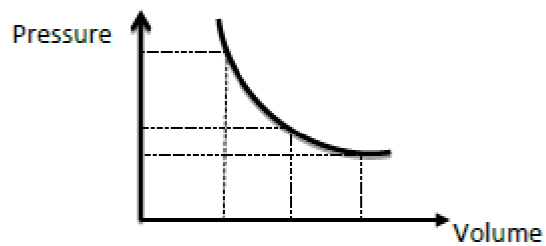
<u>Substrand 3.2:</u> Statics fluids

LESSON 67 LO: study Boyle's law.

<u>Boyle's Law</u>

"The <u>pressure</u> of a given mass of an ideal gas is <u>inversely proportional</u> to its <u>volume</u>, at a <u>constant temperature</u>."

The graph shows an *inverse relationship* between volume, V and pressure, P.



This is known as Boyle's Law and can be written:

$$P \alpha \frac{1}{V} \text{ (Temperature constant)}$$

Mathematically, when solving problems, the relationship is written:

$$P_1V_1 = P_2 V_2$$

Where P_1 : is the initial pressure, V_1 : is the initial volume
P_2 : is the final pressure, V_2 : is the final volume

Example: *An amount of air at atmospheric pressure (10^5 Pa) is contained inside a bicycle pump with its nozzle sealed. The volume of the air is 12 cm^3. What is the pressure of the air inside the pump if the handle is pulled out to a volume of 24 cm^3?*

***Solution*:** Initially the pressure (P_1) is 10^5 Pa and the volume, V_1 is 12 cm^3. After the handle is pulled out, the new volume, V_2, is 24 cm^3. Calculate the pressure required, P_2.

$$P_1V_1 = P_2 V_2$$

$10^5 \times 12 = P_2 \times 2$ [substituting]

$P_2 = \frac{10^5 \times 12}{24}$ [rearranging]

= <u>**5.0×10^4 Pa**</u>

ACTIVITY

Fluids and Statics

1. $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
2. $\rho = \frac{m}{V}$
3. $P = \frac{F}{A}$
4. $P = \rho g h$

2019

If the temperature of a gas is constant and pressure is decreased, the volume will

A. increase.
B. decrease.
C. remain the same.
D. change randomly.

A certain amount of air at atmospheric pressure (1×10^5 Pa) is contained inside a pump. The volume of the air is 15 cm^3. What is the pressure of the air inside the pump if the handle is pulled out to a volume of 25 cm^3 (Assume the temperature remains constant).

(2 marks)

FY12CE 2018

A group of students were given 20 ml of an unknown gas in a closed container. The pressure and temperature of the gas inside the container was 2×10^3 Pa and 25°C respectively. Which of the following quantities should remain constant if the students are trying to test Boyle's Law?

A. Volume of gas
B. Pressure of gas
C. Temperature of gas
D. Speed of gas particles

FY12CE 2017

The law that states pressure is inversely proportional to volume at constant temperature is

A. Boyle's Law.
B. Charles' Law.
C. Hooke's Law.
D. Pressure Law.

FY12CE 2016

The pressure of a gas increases at constant temperature if its volume

A. increases.
B. decreases.
C. equals to zero.
D. remains the same.

LESSON 68 LO: solve problems related to different types of pressure.

PRESSURE LAW

Conclusion

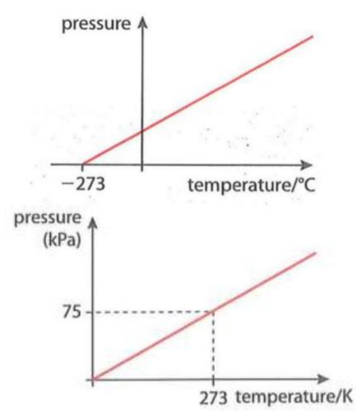
$P \alpha T \longrightarrow P/T = \text{constant}$

$P_1/T_1 = P_2/T_2$

Pressure Law

Pressure of a fixed mass of gas at constant volume is directly proportional to its Kelvin temperature.

Pressure Law



Pressure and Temperature are directly proportional as long as the temperature is measured in Kelvins

ATMOSPHERIC PRESSURE

- Is force per unit area exerted by the weight of the column of air above the measuring point.
- Expressed in various units.

1 atm = 1.0325×10^5 Pa
1 atm = 760 mmHg
1 atm = 1.01325 Bar

GUAGE PRESSURE

- **Pressure measured by gauge. (This device measures the pressure relative to the atmospheric pressure. i.e. it is calibrated against the atmospheric pressure.)**

For Pressure in a uniform fluid:
The **gauge pressure** at a particular depth is directly proportional to ...
- the density of the fluid **ρ**,
- the acceleration due to gravity *g*, and
- the depth ***h***.

Thus, the Absolute pressure in a uniform fluid at a particular depth is given by :

$$\text{Total (or Absolute Pressure)} = P_{GAUGE} + P_{ATMOSPHERE}$$

$$P_{TOTAL} = P_{ATMOSPHERE} + \rho g h$$

Example 1
A diver in the ocean measures gauge pressure to be 515 kPa. What is the absolute pressure?

$P = P_A + P_G$
$P = 101\text{ kPa} + 515\text{ kPa}$
$P = \underline{616\text{ kPa}}$

Example 2
What is the absolute pressure at the bottom of the swimming pool whose depth is 2 m?

$P = P_A + P_G$
$P = P_A + \rho g h$
$P = 101300\text{ Pa} + (1000\text{ kg/m}^3)(9.8\text{ m/s}^2)(2\text{ m})$
$P = \underline{120900\text{ Pa} = 1.209 \times 10^5\text{ Pa.}}$

ACTIVITY

Fluids and Statics

1. $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
2. $\rho = \frac{m}{V}$
3. $P = \frac{F}{A}$
4. $P = \rho g h$

2019

Calculate the total pressure experienced by the diver who is at a depth of 5 m below the sea level. The atmospheric pressure at sea level is 1.01×10^5 Pa and the density of sea water is 1029 kgm^{-3}. **(2 marks)**

FY12CE 2018

A diver in the ocean measures gauge pressure to be 500 kPa. State **two** quantities that determine the gauge pressure of a fluid. **(1 mark)**

FY12CE 2017

A diver in the ocean measures gauge pressure to be 500 kPa. What is the absolute pressure? **(1 mark)**

FY12CE 2016

Calculate the gauge pressure of water at a depth of 2 m. The density of water is 1000 kg/m^3. **(1 mark)**

FY12CE 2015

A diver in the ocean measures gauge pressure to be 520 kPa.

(i) State **two** quantities used to calculate gauge pressure.

(ii) Use the formula $P = P_A + P_G$ and atmospheric pressure = 101 kPa to calculate the absolute pressure.

2014

Calculate the gauge pressure of water at a depth of 2 m. The density of water is 1000 kg/m^3. **(1 mark)**

STRAND 4 : GEOMETRICAL OPTICS AND WAVE MOTION

STRAND 4.1 LIGHT

LESSON 69 LO: study and use Snell's Law.

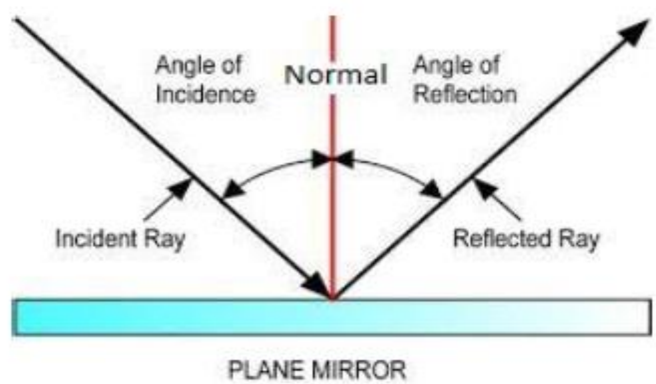
LIGHT

- Is an electromagnetic wave or EM[Electromagnetic Radiation]
- Travels at a speed of c= 3 x 10^8 m/s.
- Travels in a straight line.(straight line proportion).

PROPERTIES OF LIGHT

1. **Rectilinear propagation**: travels in a straight line.
2. **Reflection**: bouncing off shiny surfaces.
3. **Refraction**: bending when travelling into different medium.

REFLECTION OF LIGHT



Laws of reflection

1. Angle of incidents = the angle of reflection.

$$\theta_1 = \theta_2 \quad \text{or} \quad \hat{i} = \hat{r}$$

2. Incident ray, reflected rays and normal all lie in the same plane.

3. Normal is the line perpendicular to the plane and to the surface at the point where incident and reflected ray meet.

4. Angle of incident and angle of reflection is always measured towards the normal.

REFRACTION

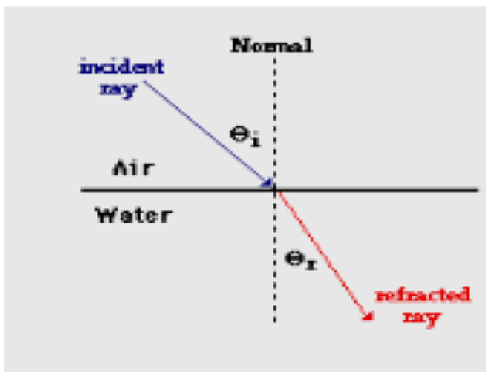
- Bending of light as it passes from one medium to another.
- Direction changes due to change of its velocity.

Laws of Refraction:

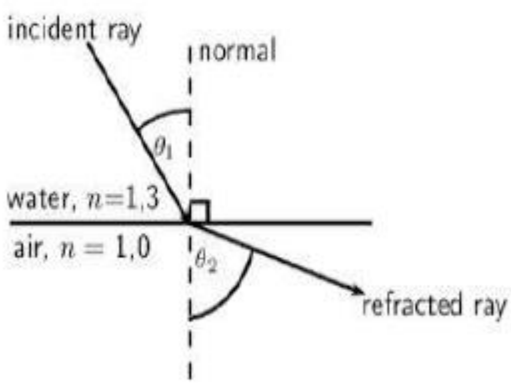
1. The incident ray, refracted ray and the planar are co-planar.

2. Angle of incident and refracted angle are measured towards the normal.

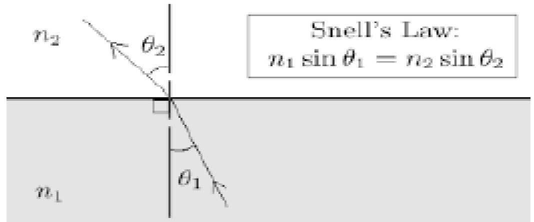
3. When light travels from less dense material to move dense the refracted ray bend towards the normal



4. When light travels from more dense to less dense the refracted ray bend away from normal.

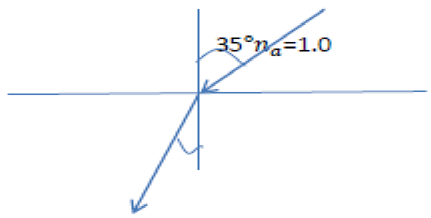


5. Snell's law determines the amount that light is bending or refraction.



Example:

Calculate the angle of refraction for light travelling from air (n_a=1.0) into glass (ng=1.5) if the angle of incidence is 35°.



$\theta_2 n_g$=1.5

$n_1 \sin\theta_{1=n_2} \sin\theta_2$

$1.0 \sin 35 = 1.5 \sin\theta_2$

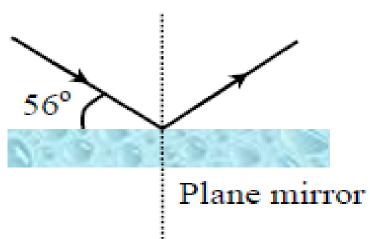
∴

$\sin\theta_2$=0.3824

θ_2=22.5

Activity
2017

The diagram given below shows a ray of light striking a plane mirror at an angle of 56°.



(i) Label the **incident ray**, **angle of incidence**, **reflected ray** and **angle of reflection** on the diagram given in the **Answer Booklet**. **(2 marks)**

(ii) Calculate the angle of reflection. **(1 mark)**

(iii) Hence, calculate the angle between the incident and the reflected ray. **(1 mark)**

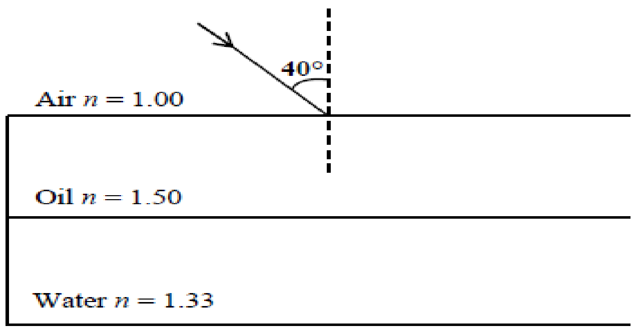
2016

Which of the following **best** represents the law of reflection for a well-polished surface?

A. $\hat{i} = \hat{r}$
B. $\hat{i} \neq \hat{r}$
C. $\hat{i} < \hat{r}$
D. $\hat{i} > \hat{r}$

2015

Tom noticed a puddle of water with oil floating on top. The diagram below shows a ray of light travelling from air as it meets the air-oil interface.



(i) Complete the path of the ray of light in the diagram provided in the **Answer Book** to show what happens to the ray as it enters the oil, and then the water.

(ii) Calculate the angle of refraction when light enters oil from air.

2014

Light, when it hits a plane mirror can be reflected. One of the 'Laws of Reflection' states that the angle of incidence is

A. less than the angle of reflection.
B. greater than the angle of reflection.
C. equal to the angle of reflection.
D. not equal to the angle of reflection.

2013

The formation of an **inverted** image on the screen of a pin-hole camera shows that light

A. creates shadows.
B. is affected by gravity.
C. travels in straight lines.
D. can bend around objects.

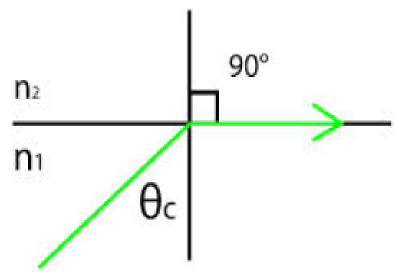
LESSSON 70 LO: calculate critical angle and refractive index.

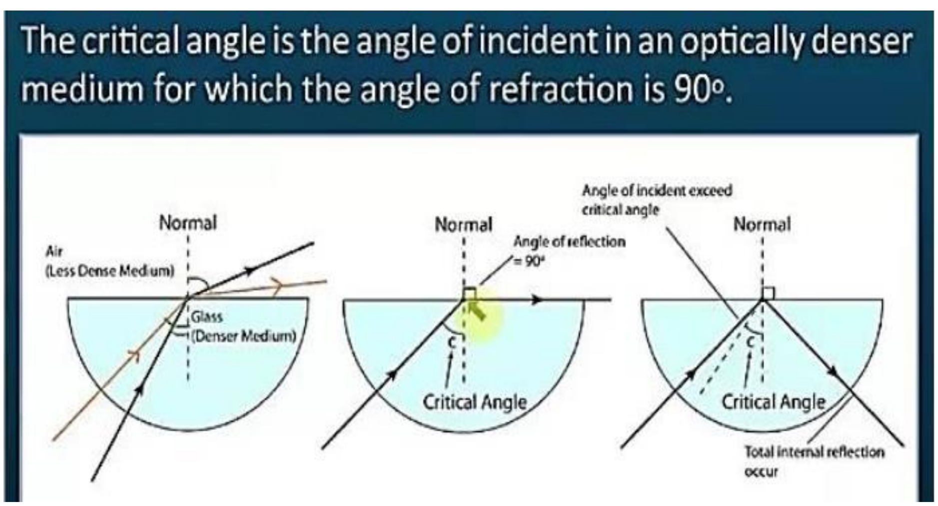
CRITICAL ANGLE

$$\sin \vartheta_c = \frac{n_2}{n_1}$$

Or use snells law note that ($\vartheta_1 = \vartheta_c$ and ϑ_2= 90^0)

Critical angle is the angle of incidence which gives an angle of refraction of 90°. This only happens if the ray of incident is moving from more dense substance to less dense.

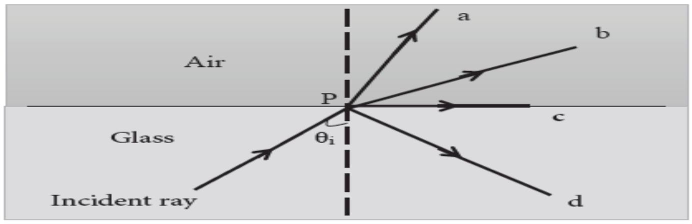




Critical angle is the angle of incidence where the angle of refraction is ____^{0}.

2019

A ray of light travelling in glass reaches a point P as shown. The angle of incidence, θ_i, is also the critical angle for glass.

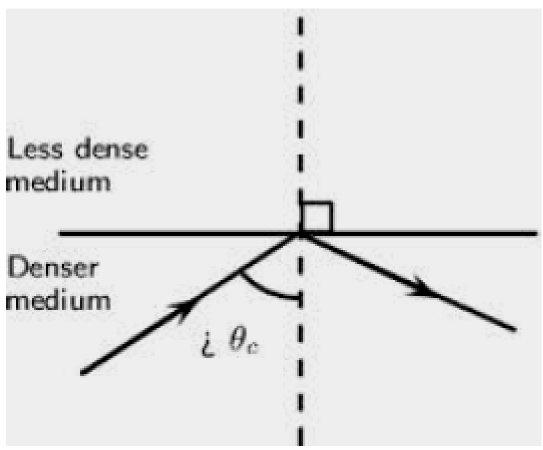


In which direction will the ray travel after passing point P?

A. a
B. b
C. c
D. d

TOTAL INTERNAL REFLECTION

- Angle of incidence is greater than the critical angle.
- Application: formation of mirages and apparent pools of water on bitumen roads in hot weather.



Different substance (transparent material) has different refractive index.

Substance	n	Substance	n
diamond	2.24	Paraffin oil	1.44
Ruby	1.76	Ethanol	1.36
Flint glass	1.65	Water	1.33
Crown glass	1.52	Ice	1.31
Perspex	1.49	Air	1.00

Relative refractive index for two media is the ratio $\frac{\sin i}{\sin r}$ for light going from one substance into the other.

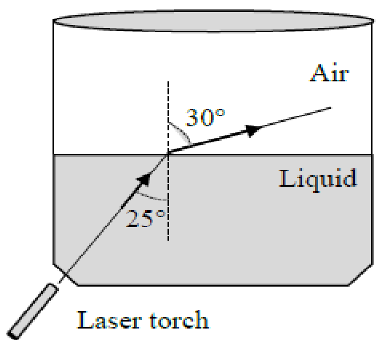
$$n_{12} = \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

The summary formula is:

$$n_{12} = \frac{\aleph_1}{\aleph_2} = \frac{v_1}{v_2} = \frac{sin\theta_1}{sin\theta_2} = \frac{n_2}{n_1}$$

2018

A ray of light from a laser torch is incident from the surface of a liquid in a beaker into air under standard temperature conditions as shown in the diagram below. The light ray makes an angle of incidence of 25° and angle of refraction of 30°.



(i) Calculate the index of refraction of the liquid. **(1 mark)**

(ii) Determine the critical angle of the liquid. **(2 marks)**

(iii) State the ideal condition for total internal reflection to occur. **(1 mark)**

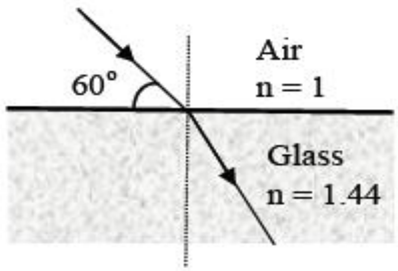
2017

Critical angle is the angle of incidence where the angle of refraction is

A. 0°
B. 45°
C. 90°
D. 180°

2016

A ray of light travels from air into glass as shown below.



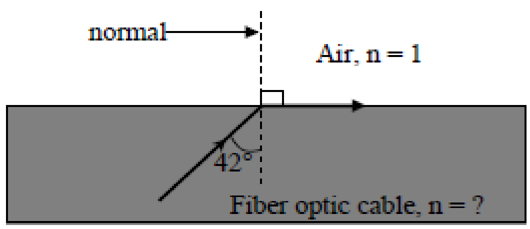
(i) What happens to the speed of light when it travels from air into glass?

(ii) Calculate the angle of refraction.

(iii) Determine the critical angle of light travelling from glass into air.

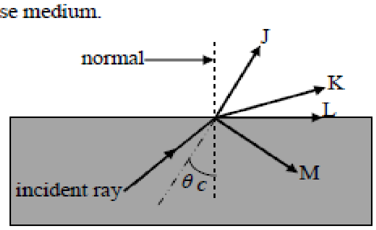
2014

A straight length of fiber optic cable is shown below.
Use the information provided in the diagram to find the refractive index of the fiber optic material used.



2013

The diagram below shows a ray of light travelling from an optically more dense medium to an optically less dense medium.



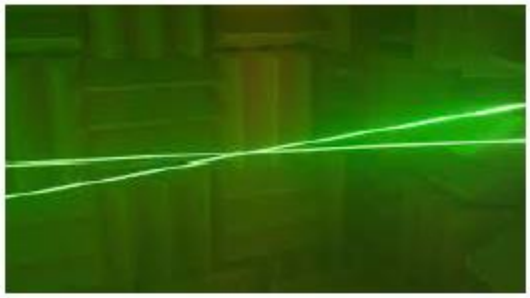
If the angle of incidence is more than the critical angle, θ_C, which of the rays above is the correct pathway of the transmitted ray?

A. J
B. K
C. L
D. M

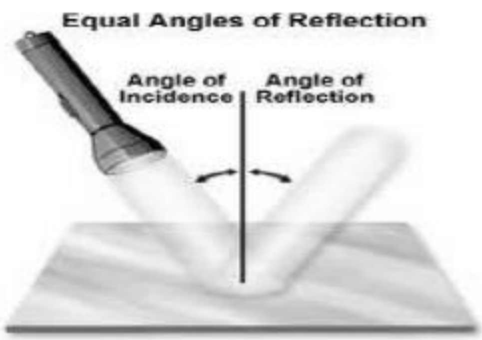
LESSON 71 **LO: describe phenomena of particle model of light**

4.1.14 PARTICLES MODEL OF LIGHT.

Light is a stream of particles called protons travelling at a very high speed. This can account for way of light form sharp shadows and how two beams can cross each other without apparent interaction.



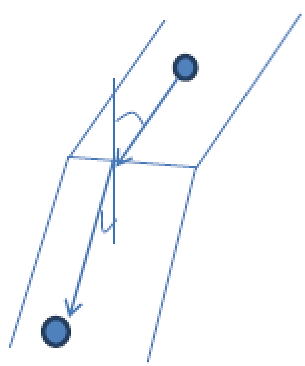
Moving Particles of light also obeys law of reflection.



Particle model also explain the law of refraction .Example roll a ball down two connecting ramps of different slope.

θ_1

θ_2

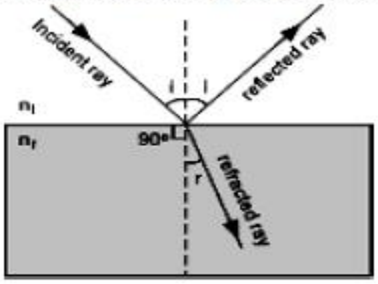


But the particle model requires the velocity to increase in the denser medium (i.e. when ray bands towards the normal).

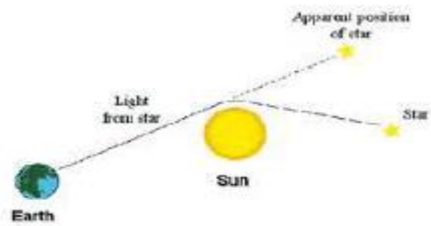
Model correctly predicts an inverse square law of intensity or illumination. It predicts that a substance which absorbs light is heated and experiment shows this to be true.

But particle model of light does not satisfaction explain the following

1. The existence of partial reflection and refraction at a boundary between two medium.

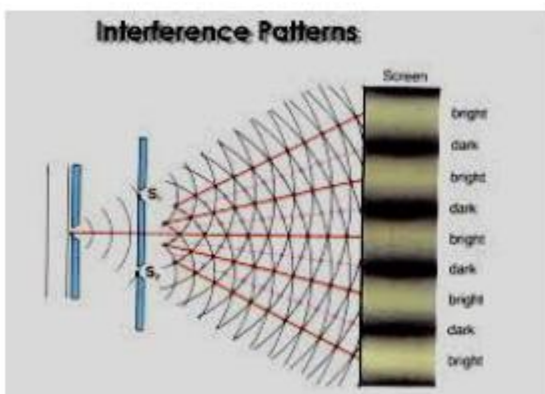


2. Diffraction- The bending of light around objects



3. The speed of light in water when measured by Focoult was found to be lower than the speed of light in air, particle theory predicting it should be greater.

4. Interference – how two beams of light incident on the screen and produce bright and dark band



	Phenomenon	Can be explained in terms of waves.	Can be explained in terms of particles.
2	Reflection	∿∿∿ ✓	●→ ✓
3	Refraction	∿∿∿ ✓	●→ ✓
4	Interference	∿∿∿ ✓	●→ ⊗
5	Diffraction	∿∿∿ ✓	●→ ⊗
6	Polarization	∿∿∿ ✓	●→ ⊗
7	Photoelectric effect	∿∿∿ ⊗	●→ ✓

Activity

2018

Which of the following phenomena does the particle model of light satisfactorily explain?

A. Law of refraction
B. Diffraction of light
C. Interference of light
D. Partial reflection and refraction of light

2017

State **one** weakness of the particle model of light.

2015

Light bends around objects as a result of

A. interference.
B. diffraction.
C. dispersion.
D. reflection.

2014

Which natural phenomena given below can be attributed to **dispersion**?

A. Thunder
B. Rainbow
C. Lightning
D. Lunar eclipse

2013

The formation of an **inverted** image on the screen of a pin-hole camera shows that light

A. creates shadows.
B. is affected by gravity.
C. travels in straight lines.
D. can bend around objects.

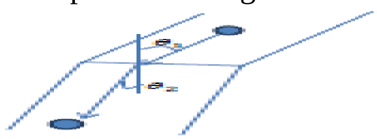
2012

Which of the following explanations of refraction is based on particle model of light?

A. As light enters an optically denser medium, it stops.
B. As light enters an optically denser medium, it speeds up.
C. As light enters an optically denser medium, it decelerates.
D. As light enters an optically denser medium, it maintains its speed.

2011

Which of the following about refraction of particles at a gravitational boundary is correct?



A. Particles bend towards the normal as they speed up.
B. Particles bend towards the normal as they slow down.
C. Particles bend away from the normal as they slow down.
D. Particles go straight through without bending as they speed up.

2006

Of these phenomena: parallax, diffraction, intereference and photoelectricity, which two strongly support particle theory of light?

A. Parallax and Diffraction
B. Photoelectricity and diffraction.
C. Diffraction and Interference.
D. Photoelectricity and parallax.

2004

Which of the following conclusively demonstrates that light can be thought of as a stream of particles?

A. Interference
B. Diffraction
C. Refraction
D. Photoelectric effect