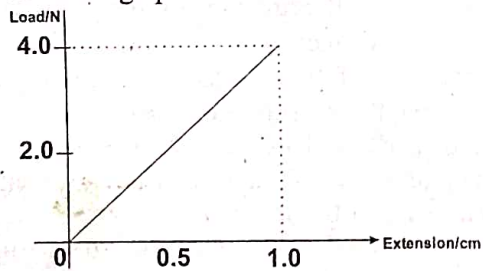


WASSCE SC 2021 PHYSICS ESSAY 2

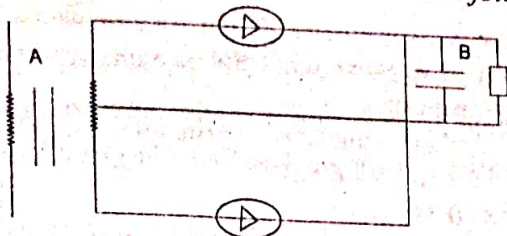
1. The load-extension graph of an elastic material is illustrated below



Use the graph to determine the work done in stretching the material.

2. (a) Name **two** artificial satellites. (b) A geostationary satellite moves in an orbit of radius 6300km. Calculate the speed with which it moves in the orbit. [$\pi = \frac{22}{7}$]
3. A projectile is fired at an angle of 30° to the horizontal with a velocity of 40ms^{-1} . Calculate the velocity attained after 1s. [$g = 10\text{ms}^{-2}$].

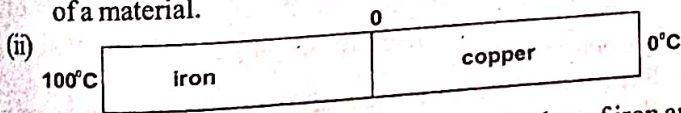
4. The circuit diagram below is a simple current rectifier circuit. Use it to answer the questions that follow.



- (a) State the function of each of the parts labelled A and B.
 - (b) Sketch the output signal produced.
5. (a) Explain the wave-particle duality of light. (b) A particle of wavelength 4.2×10^{-11} m travels with a momentum of 1.6×10^{-23} kg ms⁻¹. Determine the value of the Planck's constant, h .
 6. State three observable phenomena where a particle behaves like waves.
 7. (a) State the scientific principle underlying the operation of fibre optics. (b) Explain each of the following terms as used in fibre optics: (i) core; (ii) cladding.

PART II

8. (a)(i) State Hooke's law (ii) A spring has a length of 0.20m when a mass of 0.30kg hangs on it, and a length of 0.75m when a mass of 1.95kg hangs on it. Calculate the: (i) force constant of the spring; (ii) length of the spring when it is unloaded [$g = 10\text{m s}^{-2}$]
(b)(i) What is diffusion? (ii) State two factors that affect the rate of diffusion of a substance. (iii) State the exact relationship between the rate of diffusion of a gas and its density. (c) A satellite of mass, m orbits the earth of mass, M with a velocity, v at a distance R from the centre of the earth. Derive the relationship between the period T , of orbit and R .
9. (a)(i) Define dew point. (ii) Explain why dew forms more quickly on the metals parts than on the rubber parts of a bicycle placed in the open overnight. (b)(i) Explain the statement, the specific heat capacity of copper is $400\text{J kg}^{-1}\text{K}^{-1}$. (ii) Two meals, P and Q are supplied with the same quantity of heat. If the ratio of the specific heat capacity of P to Q is 3:1 and their masses are in the ratio 1:2 respectively, calculate the ratio of the temperature rise of P to Q. (c)(i) Define coefficient of thermal conductivity of a material.

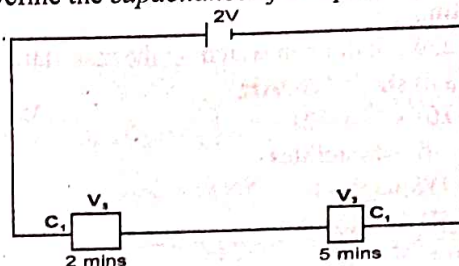


The diagram above illustrates a composite bar of iron and copper. The bar is insulated along its sides and it has a diameter of 10mm. The length and thermal conductivity of the iron are 0.15m and $40\text{W m}^{-1}\text{K}^{-1}$, respectively and those of copper are 0.05m and $360\text{W m}^{-1}\text{K}^{-1}$, respectively. If the free ends of the iron and copper are kept at 100°C and 0°C respectively, calculate the (i) temperature θ at the interface between the bars; (ii) rate of heat flow along the bar.

10. (a)(i) Define each of the following terms as it relates to converging lenses; (i) focal length; (ii) optical centre; (iii) Draw a ray diagram to illustrate how a converging lens is used to produce a virtual image of an object.
(b)(i) Name the primary colours of light. (ii) Match each

primary colour to its corresponding complementary colour. (c) A ray passes symmetrically through a glass prism of angle 60° and refractive index of 1.5. Calculate the angle of: (i) incidence; (ii) minimum deviation.

11. (a)(i) What is meant by the root-mean-square value of an alternating current? (ii) Define impedance of an alternating current circuit. (b) An electrical device rated 120V, 60 W is operated on a 240V, 50Hz mains supply. The circuit has a capacitor connected in series with the electrical device and the supply. Calculate the capacitance of the capacitor. [$\pi = 3.142$]
(c)(i) Define the capacitance of a capacitor.
(ii)



The circuit diagram above illustrates two capacitors of capacitances C_1 and C_2 connected in series across a 2.1V source. (I) Obtain an expression for the total capacitance in terms of C_2 (ii) Calculate the potential difference across each capacitor.

12. (a)(i) State the principal factor that determines the relative stability of a radioactive nucleus. (iii) Arrange the following radionuclides in decreasing order of stability.

Justify your answer ${}_{20}^{40}\text{X}$, ${}_{20}^{40}\text{W}$ and ${}_{20}^{40}\text{Y}$

- (b)(i) Explain the term ionization potential

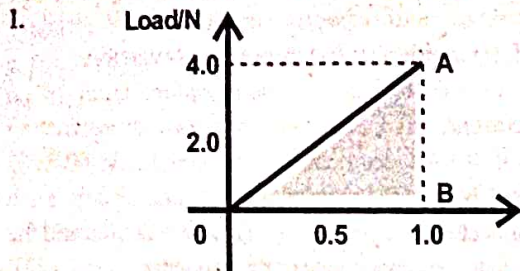
(ii)

n	Energy/eV
e	0
4	-0.85
3	-1.50
2	-3.40
1	E_0

The diagram above illustrates energy levels in the hydrogen atom. E_0 is the energy of the ground state.

- (I) When an electron makes a transition from level $n=3$ to level $n=1$, it emits a photo of wavelength $1.02 \times 10^{-7}\text{m}$. Calculate E_0 . (II) Calculate the ionization potential of the hydrogen atom. (c)(i) Explain the statement, the work function of sodium is 2.0eV. (ii) Light of wavelength 160nm is shone on the surface of a sodium metal of work function 2.0eV. Determine whether photoelectrons will be emitted. [$h = 6.6 \times 10^{-34}$ Js, ($c = 3.0 \times 10^8$ ms⁻¹, $1\text{eV} = 1.6 \times 10^{-19}$ J)]

ANSWERS TO WASSCE SC 2021 PHYSICS 2 ESSAY



Base of $\Delta OAB = 1.0\text{cm}$
 $= 0.01\text{m}$

Hence, work done in stretching the material
 $= \text{area of shaded } \Delta OAB$
 $= \frac{1}{2} \times 0.01 \times 4 = 0.02\text{J}$

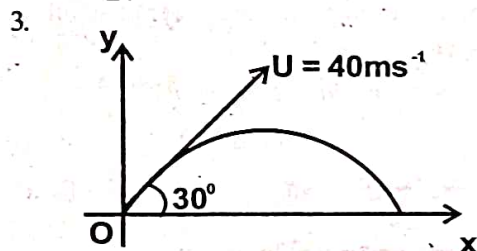
2. (a) Artificial satellites
 (I) Spunik - 1
 (II) ResourceSat - 1

(b) From $V = \omega r$

$$V = 2\pi r \frac{1}{T}$$

Since the earth makes 1 complete revolution in 24 hours,
 period, $T = 24$ hours for a geo-stationary satellite.

Hence, speed of the satellite $= \frac{2 \times \frac{22}{7} \times 6300}{24}$
 $= \frac{44 \times 9}{24} = 16.5\text{kmh}^{-1}$



Vertical component of velocity after 1s is

$$V_y = 40\sin 30^\circ - 10 \times 1$$

$$= 40 \times 0.5 - 10$$

$$= 20 - 10 = 10\text{ms}^{-1}$$

Horizontal component of velocity after 1s is

$$V_x = 40\cos 30^\circ \text{ (since it is independent of } g)$$

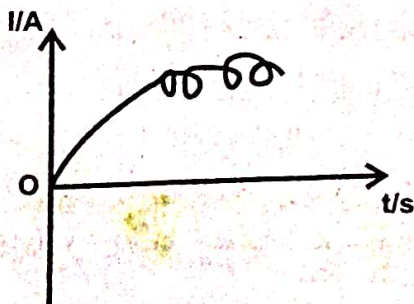
$$V_x = 40 \times 0.866 = 34.64\text{ms}^{-1}$$

Hence, resultant velocity after 1 second is

$$V = \sqrt{V_x^2 + V_y^2} = \sqrt{34.64^2 + 10^2} = \sqrt{1299.93}$$

$$\approx 36.05\text{ms}^{-1}$$

4. (a) Function of the part labelled A: It produces the alternating current.
 Function of the part labelled B: It smoothens the rectified current.
 (b) Output signal



(5)(a) Wave-particle duality of light is a term which is used to explain the fact that light exhibits both particle and wave nature/properties.

(b) By Heisenberg's uncertainty principle, $\Delta x \cdot \Delta p \geq h$
 $\therefore h \approx 4.2 \times 10^{-11} \times 1.6 \times 10^{23}$
 $= 6.72 \times 10^{-34}\text{Js}$

6. Observable phenomena where a particle behaves like waves: Diffraction, reflection, polarisation and interference.

7. (a) The scientific principle underlying the operation of fibre optics is *total internal reflection*.

(b) *Core* is the central or inner part of the optical fibre, that acts as the light carrying portion of the fibre.

Cladding is the outer layer that surrounds the core with lower refractive index.

8. (a)(i) Hooke's law states that the extension of an elastic material is proportional to the load applied, provided the elastic limit is not exceeded.

(ii) $F_1 = 0.3 \times 10 = 3\text{N}$

$$F_2 = 1.95 \times 10 = 19.5\text{N}$$

By Hooke's law, $F \propto e$

$$\Rightarrow F = Ke, \text{ where } e = l_2 - l_0$$

$$\text{When } F = 3\text{N}, e = 0.2 - l_0;$$

$$\text{so } 3 = K(0.2 - l_0)$$

$$\Rightarrow 3 = 0.2k - l_0 k \dots (1)$$

$$\text{When } F = 19.5\text{N}, e = 0.75 - l_0;$$

$$\text{so } 19.5 = k(0.75 - l_0)$$

$$\Rightarrow 19.5 = 0.75k - l_0 k \dots (2)$$

Subtract (1) from (2):

$$16.5 = 0.55k$$

$$\Rightarrow k = \frac{16.5}{0.55} = 30\text{Nm}^{-1}$$

$$\text{Using (1): } 3 = 0.2 \times 30 - l_0 \times 30$$

$$\Rightarrow 3 = 6 - 30l_0$$

$$\Rightarrow 30l_0 = 6 - 3 = 3$$

$$\therefore l_0 = \frac{3}{30} = 0.1\text{m}$$

Hence:

(I) the force constant of the spring, $k = 30\text{Nm}^{-1}$

(II) the natural length of the spring, $l_0 = 0.1\text{m}$

(b)(i) Diffusion is the process by which different forms of matter mix intimately due to random motion of their particles/molecules.

(ii) Factors that affect the rate of diffusion of a substance are:

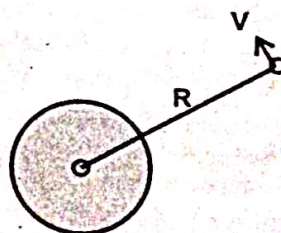
(I) Temperature of the environment

(II) Density of the substance

(III) Medium of diffusion

(iii) Rate of diffusion $= \frac{K}{\sqrt{\text{density of gas}}}$ (Graham's law),
 where k is a constant of proportionality.

(c)



Using centripetal force

$$= \frac{Mv^2}{R} = \frac{GMm}{R^2}$$

But $V = WR = 2\pi rR = \frac{2\pi rR}{T}$

Continuing,

$$m \left(\frac{2\pi rR}{T} \right)^2 = \frac{GMm}{R^2}$$

$$\Rightarrow \frac{(2\pi rR)^2}{R} = \frac{GM}{R}$$

$$\Rightarrow \frac{4\pi^2 R^2}{T^2} = \frac{GM}{R}$$

$$\Rightarrow 4\pi^2 R^2 \times R = GMT^2$$

$$\therefore \frac{4\pi^2 R^3}{GM} = T^2$$

$$\Rightarrow T^2 \propto R^3$$

(9)(a)(i) Dew point is defined as the temperature at which water vapour moisture present in the atmospheric air is just sufficient to saturate it.

(ii) **Explanation of why dew forms more quickly on metal parts than rubber parts:** Metal is a better conductor of heat than rubber. At night, metal loses heat faster than rubber and becomes colder. Warm air gains latent heat of vaporisation from metal faster than rubber. Dew are then formed on the metal parts.

(b)(i) 'The specific heat capacity of copper is $400 \text{ J kg}^{-1} \text{ K}^{-1}$ '.

The statement means that 400J of heat energy is required to change the temperature of 1kg of copper by 1 kelvin.

(ii) Using Heat = $mc\Delta\theta$, where:

m = mass of substance

c = specific heat capacity

$\Delta\theta$ = change in temperature

$C_p : C_Q = 3:1$, $M_p : M_Q = 1:2$ (given)

Since the metals P and Q are supplied with the same quantity of heat,

$$M_p \times C_p \times \Delta\theta_p = M_Q \times C_Q \times \Delta\theta_Q$$

ie $1 \times 3 \times \Delta\theta_p = 2 \times 1 \times \Delta\theta_Q$

$$\Rightarrow \frac{\Delta\theta_p}{\Delta\theta_Q} = \frac{2}{3}$$

Hence, $\Delta\theta_p : \Delta\theta_Q = 2 : 3$

(c)(i) **The coefficient of thermal conductivity of a material** is defined as the time rate of flow of heat per unit cross-sectional area per unit temperature gradient.

(ii) Using the equation for thermal conductivity,

$$\frac{H}{t} = \frac{KA(\theta_2 - \theta_1)}{L}, \text{ where:}$$

H = heat flowing in the bar

t = time taken for the heat to reach the interface

k = coefficient of thermal conductivity of the material.

A = area through which heat is flowing

$\theta_2 - \theta_1$ = temperature change.

Thus $H = \frac{KA(\theta_2 - \theta_1)}{L}$

For the iron bar: $H = \frac{40At(100 - \theta)}{0.15} \dots (1)$

For the cooper bar: $H = \frac{360At(\theta - 0)}{0.05} \dots (2)$

At the interface, heat lost = heat gained: i.e.

$$\frac{40At(100 - \theta)}{0.15} = \frac{360At(\theta - 0)}{0.05}$$

$$\Rightarrow 100 - \theta = \frac{360t(\theta) \times 0.15}{40t \times 0.05}$$

$$\Rightarrow 100 - \theta = 27\theta$$

$$\Rightarrow 100 = 27\theta + \theta = 28\theta$$

$$\therefore \theta = \frac{100}{28} \approx 3.57^\circ\text{C}$$

From (i), $\frac{H}{t} = \frac{40At(100 - 3.57)}{0.15}$,

where $A = \pi \times \left(\frac{10}{2} \times 10^{-3}\right)^2$

$$= \frac{22}{7} \times (5 \times 10^{-3})^2$$

$$= \frac{22}{7} \times 25 \times 10^{-6}$$

$$= 78.57 \times 10^{-6} \text{ m}^2$$

$$\therefore \frac{H}{t} = \frac{40 \times 78.57 \times 10^4 \times 96.43}{0.15} = 2.02 \text{ Js}^{-1}$$

Hence:

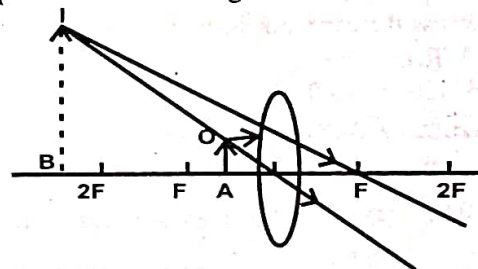
(I) the temperature at the interface, $\theta = 3.57^\circ\text{C}$;

(II) the rate of heat flow along the bar = 2.02 Js^{-1}

10(a)(i)(I) **Focal length** of a converging lens is the distance from the optical centre to its principal focus.

(II) **Optical centre** of a converging lens is the centre of the lens through which a light ray can pass without being deviated by the lens.

(ii) Diagram illustrating how a converging lens is used to produce a virtual image



OB is the object IB is the virtual image

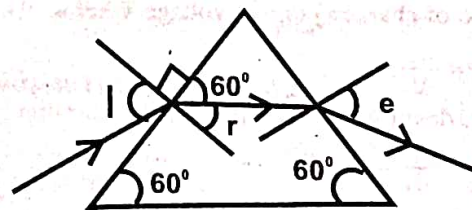
(b)(i) Primary colours of light are red, green and blue.

(ii) Red \longrightarrow cyan

Green \longrightarrow Magenta

Blue \longrightarrow Yellow

(c)(i)



From the diagram, angle of refraction, $r = 90^\circ - 60^\circ = 30^\circ$

By Snell's law of refraction, $n = \frac{\sin i}{\sin r}$ (all symbols in usual

notations) $1.5 = \frac{\sin i}{\sin 30}$

$$\Rightarrow \sin i = 1.5 \sin 30^\circ = 1.5 \times 0.5 = 0.75$$

$$\Rightarrow i = \sin^{-1}(0.75) \approx 48.6^\circ$$

Hence, angle of incidence, $i = 48.6^\circ$

(ii) Using the formula for determining the refractive index of a triangular glass prism,

$$n = \frac{\sin\left(\frac{A+Dm}{2}\right)}{\sin\frac{A}{2}} = 1.5 = \frac{\sin\left(\frac{60^\circ+Dm}{2}\right)}{\sin\frac{60^\circ}{2}}$$

$$\Rightarrow 1.5 = \frac{\sin\left(\frac{60^\circ+Dm}{2}\right)}{\sin 30^\circ} \Rightarrow 1.5 \sin 30^\circ = \sin\left(\frac{60^\circ+Dm}{2}\right)$$

$$\Rightarrow 1.5 \times 0.5 = \sin\left(\frac{60^\circ+Dm}{2}\right) \Rightarrow 0.75 = \sin\left(\frac{60^\circ+Dm}{2}\right)$$

$$\Rightarrow \left(\frac{60^\circ+Dm}{2}\right) = \sin^{-1}(0.75) \approx 48.6^\circ$$

$$\Rightarrow \left(\frac{60^\circ+Dm}{2}\right) = 48.6^\circ \Rightarrow 60^\circ + Dm = 97.2^\circ$$

$$\Rightarrow Dm = 97.2^\circ - 60^\circ = 37.2^\circ$$

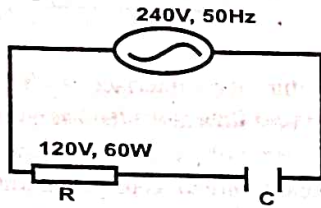
Hence, angle of minimum deviation, $Dm = 37.2^\circ$

11. (a)(i) The *root-mean-square* value of an A.C is the value of the direct current that has the same heating effect as

the A.C. of peak value I_0 . Thus, $I_{r.m.s} = \frac{I_0}{\sqrt{2}}$

- (ii) *Impedance*, Z of an A.C. is the overall opposition to the flow of an alternating current (A.C.) by both the resistive reactive components.

(b)



From $P = IV \Rightarrow I = \frac{P}{V}$, current in the circuit,

$$I = \frac{60}{120} = 0.5A$$

Using $V^2 = V_R^2 + V_C^2$,
voltage across the capacitor is given by

$$V_C^2 = V^2 - V_R^2, \text{ i.e.}$$

$$V_C^2 = 240^2 - 120^2 = 43200$$

$$\Rightarrow V_C = \sqrt{43200} \approx 207.85V$$

By Ohm's law, $V_C = IX_C$, i.e.

$$207.85 = 0.5 \times \frac{1}{2\pi f C}$$

$$\Rightarrow 207.85 = \frac{0.5}{2 \times 3.142 \times 50 \times C} \Rightarrow 207.85 \times 314.2 \times C = 0.5$$

$$\Rightarrow C = \frac{0.5}{2 \times 3.142 \times 50 \times C} \approx 7.656 \times 10^{-6}F \approx 7.66\mu F$$

Hence, capacitance of the capacitor is $0.00000766F$ or $7.66\mu F$

- (c)(i) *Capacitance* of a parallel plates capacitor is defined as the ratio of charge Q to unit voltage V across the plates

$$\text{Thus } C = \frac{Q}{V}$$

- (ii) (I) Let C denote the total capacitance in the circuit.

$$\text{Then } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow C = \frac{C_1 C_2}{C_1 + C_2} \dots (1)$$

$$\text{From } C \propto \frac{1}{d} \Rightarrow C = \frac{k}{d}$$

$$C_1 = \frac{k}{2} \Rightarrow k = 2C_1$$

$$C_2 = \frac{k}{5} \Rightarrow k = 5C_2$$

$$K = k \Rightarrow 2C_1 = 5C_2$$

$$= C_1 = \frac{5}{2} C_2 \dots (2)$$

Substitute $\frac{5}{2} C_2$ for C_1 in (i):

$$C = \frac{\frac{5}{2} C_2 \times C_2}{\frac{5}{2} C_2 + C_2} = \frac{\frac{5}{2} C_2 \times C_2}{\frac{7}{2} C_2} = \frac{5}{2} C_2 \times \frac{2}{7} = \frac{5}{7} C_2$$

$$\therefore C = \frac{5}{7} C_2$$

$$(ii) C = \frac{Q}{V} \Rightarrow Q = CV$$

$$\therefore \text{Total charge, } Q = \frac{5}{7} C_2 \times 2 = \frac{10}{7} C_2$$

$$\text{From } C = \frac{Q}{V}, V = \frac{Q}{C}$$

Hence:

P.D. across C_1 is

$$V_1 = \frac{Q}{C_1} = \frac{10}{7} C_2 \div \frac{5}{2} C_2 = \frac{10}{7} C_2 \times \frac{2}{5 C_2} = \frac{4}{7} \approx 0.57V;$$

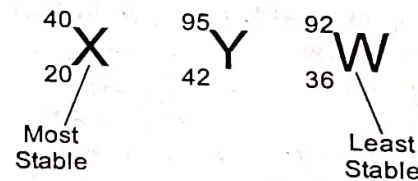
$$\text{P.D. across } C_2 \text{ is } V_2 = \frac{Q}{C_2} = \frac{10}{7} C_2 \times \frac{1}{C_2} = \frac{10}{7} = 1.43V$$

12. (a)(i) The principal factor that determines the relative stability of a radioactive nucleus is *neutron-proton ratio*.
(ii) Arrangement of radioactive nuclides W , X and Y in decreasing order of stability:

$${}_{20}^{40}X: \frac{\text{Neutron}}{\text{proton}} = \frac{40-20}{20} = 1$$

$${}_{36}^{92}W: \frac{\text{Neutron}}{\text{proton}} = \frac{96-36}{36} = 1.56$$

$${}_{42}^{95}Y: \frac{\text{Neutron}}{\text{proton}} = \frac{95-42}{42} = 1.26$$



- (b)(i) *Ionization potential* is the minimum energy required to remove an electron completely from an atom.

- (ii) (I) Using $\Delta E = \frac{hc}{\lambda}$, i.e. $E_2 - E_0 = -1.5 - E_0 =$

$$\frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.02 \times 10^{-7}}$$

$$\Rightarrow -1.5 - E_0 = \frac{6.6 \times 3}{1.02} \times 10^{-34+8+7}$$

$$\Rightarrow -1.5 - E_0 = 19.41 \times 10^{-19}J$$

$$\Rightarrow -1.5 - E_0 = \frac{19.41 \times 10^{-19}}{1.6 \times 10^{-19}} = 12.13$$

$$\Rightarrow -1.5 - 12.13 = E_0$$

$$E_0 = -13.63eV$$

- (ii) Ionization potential = $E_0 - E_2 = 0 - (-13.63) = 13.63eV$

- (c)(i) $2.0eV$ is the minimum amount of energy required to remove an electron from the surface of sodium metal.

- (ii) $160 \text{ nanometers} = 160 \times 10^{-9}m$

$$E = hf = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{160 \times 10^{-9}}$$

$$= \frac{6.6 \times 3}{160} \times 10^{-34+8+9} = 0.124 \times 10^{-17} = 1.24 \times 10^{-18}J$$

$$\text{Energy (in eV)} = \frac{1.24 \times 10^{-18}}{1.6 \times 10^{-19}} = 0.775 \times 10^{-18+19}$$

$$= 7.75 \times 10^{-19+19} = 7.75eV$$

Since the energy of the incident photon ($7.75eV$) is greater than the work function of sodium ($2.0eV$), photoelectrons will be emitted.