

# **H2 PHYSICS**

**Exam papers with worked solutions**

**(Selected from Top JC)**

## **SET C**

## **PAPER 3**

## **ANSWER**

Compiled by

# **THE PHYSICS CAFE**

1

$$(a) \omega = \frac{2\pi}{T}$$
$$= 2.66 \times 10^{-6} \text{ rads}^{-1}$$

$$(b) a = r \omega^2$$
$$= 2.7 \times 10^{-3} \text{ ms}^{-2}$$

(c) **Acceleration** is directed **towards the centre** [B1] and thus it always **perpendicular to velocity** [B1], hence it does not change the magnitude of the velocity (i.e. speed).

$$(d) F = ma$$
$$= 1.98 \times 10^{20} \text{ N}$$

(e) The moon has an initial speed. Due to inertia, it has the tendency to move in the tangential direction.

Force is the rate of change of momentum. The resultant force is towards the centre does not mean the final momentum is towards the centre.

The path that the Moon will take follows the direction of the final momentum rather than the direction of the *change* in momentum.

2

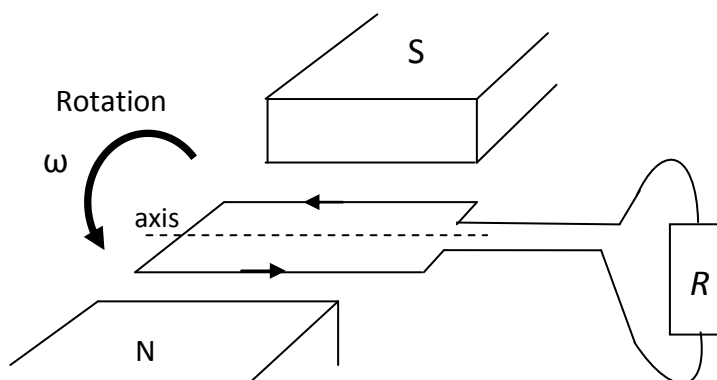
- (a) By Faraday's Law of Electromagnetic Induction, the **magnitude** of the induced e.m.f. is equal to the **rate of change** of the magnetic flux linkage.

When the coil is rotating, there is a continuous change in the angle between the magnetic field and the area enclosed by the coil, thus the magnetic flux linkage with the coil is continuously changing. By Faraday's Law of Electromagnetic Induction, an e.m.f. is induced.

Since induced e.m.f. is formed in a closed circuit, induced current will flow.

- (b) When the coil rotates, there is an increase in magnetic flux linkage through the coil. By **Lenz's Law**, the induced current will flow in the direction to produce a magnetic field to **oppose the change in magnetic flux linkage** [B1]. The direction of the induced current can be found by **Right-hand Grip Rule** [B1] as shown in the diagram [B0].

Note: Award maximum 1 mark if student explains using Fleming's Right Hand Rule and draw the direction of the current correctly.



(c) Angular velocity,  $\omega = 2\pi f = 2\pi(50) = 100\pi$

Magnetic Flux linkage,  $\Phi = NBA \sin \omega t$

(since at  $t = 0$  s,  $\Phi = 0$  Wb)

$$= (30)(0.8)(2.5) \sin(100\pi t)$$

$$= 60 \sin(100\pi t)$$

$$\text{Induced e.m.f. } \varepsilon = -\frac{d\phi}{dt}$$

$$= -\frac{d}{dt} [60 \sin(100\pi t)]$$

$$= -100\pi (60) \cos(100\pi t)$$

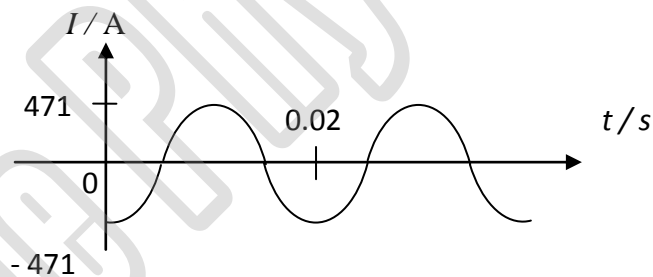
$$= -6000\pi \cos(100\pi t)$$

$$\text{Current, } I = \frac{\varepsilon}{R}$$

$$= \frac{-6000\pi \cos(100\pi t)}{40}$$

$$= -150\pi \cos(100\pi t)$$

$$= -471 \cos(100\pi t)$$



$$(d) I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{471}{\sqrt{2}} = 333 \text{ A}$$

$$P_{\text{mean}} = I_{\text{rms}}^2 R = 333^2 (40) = 4.4 \times 10^6 \text{ W}$$

3

(a) (i) The electromotive force of a source can be defined as the work done in transforming non-electrical energy into electrical energy per unit charge that passes through it.

(ii) p.d. across potentiometer wire =  $10/(10+47) \times 6 = 1.053 \text{ V}$

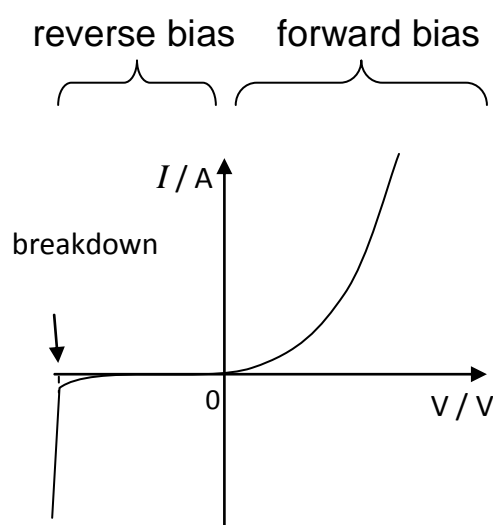
p.d. across 80cm of wire =  $80/100 \times 1.053 = 0.842 \text{ V}$

emf of solar cell = p.d. across balance length =  $0.842 \text{ V}$

(iii) At null deflection, no current passes through the solar cell. There is no potential drop across the internal resistance.

(i) In **forward bias**, a diode is connected to the supply such that it has **low resistance** to current flow. In **reverse bias**, the diode is connected with **high resistance** to the current flow, until the breakdown voltage is reached.

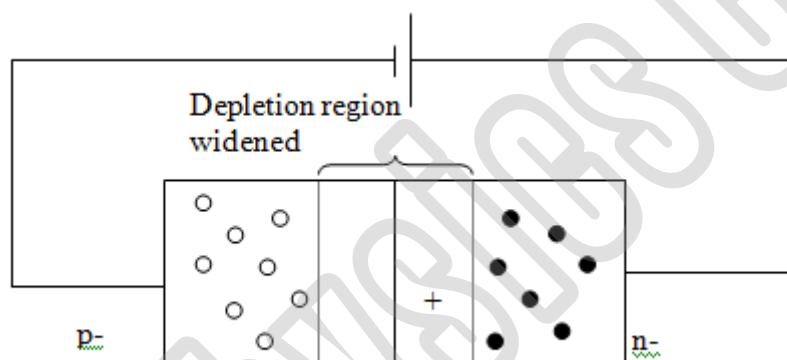
[B1]



(ii) The **breakdown voltage** is the voltage at which (in reverse bias) the resistance of the diode "breaks down". At this voltage,

the **current flows with almost no resistance.**

- (iii) For a **reverse-bias diode**, the n-type semiconductor connected to the positive terminal of the battery and the p-type semiconductor connected to the negative terminal. The holes in the p-type semiconductor move to the negative terminal of the battery, leaving behind more negative ion cores, and the electrons in the n-type semiconductor move to the positive terminal of the battery, leaving behind more positive ion cores. The ions set up an opposing electric field to the cell and a depletion region is formed and the diode acts as insulator. As the voltage of the battery increases, the depletion region widens.



[B1]

There comes a point when all the holes in the p-type semiconductor have moved to the negative terminal of the battery and all the electrons in the n-type semiconductor have moved to the positive terminal of the battery. The depletion region is not able to widen any further and the opposing electric field has reached the maximum value. If the external applied potential difference due to the cell is larger than the voltage due to the opposing electric field, the resistance of the diode “breaks down”. At this voltage, the current flows with almost no resistance.

4

(a)(i) **Electric field strength** is defined as the **force per unit positive charge** acting on a charge.

(ii) The **magnetic flux density** is defined as the **force per unit current per unit length** of the conductor when the conductor is placed at **right angles** to the magnetic field.

[

$$\begin{aligned} \text{(b)} E &= \frac{V}{d} \\ &= \frac{V_+ - V_-}{d} \\ &= \frac{600 - (-600)}{0.02} \\ &= 60000 \text{ Vm}^{-1} \end{aligned}$$

(c) For the electrons that passed straight through,

$$\begin{aligned} F_E &= F_B \\ qE &= Bqv \sin \theta \quad \text{where } \theta = 90^\circ \\ qE &= Bqv \\ v &= \frac{E}{B} \quad \text{----- (1)} \end{aligned}$$

To find  $v$ , we are given  $KE = 250 \text{ eV} = 4 \times 10^{-17} \text{ J}$

$$\begin{aligned} \frac{1}{2} mv^2 &= 4 \times 10^{-17} \\ \frac{1}{2} (9.11 \times 10^{-31}) v^2 &= 4 \times 10^{-17} \\ v &= 9.37 \times 10^6 \text{ ms}^{-1} \end{aligned}$$

From eqn (1)

$$\begin{aligned} v &= \frac{E}{B} \\ 9.37 \times 10^6 &= \frac{60000}{B} \end{aligned}$$

$$B = 0.0064 \text{ T}$$

(d) Magnetic field is directed **out of plane of paper**.

Using **Fleming's Left-Hand Rule** with "current" in opposing direction as the motion because electrons are negatively charged

**(e)** Higher KE electrons have greater velocity  $v$

$$\begin{aligned}\text{Since } F_E &= qE \\ F_B &= Bqv\end{aligned}$$

**$F_B$  will increase** while  $F_E$  will not be affected by  $v$  i.e.  **$F_E$  remains constant.**

Since  $F_B$  is directed upwards, the electrons will be **deflected upwards** towards plate X.



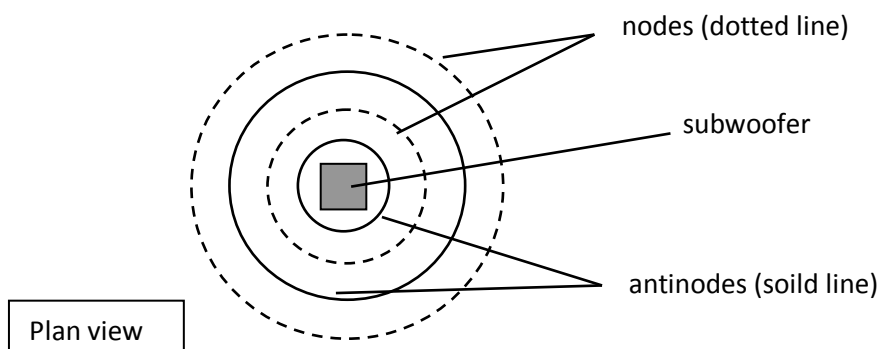
- 5(a) Conditions are: Two progressive waves of
- (i) Equal amplitude
  - (ii) Equal frequency
  - (iii) Traveling in opposite directions at the same speed

meet

- (b) (Assumption) Taking into consideration only the first reflections (or appropriate distance, e.g. Radius =  $(2n+1)\lambda/4$  where  $n = 0, 1, 2, 3, \dots$  or  $n\lambda/2$  times of wavelength where  $n = 1, 2, 3, \dots$  where  $n$  is an integer

Since these reflected waves from the wall suffer no loss in loudness, stationary waves with distinct nodes (soft) and antinodes (loud) will be produced.

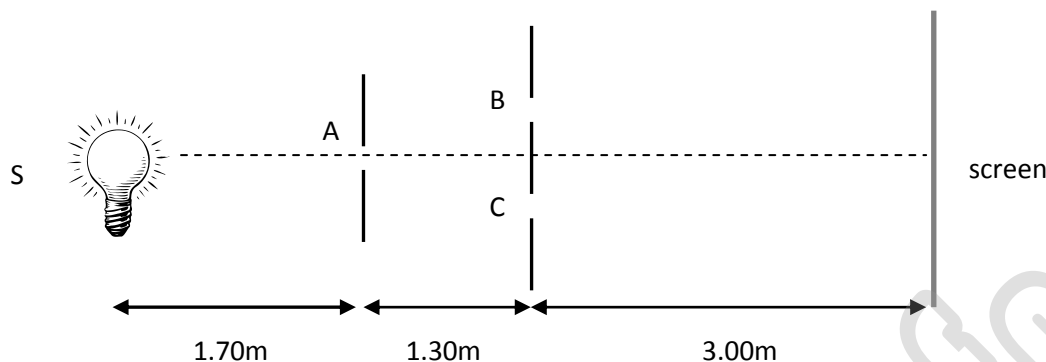
Since the room is circular with the subwoofer in the centre, no other interference is expected besides the interference between the original and reflected wave. Hence, the resultant stationary wave pattern will be concentric circles of nodes and antinodes.



Diagram

- (ii)  $\lambda = v_{\text{sound}} / f_{\text{sound}} = 5 \text{ m}$   
Hence,  $d_{\text{fluctuation}} = 2.5 \text{ m}$   
 $f_{\text{fluctuation}} = v_{\text{man}} / d_{\text{fluctuation}} = 0.4 \text{ Hz}$

(c) The figure below shows a double slit setup used to measure the wavelength of light from a monochromatic lamp S.



(i) To ensure wave coherence at B and C.

(ii)  $x = \lambda D / a$   
where  $D = 3.00\text{m}$  and  $x = (9.50 / 5) \text{ mm}$   
 $\lambda = 6.33 \times 10^{-7} \text{ m}$

(iii)

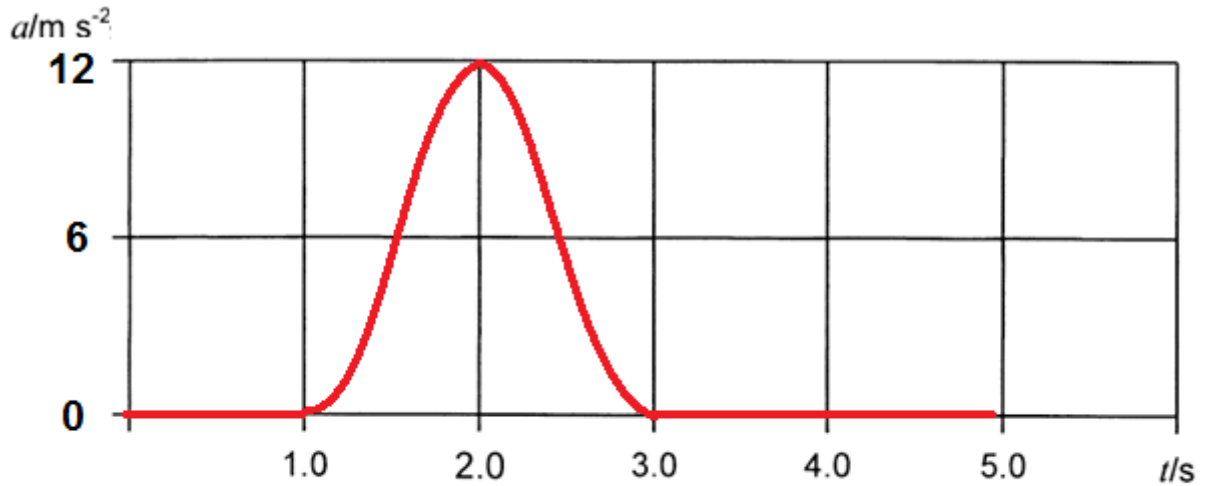
1. Only fringe separation increases , no change to intensity and contrast since  $x = \lambda D / a$
2. no change to fringe separation, but fringe pattern shifts to side nearer C [1], no change to intensity and contrast assuming no reflection and no absorption.

[Accept: Intensity decrease and Contrast decrease if consider reflection of light by the glass and absorption of light energy by the glass]

3. no change in fringe separation , contrast decreases (bright gets less bright, dark gets less dark) because different intensity, destructive interference is not complete, dark fringe is less dark. Intensity decreases

6(a)(i) Instantaneous acceleration can be determined by finding the value of the gradient of the velocity-time graph at a particular time.

(a)(ii)



**Figure 6.2**

(a)(iii) 2.5 s

(a)(iv) Runner A.

Area under the v-t graph is the displacement.

Area under the graph for runner A is larger than that of Runner B.

- (b)(i) Assumption: No work done against friction and air resistance.  
By Conservation of Energy, potential energy loss = kinetic energy gained

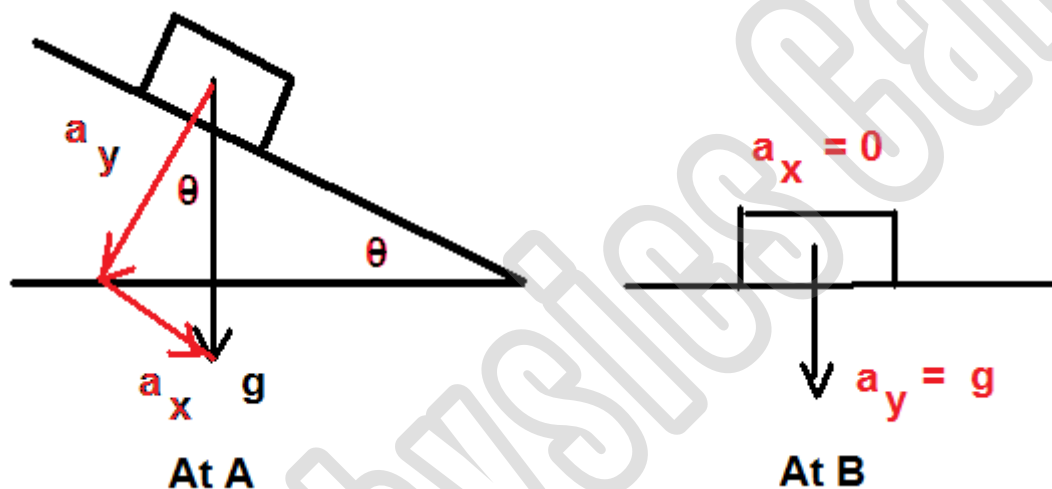
$$mgh = \frac{1}{2}mv^2$$

$$v = (2 \times 9.81 \times 1.5)^{\frac{1}{2}} = 5.42 \text{ m s}^{-1}$$

The velocity is  $5.42 \text{ m s}^{-1}$  towards the right.

- (b)(ii) As skateboarder move from A to B, his angle with the horizontal gets smaller.

Since  $a_x = g \sin \theta$ ,  $a_x$  is larger at A and it decreases to 0 at B.



Alternative:

As the skater descend, his potential energy loss is getting smaller as the slope gets more gentle, hence his kinetic energy gain is getting smaller.

The rate of gain in velocity is also smaller. Since acceleration is defined as the rate of change of velocity with time, the acceleration will also be smaller.

(b)(iii) (1) Horizontal distance =  $5.42 \times 0.45$   
= 2.44 m

(b)(iii)(2)

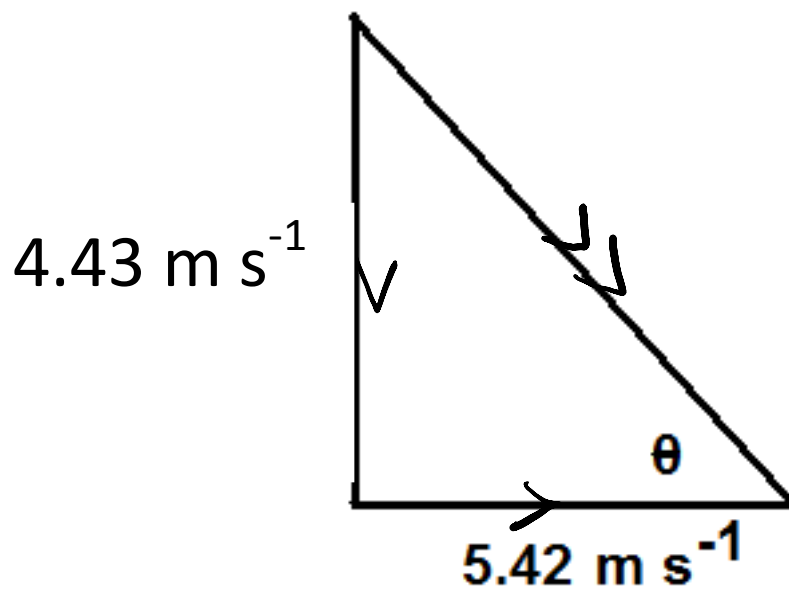
Using vertical height of 1 m,  
For vertical direction,  $v^2 = u^2 + 2as$   
 $v = 4.43 \text{ m s}^{-1}$

(b)(iii)(3)

Magnitude of velocity =  $(4.43^2 + 5.42^2)^{1/2} = 7.00 \text{ m s}^{-1}$

$$\tan \theta = (4.43 / 5.42)$$
$$\theta = 39.3^\circ$$

The resultant velocity is  $7.00 \text{ m s}^{-1}$  at an angle  $39.3^\circ$  with the horizontal.



(c)(i) Archimedes' Principle states that the upthrust on a fully submerged or partially submerged object is equal to the weight of the fluid that is displaced by the object.

(c)(ii) Both Joshua and Cherie were wrong.

The dinghy and the guests when floated independently or as a combined system, the amount of water displaced in both situations are exactly the same.

By Law of Flotation, the weight of displaced amount of water will be the total weight of the guests and the dinghy, which remained unchanged.

Hence the water level will rise to the same level in both situations.

(c)(iii) The answer is different.

The bricks are much denser than the guests and water, displacing much less water due to its much smaller volume when put in the pool as compared to the volume of the floating guests of the same weights.

Hence rise in the water level of the pool (the amount of water displaced is lesser) will be lesser compared to that in (c)(ii), that is, the water level will fall.

Alternative:

The bricks will sink to the bottom of the pool ( $W > U$  where  $W$  is the weight of the bricks and  $U$  is the upthrust acting on the bricks), hence displacing weight of water that is less than its own weight.

Therefore the volume of water of water displaced by the bricks will be lesser. The water level will fall.

7 a) (i) Wave particle duality means that all matter exhibits both wave-like and particle-like properties. [1] De Broglie relation shows the relation between the wave-like (wavelength) and particle-like (momentum) properties of matter. [1]

$$(ii) \quad E_K = \frac{3}{2} kT = \frac{3}{2} (1.38 \times 10^{-23}) (273.15 + 30) = 6.28 \times 10^{-21} \text{ J}$$

$$\begin{aligned} E_K &= p^2/2m \rightarrow p = \sqrt{2mE_K} \\ \text{So, } \lambda &= h/p = h/(\sqrt{2mE_K}) \\ &= 6.63 \times 10^{-34} / [\sqrt{2(0.020/6.02 \times 10^{23})(6.28 \times 10^{-21})}] \\ &= 3.25 \times 10^{-11} \text{ m} \end{aligned}$$

$$\begin{aligned} b) (i) \quad E_{ph} &= hc/\lambda = 6.63 \times 10^{-34} (3 \times 10^8) / 2.55 \times 10^{-7} \\ &= 7.80 \times 10^{-19} \text{ J} \\ &= 4.88 \text{ eV} \end{aligned}$$

$$\begin{aligned} (ii) \quad \text{When } I = 0, \text{ KE lost} &= \text{EPE gained} = eV_S = eEd \\ \text{Hence, } E_{ph} &= \phi + \text{KE} \\ \rightarrow \phi &= E_{ph} - \text{KE} = E_{ph} - eEd \\ &= 7.80 \times 10^{-19} - 1.6 \times 10^{-19}(7.5)(0.50) \\ &= 1.8 \times 10^{-19} \text{ J} \end{aligned}$$

c)(i) An electron with energy of 0 eV has sufficient energy to leave the atom, causing the atom to become ionized.

(ii) When the electron in the atom is at an excited energy state, it will lose its energy and drop down to lower energy states. This loss of energy is emitted as a photon and will be detected as an emission line on a screen. As there are various energy levels in each atom, there are many possibilities for the energy of the photons emitted, and hence photons emitted will be of various wavelengths, giving rise to different emission spectral lines.

(iii) An emission spectrum has various coloured lines on a black background.

$$\begin{aligned} \text{(iv)} \quad n = 1 \quad \Delta E &= E_f - E_i = hc/\lambda \\ \rightarrow \lambda &= hc/E = (6.63 \times 10^{-34})(3 \times 10^8)/(13.60)(1.6 \times 10^{-19}) \\ &= 9.14 \times 10^{-8} \text{ m} \end{aligned}$$

$$\begin{aligned} n = 2 \quad \lambda &= (6.63 \times 10^{-34})(3 \times 10^8)/(3.40)(1.6 \times 10^{-19}) \\ &= 3.66 \times 10^{-7} \text{ m} \end{aligned}$$

$$\begin{aligned} n = 3 \quad \lambda &= (6.63 \times 10^{-34})(3 \times 10^8)/(1.50)(1.6 \times 10^{-19}) \\ &= 8.29 \times 10^{-7} \text{ m} \end{aligned}$$

Visible range of light has wavelengths 400 – 700 nm, hence the transition from  $n = 2$  to infinity absorbs photon of wavelength 366 nm, which can be at the lower range of visible light.

$$\begin{aligned} \text{(v)} \quad E_K &= \frac{1}{2} m v^2 \rightarrow v = \sqrt{2E_K/m} = \sqrt{2(10.2)(1.6 \times 10^{-19})/(9.11 \times 10^{-31})} \\ &= 1.89 \times 10^6 \text{ ms}^{-1} \end{aligned}$$