Inter (Part-I) 2021

Physics	Group-I	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Write the dimensions of: (a) pressure (b) density.

Ans **(i) Dimension of Pressure:**

$$\text{Dimension of pressure} = \frac{\text{Dimension of force}}{\text{Dimension of area}}$$

As $$P = \frac{F}{A} = \frac{ma}{A}$$

$\therefore$ $$\text{Dimension of pressure} = \left[\frac{MLT^{-2}}{L^2}\right]$$

or $$[P] = [MLT^{-2}][L^{-2}]$$

or $$[P] = [M][L^{-1}][T^{-2}]$$

Hence, $$\boxed{[P] = [ML^{-1}T^{-2}]}$$

(ii) Dimension of Density:

As $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$$

$$\text{Dimension of density} = \left[\frac{M}{L^3}\right]$$

or $$[\rho] = \left[\frac{M}{L^3}\right]$$

$$= [M]\{L^{-3}\}$$

Hence, $$[\rho] = [ML^{-3}]$$

(ii) How the uncertainty in the time period of vibrating body is found?

Ans The uncertainty in the time period of a vibrating body is found by dividing the least count of timing device by the number of vibrations. For example, the time of 30 vibrations of a simple pendulum recorded by a stopwatch accurate up to one-tenth of a second is 54.6 s, the period

$T = \frac{54.6}{30}$ s = 1.825 with uncertainty $\frac{0.1}{30}$ s= 0.003 s

Thus, period T is quoted as T = 1.82 ± 0.003 s.

Hence, it is advisible to count large number of swings to reduce timing uncertainty.

(iii). Wite two uses of dimensions.

Ans Following are two uses of dimensions:

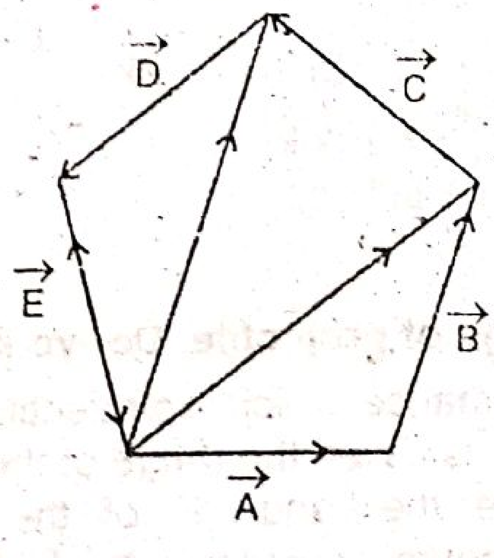
1. We can check the correctness of a given formula or an equation.
2. We can also derive the formula or an equation by using it.

(iv) Does dimensional analysis give any information on constant of proportionality that may appear in an algebraic expression? Explain.

Ans By dimensional analysis, an algebraic expression of a physical quantity can be derived but constant of proportionality cannot be determined. It can be determined by experiments.

(v) Suppose the sides of a closed polygon represent vectors arranged head to tail. What is the sum of these vectors?

Ans As we know that the resultant of a number of vectors which make a closed path is equal to zero.



If the vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$, and $\vec{E}$ are represented by the sides of a closed polygon, then they are added by using head to tail rule. Thus, the sum will be zero because the tail of the first vector coincides (meets) with the head of last vector.

Hence,

$$\vec{A} + \vec{B} + \vec{C} + \vec{D} + \vec{E} = 0$$

Hence, the sum of vectors of closed polygon becomes zero, because their resultant is represented in magnitude and direction by the closing side of the polygon taken in opposite order.

(vi) Two vectors have unequal magnitudes. Can their sum be zero? Explain.

Ans If two vectors have unequal magnitudes, then their sum can never be zero, whereas, if two vectors of equal magnitude are acting in opposite direction, then their sum will be equal to zero.

(vii) If $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$, $\vec{B} = 3\hat{i} - 2\hat{k}$, Find $\vec{A}.\vec{B}$.

Ans $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$

$\vec{B} = 3\hat{i} - 2\hat{k}$

$$\vec{A}.\vec{B} = (2\hat{i} + 3\hat{j} - \hat{k}) . (3\hat{i} - 2\hat{k})$$
$$= 6 (\hat{i}.\hat{i}) + 2 (\hat{k}.\hat{k})$$
$$= 6(1) + 2(1)$$
$$= 6 + 2 = \boxed{8}$$

(viii) Define range of projectile. Derive its expression.

Ans Maximum distance which a projectile covers in the horizontal direction is called the range of the projectile.

To determine the range R of the projectile, we multiple the horizontal component of the velocity of projection with total time taken by the body after leaving the point of projection.

Thus, $R = v_{ix} \times t$

$$R = \frac{v_i \cos\theta \times 2 v_i \sin\theta}{g}$$

$$R = \frac{v_i^2}{g} 2 \sin\theta \cos\theta$$

$$\boxed{R = \frac{v_i^2}{g} \sin 2\theta}$$

(ix) State the law of conservation of linear momentum, pointing out the importance of isolated system.

Ans It states that the total linear momentum of an isolated system always remains constant.

Importance:

Its importance can be understood by many examples of isolated system which conserve momentum.

1. Molecules of a gas enclosed in a vessel at constant temperature.
2. Rocket and its fuel.
3. Gun and bullet.
4. Elementary particles of an atom, such as proton, electron and neutron when they suffer collision.

(x) Find the angle of projection for which range of projectile is equal to four times the maximum height.

Ans Angle of projection = θ = ?

Maximum height = $h = \frac{v^2 \sin^2\theta}{2g}$

Range of projectile = $R = \frac{v^2 \sin 2\theta}{g}$

According to the question,

$4h = R$

Putting the values, we get

$$4\left(\frac{v^2 \sin^2 \theta}{2g}\right) = \frac{v^2 \sin 2\theta}{g}$$

$$\frac{4}{2}\left(\frac{\sin^2 \theta}{g}\right) g = \frac{v^2 \sin 2\theta}{v^2}$$

$$2 \sin^2 \theta = \sin 2\theta$$

$$2 \sin^2 \theta = 2 \sin \theta \cos \theta$$

$$\frac{2 \sin^2 \theta}{2 \sin \theta \cos \theta} = 1$$

$$\frac{\sin \theta}{\cos \theta} = 1$$

$$\tan \theta = 1$$

$$\theta = \tan^{-1}(1)$$

$$\theta = 45^\circ$$

(xi) What is the principle of rocket propulsion?

Ans The motion of a rocket is an application of the law of conservation of momentum and Newton's third law of motion. A rocket has combustion chamber in which liquid or solid fuel is burnt and jets of hot gases are ejected out with a very high velocity from an opening at the tail of the rocket. The gases rushed out from the rocket gain a downward momentum and the rocket moves upward to balance the momentum of gases.

(xii) Explain, how the swing is produced in a fast moving cricket ball?

Ans When cricket ball is bowled by a fast bowler, then velocity of air on one side of ball increases due to less friction. According to Bernoulli's equation, when velocity is high, then pressure is low and the ball moves in a curved shaped path towards the shined side which is called swing.

3. Write short answers to any EIGHT (8) questions: (16)

(i) Calculate the work done in kilo joules in lifting a mass of 10 kg (at a steady velocity) through a vertical height of 10 m.

Ans Mass = m = 10 kg

Acceleration due to gravity = g = 9.8 m/s^2
Vertical height = h = 10 m

$$W = P.E = mgh$$
$$= 10 \times 9.8 \times 10 = 980 \text{ J}$$
$$= 0.98 \text{ kJ}$$

(ii) When a rocket re-enters the atmosphere, its nose cone becomes very hot. Where does this heat energy come from?

Ans There is a large number of dust particles and water vapours present in the air. When a rocket re-enters the atmosphere, it has to face the resistance due to particles. Some K.E. of the rocket is converted into heat energy. Therefore, the cone nose of the rocket becomes very hot due to the heat energy produced by the fluid friction of atmosphere.

(iii) Define: (a) gravitational field. (b) conservative field.

Ans **(a) Gravitational Field:**

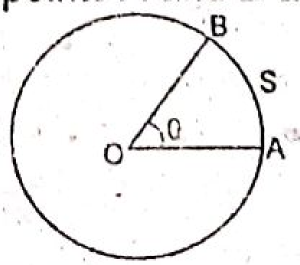
The space around the Earth in which its gravitational force acts on a body is called the gravitational field.

(b) Conservative Field:

The field in which the work done be independent of the path followed or work done in a closed path be zero, is called a conservative field.

(iv) Prove that s = rθ where θ is in radian.

Ans Consider a circle of radius "r". Let "S" be an arc length of this circle connecting the points A and B as shown in figure below:



By the definition of radian, we can understand that

$1 \text{ radian} \propto r \Rightarrow 1 \text{ radian} = kr$ (i)

and $\theta \text{ radian} \propto s \Rightarrow \theta \text{ radian} = ks$ (ii) where k is constant of proportionality by dividing eq. (ii) by eq. (i), we get

$$\frac{\theta \text{ radian}}{1 \text{ radian}} = \frac{ks}{kr}$$

$$\frac{\theta}{1} = \frac{s}{r}$$

$$s = r\theta$$

(v) When mud flies off the tyre of a moving bicycle, in what direction does it fly? Explain.

Ans The mud will fly off tangentially along a straight line. When the tyre rotates, a centripetal force acts on the mud, which is equal to the adhesive force between the tyre and mud. When the angular speed of the tyre increases, the centripetal force on the mud also increases. When this centripetal force is greater than the adhesive force, the mud leaves the tyre and flies off tangentially along a straight line due to centrifugal force, which is simply the reaction of the centripetal force.

(vi) Show that orbital angular momentum $L_o = mvr$.

Ans Angular momentum is given as:

$$\vec{L} = \vec{r} \times \vec{p}$$

Magnitude of angular momentum is:

$$L_o = r\, p \sin\theta \qquad (i)$$

where θ is angle between r and p.

Linear momentum is given as:

$$\vec{p} = m\vec{v}$$

Magnitude of linear momentum is:

$$p = mv$$

Putting this value in (i),

$$L_o = r\, m\, v \sin\theta$$

Let the object is moving in such a way that

$$\theta = 90$$

$$L_o = m\, v\, r \sin 90^\circ$$

$L_o = m v r$ (1)

$L_o = m v r$ Hence Proved.

(vii) Define forced oscillations. Give its example.

Ans **Free Oscillations:**

When a body oscillates with its natural frequency without the interference of an external force, it is said to be performing free vibrations or oscillations.

Forced Oscillations:

If a freely oscillating system is forced to vibrate under an external force, then forced vibrations will be produced which are known as forced oscillations.

(viii) If a mass spring system is hung vertically and set into oscillations, why does the motion eventually stop?

Ans A damped oscillator eventually comes to rest as its mechanical energy is dissipated. Same is the case with mass hanging vertically with spring air resistance plays a vital role in dissipation of energy.

(ix) What happens to the period of a simple pendulum if its length is doubled?

Ans As we know:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

According to given condition, if length is doubled *i.e.*, $l' = 2l$

$$T' = 2\pi\sqrt{\frac{l'}{g}}$$

$$T' = 2\pi\sqrt{\frac{2l}{g}}$$

$$= \sqrt{2}\left(2\pi\sqrt{\frac{l}{g}}\right)$$

$$= \sqrt{2}\,T$$

$$= 1.41T$$

It means time period increases by $\sqrt{2}$ times.

→. The time period of simple pendulum is independent of mass, therefore, if mass is doubled there will be no change in 'T'.

(x) Define the terms node and antinode.

Ans **Node:**

The point is stationary wave at which amplitude of medium particle is permanently zero.

Antinode:

The point is stationary wave at which amplitude of medium particle is maximum.

(xi) If a string vibrates in four segments at a frequency of 120 Hz, determine its fundamental frequency.

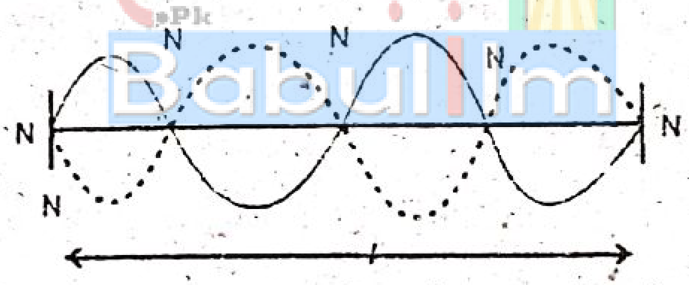
Ans Length of string = l = 120 cm

$$= \frac{120}{100} = 1.2 \text{ m}$$

Number of loops = n = 4

Frequency of vibration in four segments = f_4 = 120 Hz

Fundamental frequency = f_1 = ?



When a string vibrates in n loops, the formula for the frequency of stationary waves is given by

$$f_n = nf_1$$

where f_1 is the fundamental frequency and n is number of loops.

In the problem, number of loops is 4 *i.e.*, n = 4

Therefore,

$$f_4 = 4f_1$$

Putting the value of f_4 = 120 Hz, we get

$$120 = 4 f_1$$

$$f_1 = \frac{120}{4} = 30 \text{ Hz}$$

Hence, $\boxed{f_1 = 30 \text{ Hz}}$

(xii) Is it possible for two identical waves travelling in the same direction along a string to give rise to a stationary wave? Explain.

Ans No, it is not possible because two identical waves produce stationary waves only when they travel in opposite directions along the same string.

4. Write short answers to any SIX (6) questions: 12

(i) How would you manage to get more orders of spectra using a diffraction grating?

Ans The grating equation is given by

$$d \sin \theta = n\lambda$$

For a given wavelength λ, the order n of spectra depends upon d, that is, n is directly porportional to d *i.e.,* $n \propto d$ but

$$d = \frac{1}{N}$$

On increasing θ when θ becomes 90°

The maximum value of $\sin \theta = 1$

Therefore, we conclude that in order to get more orders spectra, we should increase the grating element 'd' *i.e.,* spacing between the lines ruled on grating or decrease the number of lines on the grating. The grating equation is given by

$$d \sin \theta = n\lambda$$

This equation shows that for a given value of wavelength 'λ' of monochromatic light, the order 'n' of spectra depends upon angle of diffraction 'θ' and grating element 'd'. ($n \propto d$ and $n \propto \theta$).

(ii) Write two parts of Huygen's principle.

Ans Huygen's principle consists of two parts:

1. Every point of a wave front may be considered as a source of secondary wavelets which spread out in forward direction with a speed equal to the speed of propagation of the wave.
2. The new position of the wave front after a certain interval of time can be found by constructing a surface that touches all the secondary wavelets.

(iii) Write two conditions for detectable interference.

Ans (1) The interfering beams must be monochromatic, that is, of a single wavelength.

(2) The interfering beams of light must be coherent.

(iv) If a person was looking through a telescope at the full moon, how would the appearance of moon be changed by covering half of the objective lens?

Ans If half of the objective lens of a telescope is covered, the moon will appear full to the person looking at it. But intensity of light depends upon the diameter of the objective lens, therefore, the intensity of the light received from the moon will decrease. Thus, its brightness is reduced by the half-covered objective lens.

(v) What is optical fibre? Write down two uses of fibre optics.

Ans **Uses:**

1. The use of light as transmission carrier wave has many advantages over radio wave carriers. It has much wider bandwidth capability and safe from electromagnetic interference.
2. Fibre optics is also used to transmit light around corners and into unapproachable places, which are unobservable in normal conditions.

(vi) Is it possible to convert internal energy into mechanical energy? Explain with an example.

Ans Yes, in adiabatic expansion, internal energy is changed into mechanical energy. According to 1st law of thermodynamics,

$$Q = \Delta U + W \qquad \because \quad Q = 0$$

$$0 = \Delta U + W$$

$$W = -\Delta U$$

Example:

In petrol engine, hot gases expand and piston moves, so internal energy is converted into work.

(vii) Give an example of a process in which no heat is transferred to or from the system but the temperature of the system changes.

Ans Adiabatic process is an example of such a process. Consider a gas enclosed in a non-conducting cylinder by a non-conducting piston. If the gas is compressed, the work done on the gas will increase its temperature but no heat will leave the system.

Conversely, if the gas is allowed to expand, the work done by the gas at the cost of its internal energy will decrease its temperature but no heat will enter the system. This compression or expansion of the gas is adiabatic in nature because no heat is transferred to or from the system but its temperature changes.

(viii) Derive Charles's law on the basis of kinetic molecular theory of gases.

Ans As we know,

$$V = \frac{2N}{3P}\left(\frac{1}{2}mv^2\right)$$

When pressure is constant.

$$V \propto \left\langle \frac{1}{2}mv^2 \right\rangle \qquad \because \quad T \propto \left\langle \frac{1}{2}mv^2 \right\rangle$$

$$V \propto T$$

"The volume is directly proportional to absolute temperature of gas provided pressure is kept constant. It is known a Charles' Law."

(ix) Is it possible to construct a heat engine that will not expel heat into the atmosphere?

Ans No, it is not possible to construct a heat engine that will not expel heat into atmosphere. Since, environment act as cold body or sink of heat engine to which apart of heat energy is to be rejected.

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) Distinguish between elastic and inelastic collisions. Show that when two smooth balls undergo elastic collision in one dimension the magnitude of relative velocity of approach is equal to the magnitude of relative velocity of separation. (5)

Ans For Answer see Paper 2018, (Group-I), Q.5.(a).

(b) Two forces of magnitude 10 N and 20 N act on a body in directions making angle 30° and 60° with x-axis, respectively. Find the resultant force. (3)

Ans **Step (i) x-components**

The x-component of the first force = $F_{1x} = F_1 \cos 30^\circ$

$= 10\text{ N} \times 0.866$

$= 8.66\text{ N}$

The x-component of second force = $F_{2x} = F_2 \cos 60^\circ$

$= 20\text{ N} \times 0.5 = 10\text{ N}$

y-components:

The y-component of the first force = $F_{1y} = F_1 \sin 30^\circ$

$= 10\text{ N} \times 0.5 = 5\text{ N}$

The y-component of second force = $F_{2y} = F_2 \sin 60^\circ$

$= 20\text{ N} \times 0.866$

$= 17.32\text{ N}$

Step (ii)

The magnitude of x component F_x of the resultant force **F**

$$F_x = F_{1x} + F_{2x}$$
$$F_x = 8.66\text{ N} + 10\text{ N} = 18.66\text{ N}$$

Step (iii)

The magnitude of y component F_y of the resultant force **F**

$$F_y = F_{1y} + F_{2y}$$
$$F_y = 5\text{ N} + 17.32\text{ N} = 22.32\text{ N}$$

Step (iv)

The magnitude F of the resultant force **F**

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(18.66\text{ N})^2 + (22.32\text{ N})^2}$$
$$= 29\text{ N}$$

Step (v)

If the resultant force **F** makes an angle θ with the x-axis, then

$$\theta = \tan^{-1}\frac{F_y}{F_x} = \tan^{-1}\frac{22.32\text{ N}}{18.66\text{ N}} = \tan^{-1} 1.196 = 50^\circ$$

Q.6.(a) Prove that the work done in the gravitational field is independent of path followed by the body.

Ans For Answer see Paper 2017, (Group-II), Q.6.(a).

(b) Find the temperature at which the velocity of sound in air is two times its velocity at 10°C. (3)

Ans $10^\circ C = 10^\circ C + 273 = 283\text{ K}$

Suppose at T K, the velocity is two times its value at 283 K.

Since $\frac{v_t}{v_{283}} = \sqrt{\frac{T}{283\text{ K}}}$

Therefore, $\frac{v_t}{v_{283}} = \sqrt{\frac{T}{283\text{ K}}} = 2$

or T = 1132 K or 859 °C

Q.7.(a) Define terminal velocity. Show that terminal velocity is directly proportional to the square of radius. (5)

Ans **Terminal Velocity:**

Consider a water droplet such as that of fog falling vertically, the air drag on the water droplet increases with speed. The droplet accelerates rapidly under the overpowering force of gravity which pulls the droplet downward. However, the upward drag force on it increases as the speed of the droplet increases. The net force on the droplet is

Net force = Weight – Drag force (i)

As the speed of the droplet continues to increase, the drag force eventually approaches the weight in the magnitude. Finally, when the magnitude of the drag force becomes equal to the weight, the net force acting on the droplet is zero. Then, the droplet will fall with constant speed called terminal velocity.

To find the terminal velocity v_t in this case, we use Stokes Law for the drag force. Equating it to the weight of the drop, we have:

$$mg = 6\pi\eta r v_t$$

or $$v_t = \frac{mg}{6\pi\eta r} \quad \text{(ii)}$$

The mass of the droplet is ρV,

where, volume $V = \frac{4}{3}(\pi r^3)$

Substituting this value in the above equation, we get

$$v_t = \frac{2g\,r^2\rho}{9\eta} \quad \text{(iii)}$$

(b) A body of moment of inertia I = 0.80 kg m² about a fixed axis, rotates with a constant angular velocity of 100 rad s⁻¹. Calculate its angular momentum L and the torque to sustain this motion. (3)

Ans For Answer see Paper 2017, (Group-II), Q.6.(b).

Q.8.(a) What is phase? Derive the formula of velocity in case of a horizontal mass-spring system. (1,4)

Ans **Horizontal Mass Spring System**

Practically, for a simple harmonic system, consider again the vibrating mass attached to a spring, whose acceleration at any instant is given by Eq., which is

$$a = -\frac{k}{m}x$$

As k and m are constant, we see that the acceleration is proportional to displacement x, and its direction is towards the mean position. Thus the mass m executes SHM between A and A′ with x_o as amplitude. Comparing the above equation with $a = -w^2x$ the vibrational angular frequency is

$$\omega = \sqrt{\frac{k}{m}} \quad \dots (i)$$

The time period of the mass is

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}} \quad \dots (ii)$$

The instantaneous displacement x of the mass as given by Eq. is

$$x = x_o \sin \omega t$$

$$x = x_o \sin \sqrt{\frac{k}{m}}\,t \quad \dots (iii)$$

The instantaneous velocity v of the mass m, given by another eq. is

$$v = \omega\sqrt{x_o^2 - x^2} = \sqrt{\frac{k}{m}(x_o^2 - x^2)}$$

$$= x_o\sqrt{\frac{k}{m}\left(1 - \frac{x^2}{x_o^2}\right)} \quad \dots (iv)$$

Eq. (iv) shows that the velocity of the mass gets maximum equal to v_o, when $x = 0$. Thus

$$v_o = x_o \sqrt{\frac{k}{m}} \quad \therefore \text{(v)}$$

Then $$\bar{v} = v_o \sqrt{1 - \frac{x^2}{x_o^2}} \quad \dots \text{(vi)}$$

The formula derived for displacement and velocity are also valid for vertically suspended mass-spring system provided air friction is not considered.

(b) A heat engine performs 100 J of work and at the same time ejects 400 J of heat energy to cold reservoirs. What is the efficiency of the engine? (3)

Ans For Answer see Paper 2018, (Group-II), Q.7.(b).

Q.9.(a) What is compound microscope? Describe its construction and working. Also calculate its magnifying power. (5)

Ans For Answer see Paper 2019, (Group-I), Q.9.(a).

(b) A light is incident normally on a grating which has 2500 lines per centimeter. Compute the wavelength of a spectral line for which the deviation in second order is 15°. (3)

Ans **Solution:**

Data:

No. of lines per cm. = 2500 = 250000 / m

Angle of diffraction = θ = 15°

For second order = n = 2

To Find:

Wavelength of light = λ = ?

Formula:

$$d \sin\theta = n\lambda$$

Calculations:

Using the formula,

$$d \sin\theta = n\lambda$$

or $$\lambda = \frac{d \sin\theta}{n}$$

But $d = 1/N$ (d = grating element)

$$\therefore \quad \lambda = \frac{\sin\theta}{N \times n}$$

Putting the values, we get

$$\lambda = \frac{\sin 15^o}{250000 \times 2} = \frac{0.2588}{500000} = 5.18 \times 10^{-7}\ m$$

$$= 5.18 \times 10^{-7} \times \frac{100}{100} = 518 \times 10^{-9}\ m$$

Hence, $\boxed{\lambda = 518\ mm}$

Result:

The wavelength of spectral line is 518 nm.