_1 = 4\pi R^2 = 4\pi (5 \times 10^{-3})^2$

$A_1 = 3.14 \times 10^{-4}$ m²

Total surface area after:

$A_2 = 1000 \times 4\pi r^2 = 1000 \times 4\pi (5 \times 10^{-4})^2$

$A_2 = 3.14 \times 10^{-3}$ m²

Work done = T (A_2 - A_1)

$W = 0.472 \times (3.14 \times 10^{-3} - 3.14 \times 10^{-4})$

$W = 0.472 \times 2.826 \times 10^{-3}$

$W \approx 1.33 \times 10^{-3}$ J

7.(a)What is meant by the following?

(i)Atomic mass unit (a.m.u)
Atomic mass unit (a.m.u) is defined as one-twelfth of the mass of a carbon-12 atom, approximately 1.66×10^{-27} kg.

(ii)Binding energy
Binding energy is the energy required to completely separate all the nucleons in a nucleus, given by $E = \Delta m\, c^2$.

(iii)Mass defect
Mass defect is the difference between the total mass of nucleons in a nucleus and the actual nuclear mass, which accounts for the binding energy holding the nucleus together.

(b)Calculate the binding energy per nucleon for phosphorus $^{31}_{15}P$ given that, $^{31}_{15}P$ = 30.97376 a.m.u and ^{1}H = 1.00782 a.m.u.

Mass of 15 protons = 15 × 1.00782 = 15.1173 a.m.u
Mass of 16 neutrons = 16 × 1.0087 = 16.1392 a.m.u

Total mass of nucleons = 15.1173 + 16.1392 = 31.2565 a.m.u

Mass defect, Δm = 31.2565 - 30.97376 = 0.28274 a.m.u

Binding energy:

$E = \Delta m \times 931.5$ MeV/u

$E = 0.28274 \times 931.5$

E = 263.3 MeV

Binding energy per nucleon:

$E_{per\_nucleon} = 263.3 / 31$

$E_{per\_nucleon} = 8.49$ MeV

(c)It is observed that thorium nucleus $^{226}_{90}Th$ originally at rest decays to form a radium nucleus $^{222}_{88}Ra$, α-particle and γ-rays.

(i)Write down the equation for the disintegration.

$^{226}_{90}Th \rightarrow ^{222}_{88}Ra + ^{4}_{2}He + \gamma$

(ii)Determine the energy of the γ-ray, if the α-particle is emitted with energy of 2.38 MeV. Given that rest mass of $^{226}_{90}Th$ = 226.0249 a.m.u, $^{222}_{88}Ra$ = 222.0154 a.m.u and α-particle = 4.0026 a.m.u.

Mass defect:

Δm = (226.0249 - (222.0154 + 4.0026)) a.m.u

Δm = (226.0249 - 226.018) a.m.u

Δm = 0.0069 a.m.u

Energy released:

E = Δm × 931.5 MeV/u

E = 0.0069 × 931.5

E = 6.43 MeV

Energy of γ-ray:

E_γ = Total energy - α-particle energy

$E_\gamma = 6.43 - 2.38$

$E_\gamma = 4.05$ MeV

7.(d)When a nucleus of deuterium (hydrogen-2) fuses with a nucleus of tritium (hydrogen-3) to helium nucleus and a neutron, 2.88×10^{-12} J of energy is released.

The equation for the reaction is represented as:

$^{1}H_{2} + {}^{1}H_{3} \rightarrow {}^{4}He_{2} + {}^{1}n_{0}$

Calculate the mass of helium nucleus produced.

Given:
Energy released, $E = 2.88 \times 10^{-12}$ J
Speed of light, $c = 3 \times 10^{8}$ m/s

Using Einstein's mass-energy relation:

$E = \Delta m\, c^2$

Solving for mass defect Δm:

$\Delta m = E / c^2$

$\Delta m = (2.88 \times 10^{-12}) / (3 \times 10^{8})^2$

$\Delta m = (2.88 \times 10^{-12}) / (9 \times 10^{16})$

$\Delta m = 3.2 \times 10^{-29}$ kg

Converting mass defect to atomic mass units (1 a.m.u = 1.66×10^{-27} kg):

$\Delta m = (3.2 \times 10^{-29}) / (1.66 \times 10^{-27})$

$\Delta m = 0.0193$ a.m.u

Mass of helium nucleus:

M_He = Mass of reactants - Mass defect

M_He = (Mass of deuterium + Mass of tritium) - Δm

Using approximate atomic masses:

$^{1}H_{2} = 2.014$ a.m.u
$^{1}H_{3} = 3.016$ a.m.u

$M_{He} = (2.014 + 3.016) - 0.0193$

$M_{He} = 5.0307 - 0.0193$

$M_{He} = 5.0114$ a.m.u

Thus, the mass of the helium nucleus produced is 5.0114 a.m.u.

8.(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 a 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. The force is maximum when the conductor is perpendicular to the field and zero when parallel.
(b) (ii)Write down the formulae for the magnetic field induced at the centre of a solenoid.

The magnetic field B 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 produces a magnetic field of 0.1 T at the centre. If the radius of solenoid is 5 cm, its length is 50 cm and carries a current of 10 A, calculate:

(i)The number of turns per unit length of the solenoid.

Using the formula:

$B = \mu_0 n I$

Solving for n:

$n = B / (\mu_0 I)$

Substituting values:

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

$n = (0.1) / (1.256 \times 10^{-5})$
$n \approx 7963$ turns per meter

(ii)The total length of a wire required.

Total number of turns, $N = n \times L$

$N = (7963) \times (0.5)$

$N \approx 3982$ turns

The total length of the wire required:

$L_{total} = N \times$ circumference of solenoid

$L_{total} = (3982) \times (2\pi \times 0.05)$

$L_{total} = (3982) \times (0.314)$

$L_{total} \approx 1250$ m

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

The Biot-Savart law states that the magnetic field dB at a point due to a small current element Idl is directly proportional to the current, the length of the element, and the sine of the angle between the element and the line joining the element to the point, and inversely proportional to the square of the distance between them. Mathematically,

$dB = (\mu_0 / 4\pi) \times (I\, dl \sin\theta) / r^2$

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

Using the formula for the magnetic field due to a moving charge in a circular orbit:

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

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

Substituting values:

$B = [(4\pi \times 10^{-7}) \times (1.6 \times 10^{-19}) \times (2.18 \times 10^6)] / [2 \times (5.3 \times 10^{-11})^2]$
$B = [(4\pi \times 10^{-7}) \times (3.488 \times 10^{-13})] / [2 \times 2.809 \times 10^{-21}]$

$B = (4.38 \times 10^{-19}) / (5.618 \times 10^{-21})$

$B \approx 0.078$ T

9.(a)Use the Rydberg constant, $R\_H = 1.0974 \times 10^7\ m^{-1}$ to calculate the shortest wavelength of the Balmer series.

The shortest wavelength in the Balmer series corresponds to a transition from $n = \infty$ to $n = 2$. The Rydberg formula is:

$1/\lambda = R\_H (1/n_2^2 - 1/n_1^2)$

For the shortest wavelength, $n_1 = 2$ and $n_2 = \infty$

$1/\lambda = (1.0974 \times 10^7) \times (1/2^2 - 1/\infty^2)$

$1/\lambda = (1.0974 \times 10^7) \times (1/4 - 0)$

$1/\lambda = (1.0974 \times 10^7) \times (1/4)$

$1/\lambda = 2.7435 \times 10^6$

$\lambda = 1 / (2.7435 \times 10^6)$

$\lambda = 3.645 \times 10^{-7}$ m

$\lambda = 364.5$ nm

(b)Use the Bohr's theory for hydrogen atom to determine the:

(i)Radius of the first orbit of the hydrogen atom in Å units.

The radius of an electron's orbit in a hydrogen atom is given by:

$r_n = (\varepsilon_0 h^2 n^2) / (\pi m e^2)$

For the first orbit, n = 1

Given:
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$h = 6.63 \times 10^{-34}$ Js
$m = 9.11 \times 10^{-31}$ kg
$e = 1.6 \times 10^{-19}$ C

$r_1 = (8.85 \times 10^{-12} \times (6.63 \times 10^{-34})^2) / (\pi \times 9.11 \times 10^{-31} \times (1.6 \times 10^{-19})^2)$

$r_1 = 5.29 \times 10^{-11}$ m

Converting to Å:

1 Å = 10^{-10} m

$r_1 = 0.529$ Å

(ii)Velocity of the electron in the first orbit.

Using Bohr's velocity formula:

$v_n = (e^2) / (2 \varepsilon_0 h n)$

For n = 1:

$v_1 = (1.6 \times 10^{-19})^2 / (2 \times 8.85 \times 10^{-12} \times 6.63 \times 10^{-34})$

$v_1 = 2.18 \times 10^6$ m/s

(c)(i)What is ionization potential of an atom?

Ionization potential is the minimum energy required to remove an electron from an isolated gaseous atom to form a positively charged ion.

(ii)Show that the ionization potential of hydrogen is 13.6 eV.

Energy of an electron in an orbit is given by:

$E_n = -(13.6 \text{ eV}) / n^2$

For the first orbit (n = 1):

$E_1 = -13.6$ eV

Ionization energy is the energy required to remove the electron from n = 1 to n = ∞:

$\Delta E = E_\infty - E_1$

Since $E_\infty = 0$ eV,

$\Delta E = 0 - (-13.6 \text{ eV})$

$\Delta E = 13.6$ eV

(iii)How can you account for the chemical behaviour of atoms on the basis of the atomic electrons and shells?

The chemical behavior of atoms is determined by the arrangement of electrons in their atomic shells.

1. The valence electrons (electrons in the outermost shell) participate in bonding and determine the reactivity of an element.
2. Elements with a full valence shell (like noble gases) are chemically stable and unreactive.
3. Elements with incomplete valence shells tend to gain, lose, or share electrons to achieve a stable configuration, leading to the formation of ionic or covalent bonds.
4. The number of valence electrons defines the group of an element in the periodic table, which correlates with its chemical properties.