Refraction Through Glass Slab

Introduction

- **Refraction:** When light travels from one medium to another, it generally bends,this bending is called refraction.
- **Snell's law:** The law of refraction is also known as Snell's law. Snell's law gives the relationship between angles of incidence and angle of refraction.

$$\frac{\sin i}{\sin r} = \text{constant}$$

Laws of refraction of light

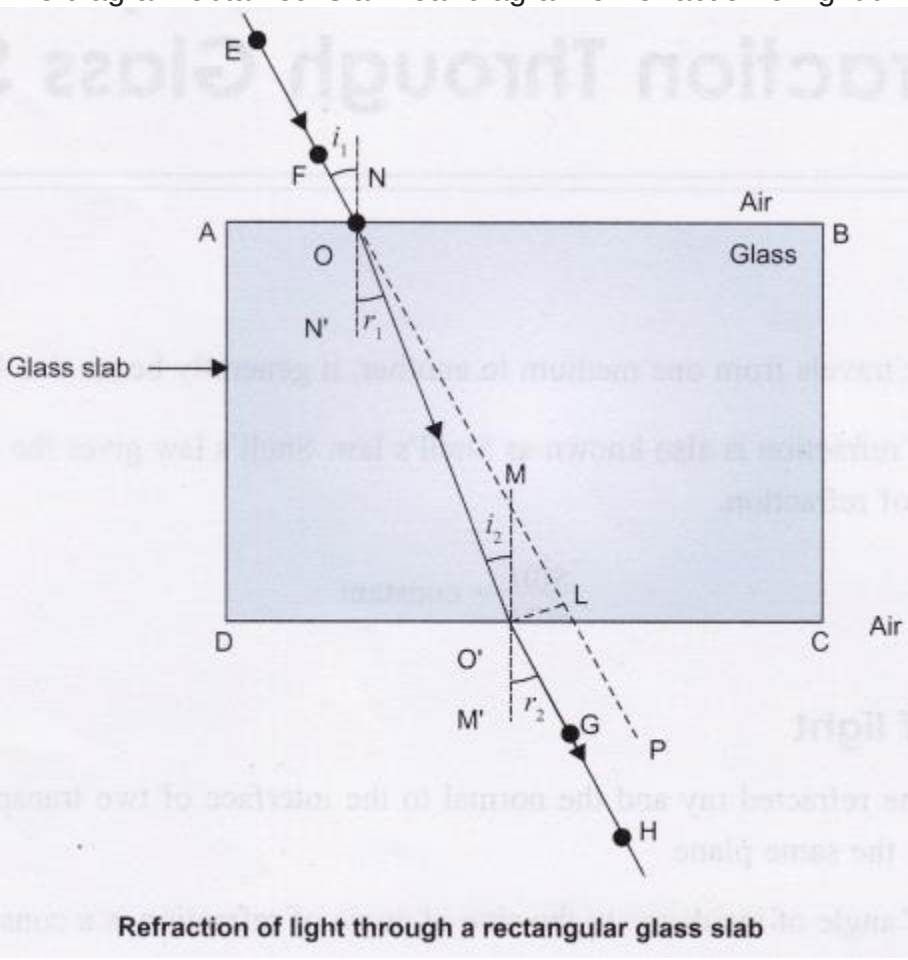
1. The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
2. The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media.
   This law is also known as Snell's law of refraction. If i is the angle of incidence and r is the angle of refraction, then:

$$\frac{\sin i}{\sin r} = \text{constant}$$

- The speed of light in a vacuum is 3.00 x 10 s m/s.
- When light travels through something else, such as glass, water or oil it travels at a different speed.
- **Refractive index:** The speed of light in a given material is related to a quantity called the refractive index, n, which is defined as the ratio of the speed of light in vacuum to the speed of light in the medium.
- **Index of refraction:** n = c/v, where the speed of light in a medium is v and c is the speed of light in vacuum.
- The ability of a medium to refract light is also expressed in terms of its optical density.
- The medium with larger refractive index is optically denser medium than the medium with comparatively smaller refractive index.
- The speed of light is higher in a rarer medium than a denser medium.
- Convex lens converges a beam of light whereas concave lens diverges a beam of light incident on them.
- **Rules of refraction:**
  Rule 1: When a light ray travels from a rarer medium to a denser medium, the light ray bends towards the normal (RDTN).

Rule 2: When a light ray travels from a denser medium to a rarer medium, the light ray bends away from the normal (DRAN).

- The diagram obtained is a linear diagram of refraction of light through glass slab.



Refraction of light through a rectangular glass slab

- **Refraction in daily life:**
  (i) Bottom of a tank or a pond containing water appears to be raised.
  (ii) Printed matter through a thick glass slab placed on a table appears to be raised.
  (iii) Pencil immersed in a glass containing water appears to be displaced at the interface of air and water.

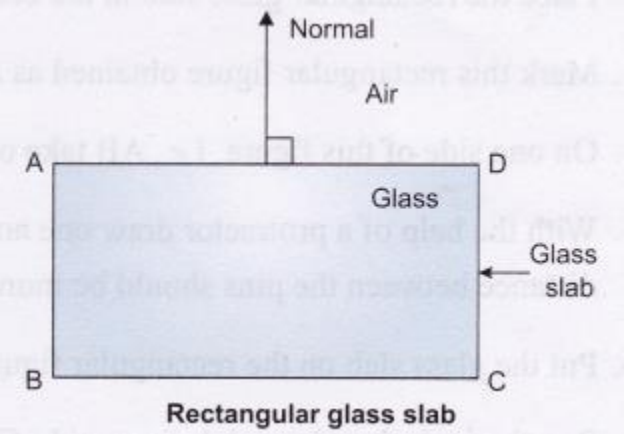
Science Lab Manual Class 10 Experiment – 5

Aim

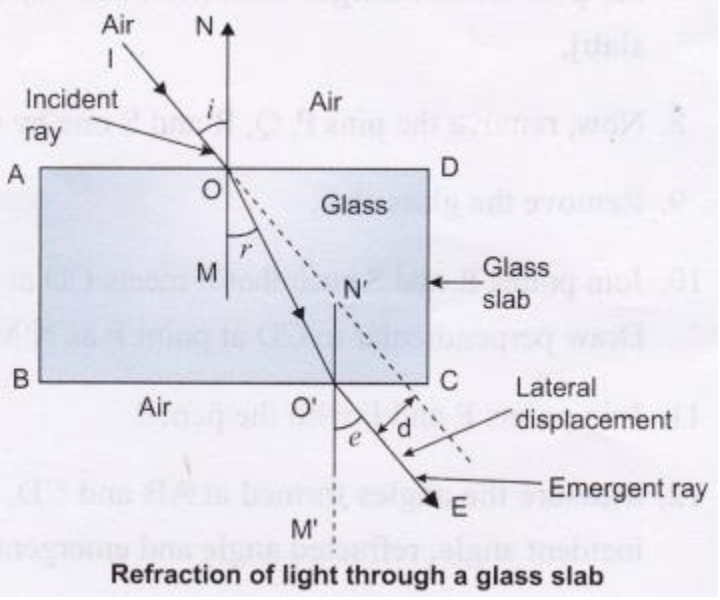
To trace the path of a ray of light passing through a rectangular glass slab for different angles of incidence. Measure the angle of incidence, angle of refraction, angle of emergence and interpret the result.

Theory

- **Refraction of Light:** When light passes from one medium to other it deviates/changes its path, this property of light is called refraction of light.
- **Normal Ray:** A ray of light which forms an angle of 90° with the refracting surface is said to be normal. When a ray of light travels along the normal, it does not suffer any refraction.
- **Incident Ray:** A ray of light that travels towards the refracting surface is called incident ray.
- **Refracted Ray:** A ray of light that changes its path when passes through a refracting surface is said to be refracted ray.



Rectangular glass slab



Refraction of light through a glass slab

- **Emergent Ray:** A ray of light which emerges out into the original medium after refraction is said to be an emergent ray.
- **Lateral Displacement:** The perpendicular shift in the path of light, seen when it emerges out from the refracting medium is called lateral displacement.
- **Angle of Incidence (i):** The angle formed between the normal and incident ray is called angle of incidence.
- **Angle of Refraction (r):** The angle formed between the refracted and normal ray is called angle of refraction.

- **Angle of Emergence (e):** The angle formed between the normal and emergent ray is called angle of emergence.
- **DRAN:** When a ray of light travels from denser medium to rarer medium it bends away from the normal.
- **RDTN:** When a ray of light travels from rarer medium to denser medium, it bends towards the normal.
- **During Refraction:**
  (i) Angle of incidence = Angle of emergence.
  (ii) Incident ray and emergent ray are parallel.
- **Laws of Refraction:**
  (i) The incident ray, the normal ray and the refracted ray, all lie in the same plane.
  (ii) The ratio of the sine of angle of incidence to the sine of angle of refraction is a constant quantity for the two given media. This law is also known as Snell's law.
  sin i/ sin r
  This constant value is called the refractive index of the second medium with respect to the first.

Materials Required

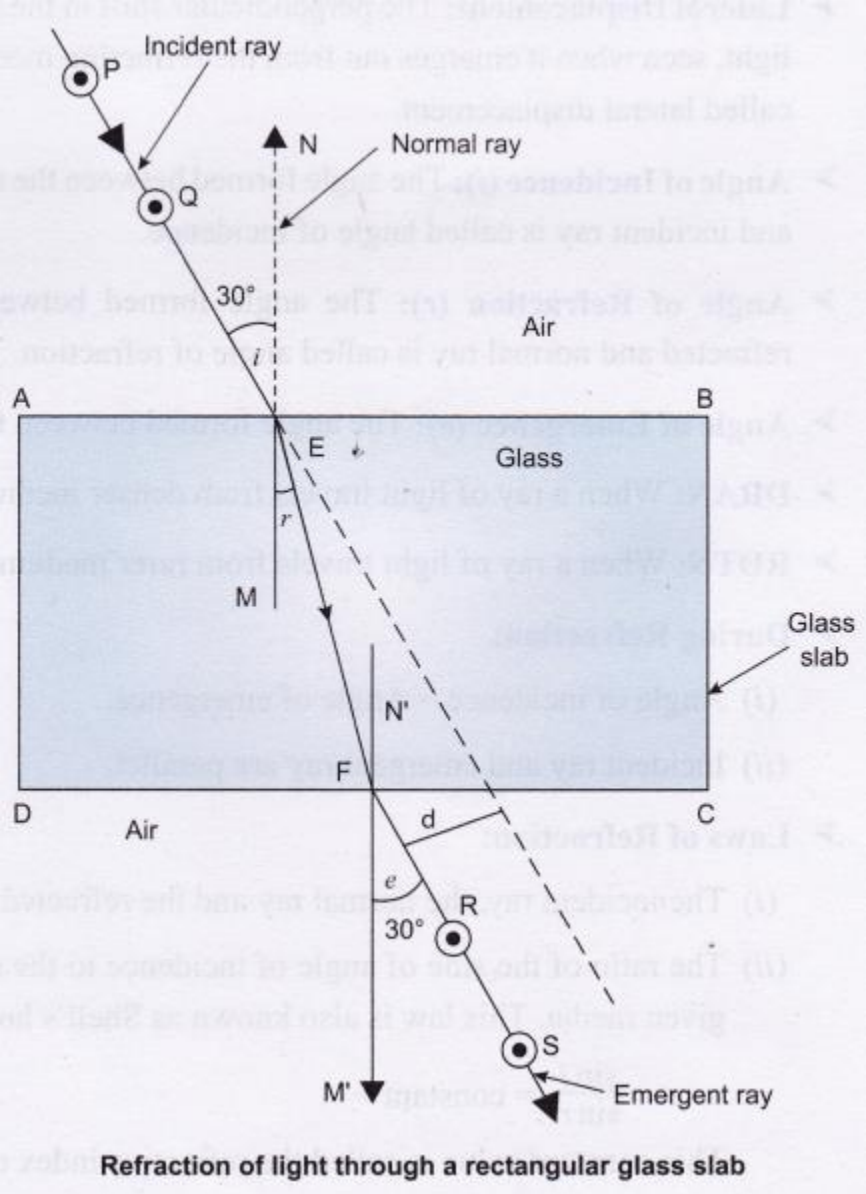
A drawing board, 4-6 all pins, white sheet of paper, rectangular glass slab, a protractor, a scale, a pencil and thumb pins.

Procedure

1. Take a soft drawing board. Fix a white sheet on it with the help of thumb pins.
2. Place the rectangular glass slab in the centre of the white paper and draw its outline boundary with pencil.
3. Mark this rectangular figure obtained as ABCD.
4. On one side of this figure, i.e., AB take one point E, draw a perpendicular EN and label it as normal ray.
5. With the help of a protractor draw one angle of 30° with the EN. Fix two pins P and Q on the ray of this angle, the distance between the pins should be more than 4-5 cm.
6. Put the glass slab on the rectangular figure ABCD.
7. See through the glass slab from side CD and fix pin R and S such that when seen through the glass slab all
   the pins lie in straight line, [i.e., Pins P, Q, R and S should lie in straight line when seen through the glass slab], ‘
8. Now, remove the pins P, Q, R and S one by one and draw small circles around the pin points.
9. Remove the glass slab.
10. Join points R and S such that it meets CD at point F.
    Draw perpendicular to CD at point F as N'M'.
11. Join points E and F with the pencil.
12. Measure the angles formed at AB and CD, i.e., the incident angle, refracted angle and emergent angle.

13. Extend ray PQ with scale and pencil in dotted line. It will be parallel to ray FRS. The distance between these two parallel rays is called lateral displacement (d).
14. Measure the lateral displacement.
15. Repeat the above procedure for angles 45° and 60°.

Diagram



Refraction of light through a rectangular glass slab

ABCD = Glass slab
EN and FM' = Normal rays
P, Q, R, S = All pins ∠PEN = ∠i = incident angle = 30°
∠MEF = ∠r = refracted angle
∠SFM'= ∠e = emergent angle = 30° ~ 31°
d = lateral displacement.

Observations Table

S.No.	Angle of incidence ∠i = ∠PEN	Angle of refraction ∠r = ∠MEF	Angle of emergence ∠e = ∠SFM’	∠i – ∠e ∠PEN – ∠SFM’
1.	30°	28°	30°	0°
2.	45°	43°	44.8°	0.2°
3.	60°	56°	59.8°	0.2°

During performing this experiment, ∠i – ∠e may not be zero at times as shown above due to human error.

Conclusion

1. The angle of incidence is nearly equal to the angle of emergence.
2. The angle of refraction is less than angle of incidence because light is travelling from rarer to denser optical medium.
3. The lateral displacement remains the same for different angles of incidences.
4. When the light ray travels from optically rarer medium (air) to optically denser medium (glass) the light bends towards the normal.

Precautions

1. The glass slab should be perfectly rectangular with all its faces smooth.
2. The drawing board should be soft so that pins can be easily fixed on it.
3. The angle of incidence should lie between 30° and 60°.
4. All pins base should lie in straight line.
5. While fixing the pins P and Q or the pins R and S, care should be taken to maintain a distance of about 5 cm between the two pihs.
6. Draw thin lines using a sharp pencil.
7. Use a good quality protractor having clear markings.
8. Place the protractor correctly to measure the angles.
9. Perpendiculars should be drawn correctly.

Sources of Error

1. The glass slab should not have any air-bubbles.
2. All measurement of angles using protractor should be done accurately.

Science Lab Manual Viva Voce

Question 1:
What is refraction of light?
Answer:
When light travels from one optical medium to another, it (changes its path) deviates from its path. This phenomenon is called refraction of light.

Question 2:
During this experiment of tracking the path of light through glass slab, what should be the angle of incidence?
Answer:
The angle of incidence should be taken between 30° to 60°.

Question 3:
What is lateral displacement?
Answer:
The perpendicular shift in the path of incident ray when it travels from one medium to another is called lateral displacement.

Question 4:
How is angle of incidence and emergence related?
Answer:
The angle of incidence and the angle of emergence are always equal or the difference may be of 1°.

Science Lab Manual Practical Based Questions

Question 1:
Out of VIBGYOR, which light bends the least on refraction and which light bends the most?
Answer:
Red light bends the least and violet light bends the most.

Question 2:
State one condition during refraction of light where light does not deviate.
Answer:
When a ray of light is perpendicular to the refracting surface it will not show any deviation.

Question 3:
If a ray of light makes an angle of 30° with the refracting surface, then what will be the

angle of incidence?

Answer:

The angle of incidence will be 90° – 30° = 60°.

Question 4:

A ray of light travels from optically denser medium to rarer medium. What will happen to its path?

Answer:

(DRAN) When light travels from optically denser medium to optically rarer medium it bends away from the normal.

Question 5:

Which property of light causes the rainbow formation?

Answer:

The refraction of light due to tiny water droplets in the atmosphere causes rainbow in the sky.

Question 6:

If a ray of light travels from water to oil, in which direction will the light bend?

Answer:

Oil is optically denser than water hence, it will bend towards the normal.

Question 7:

A ray of light travels in the path of normal ray. What will be the angle of incidence?

Answer:

As the ray of light, i.e., incident ray is forming 0° angle with normal ray hence, the angle of incidence is 0°.

Question 8:

Under what condition the emergent ray and incident ray will be parallel?

Answer:

When the angle of incidence is equal to the angle of emergence then both the rays are parallel.

Question 9:

Why does a ray of light bend towards the normal when it enters from air to glass slab?

Answer:

When light travels from rarer medium, i.e., air to the denser medium, i.e., glass slab, its speed decreases and hence it bends to take the shortest path.

Question 10:

On what factor is the lateral displacement of the glass slab dependent?

Answer:

Lateral displacement is dependent on the thickness of glass slab. When the thickness increases the lateral displacement also increases.

Question 11:
Why should we preferably take angle of incidence between 30° and 60°?
Answer:
For angles beyond 30° and 60° the refracted ray may not appear on the opposite face of the glass slab.

Question 12:
Why is emergent ray parallel to the incident ray, after the refraction of incident ray through a glass slab?
Answer:
∠i = ∠e in this case, and these are alternate angles. So, the incident ray is parallel to the emergent ray.

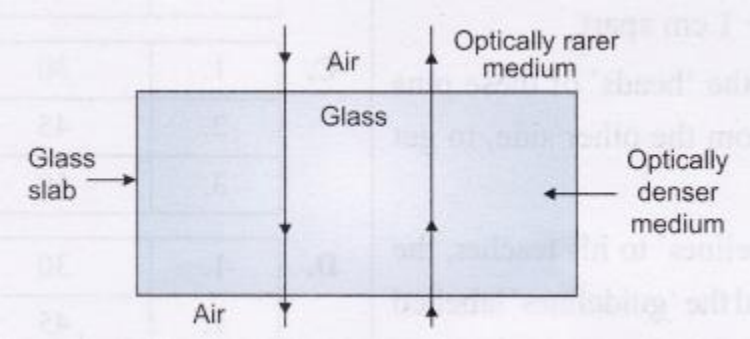
Question 13:
When a ray of light passes through a glass slab, then how many times does it change its path and why?
Answer:
The ray of light bends twice.
First time when it enters from air to the glass slab, it bends towards the normal, i.e., from rarer medium to denser medium.
Second time, when the ray moves out from the glass slab to air, it bends away from the normal, i.e., it moves from denser medium to rarer medium.

Physics Lab Manual Questions

Question 1:
Why are incident and emergent rays parallel to each other in case of a rectangular glass slab?
Answer:
The incident ray and the emergent ray are parallel to each other in case of a rectangular glass slab because the angle of incidence and angle of emergence are same at opposite parallel surfaces of slab.

Question 2:
Why does a ray of light bend towards the normal when it enters from air in a glass slab and bends away from the normal when it emerges out into air?
Answer:
When light enters from air to glass slab its speed decreases and bends towards the normal. But when the light travels from glass slab to air its speed increases and bends away from the normal.

Question 3:
Draw the path of a ray of light when it enters perpendicular to the surface of a glass slab.
Answer:
The path of light when it enters perpendicular to the surface of glass slab would be a straight line passing through
the glass slab.



Question 4:
While tracing the path of ray of light through a glass slab, the angle of incidence is generally taken between 30° and 60°. Explain the reason on the basis of your performing this experiment for different angles of incidence.
Answer:
This is because for any angle greater or smaller than this range (30 degrees to 60 degrees) the emergent ray would not appear on the opposite side of the slab.

Question 5:
How does the lateral displacement of emergent ray depend on the width of the glass slab and angle of incidence?
Answer:
The lateral displacement is directly proportional to the thickness of the glass slab and the angle of incidence.

Lab Manual Science Multiple Choice Questions

Questions based on Procedural and Manipulative Skills
Question 1:
In the experiment to trace the path of a ray of light through a rectangular glass slab using pins P_1, P_2, $P_3$and P_4, four students did the following:
A. Looked at heads of P_1 and P_2, while placing P_3, and heads of P_1, P_2 and P_3 while placing P_4 .
B. Looked at feet of P_1, P_2 while placing P_3 and feet of P_1, P_2 and P_3 while placing P_4 .
C. Looked at heads of P_1 and P_2, while placing P_3 and feet of all the pins while placing P_4.

D. Looked at feet of P_1 and P_2 while placing P_3 and heads of all the pins while placing P_4.
The correct procedure is that of student
(a) A **(b)** B **(c)** C **(d)** D.
Answer:
(b)
Explanation:
It is the correct procedure.

Question 2:
Lateral displacement depends on:
(a) angle of incidence
(b) angle of refraction
(c) thickness of glass slab
(d) angle of emergence.
Answer:
(c)
Explanation:
The bending of light depends on the medium.

Question 3:
If the angle of incidence is 0°, the angle of refraction in the same medium will be:
(a) 90° **(b)** 0°
(c) 180° **(d)** less than 0°.
Answer:
(b)
Explanation:
As per formula.

Question 4:
The relation between ∠i, ∠r and n (refractive index) is:
(a) n = sin i/sin r
(b) n = sin r/sin i
(c) n sin i = n sin r
(d) sin i = n sin r
Answer:
(a)
Explanation:
Formula of refraction.

Question 5:
A student suggested the following 'guidelines' to his friend for doing the experiment on tracing the path of a ray of light passing through rectangular glass slab for three different angles of incidence.
A. Draw the 'outline' of the glass slab at three positions on the drawing sheet.
B. Draw 'normals' on the top side of these 'outlines' near their left end.

C. Draw the incident rays on the three ‘outlines’ in the directions making angles of 30°, 45°, 60° with the normals drawn.
D. Fix two pins vertically on each of these incident rays at two points nearly 1 cm apart.
E. Look for the images of the ‘heads’ of these pins while fixing two pins from the other side, to get the refracted rays.
When he showed these ‘guidelines’ to his teacher, the teacher corrected and modified the ‘guidelines’ labelled as: (The information was insufficient or incorrect)
(a) B, C, E **(b)** B, D, E
(c) B, C, D **(d)** C, D, E.
Answer:
(b)
Explanation:
It is the correct option.

Question 6:
The incident ray and the emergent ray in the glass slab are:
(a) always parallel **(b)** converging always
(c) sometimes parallel **(d)** sometimes diverging.
Answer:
(a)
Explanation:
These two rays do not meet.

Question 7:
The speed of light is maximum in:
(a) oil **(b)** water
(c) glass **(d)** air.
Answer:
(d)
Explanation:
The speed of light is higher in a rarer medium than a denser medium.

Question 8:
In refraction of light, the angle of incidence and angle of refraction is same when:
(a) $\angle i = 90°$ **(b)** $\angle i = 180°$
(c) $\angle i = 0°$ **(d)** none of these
Answer:
(c)
Explanation:
As per the formula and law.

Question 9:
When ray of light travels from air to glass slab its wavelength:
(a) increases
(b) no change

(c) decreases
(d) depends on glass slab thickness.

Answer:

(c)

Explanation:

Speed decreases hence wavelength decreases.

Question 10:

The bending of light when it passes from one medium to the other is called:

(a) dispersion **(b)** diffraction
(c) refraction **(d)** reflection.

Answer:

(c)

Explanation:

Refraction is changing the paths of light when it passes through different media.

Question 11:

In an experiment to trace the path of a ray of light passing through a rectangular glass slab, four students tabulated their observation as given below.

	S.No.	Angle of incidence (in degree)	Angle of refraction (in degree)	Angle of emergence (in degree)
A.	1.	30	18	32
	2.	45	28	43
	3.	60	35	60
B.	1.	30	15	38
	2.	45	20	53
	3.	60	28	67
C.	1.	30	10	31
	2.	45	15	44
	3.	60	22	60
D.	1.	30	28	28
	2.	45	40	40
	3.	60	56	56

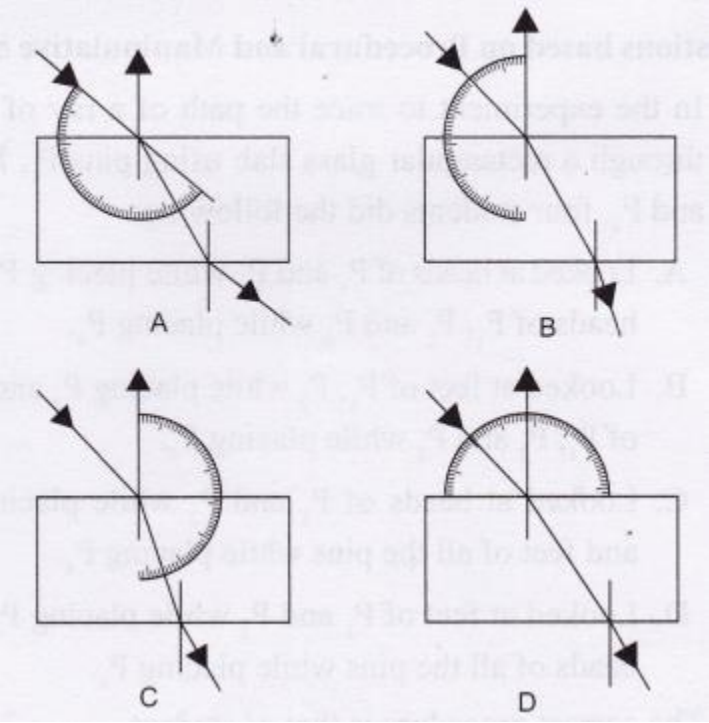
The student most likely to have done the experiment properly is

(a) A **(b)** B **(c)** C **(d)** D

Answer:
(a)
Explanation:
We must not only have the angle of emergence
(nearly) equal to the angle of incidence but also have an idea of the magnitude of the angle of refraction (for a glass slab) for the three most often used values (30°, 45°, 60°) of the angle of incidence.

Questions based on Observational Skills

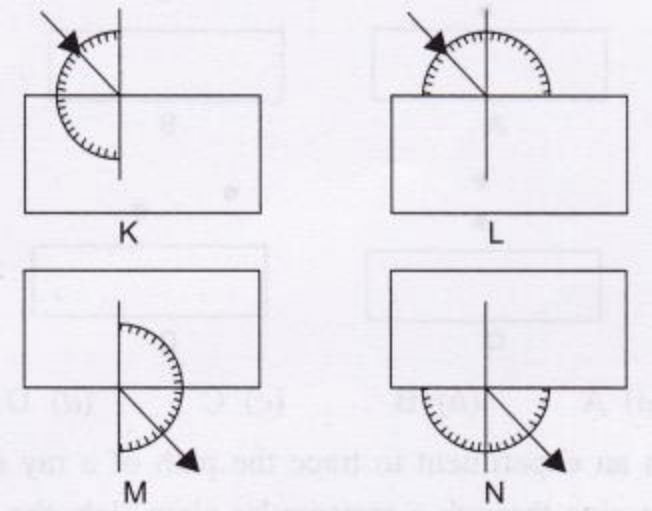
Question 12:
A student traces the path of a ray of light passing through a rectangular glass slab. For measuring the angle of incidence, he must position the protractor in the manner shown in the figure:



(a) A **(b)** B **(c)** C **(d)** D

Answer:
(b)
Explanation:
The angle is measured between the normal ray and the incident ray.

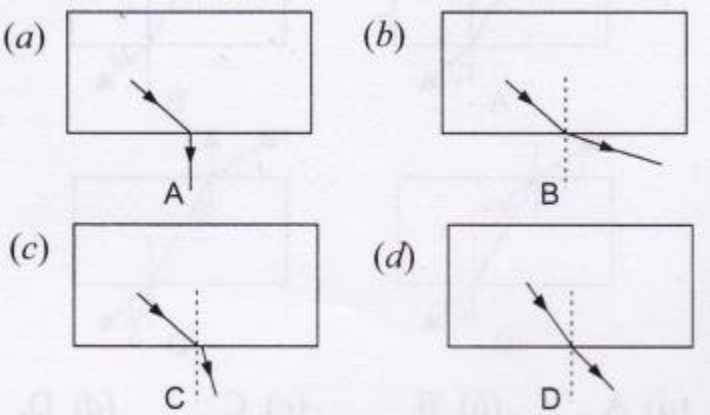
Question 13:
In an experiment on tracing the path of a ray of light passing through a rectangular glass slab, the correct setting of the protractor (D) for measuring the angle of incidence ∠i and the angle of emergence ∠e corresponds, respectively to diagram is:



(a) K and M **(b)** K and N
(c) L and M **(d)** L and N.

Answer:
(a)
Explanation:
The angles need to be measured from the normal ray.

Question 14:
Four students traced the path of a ray of light from glass to air as shown below. The correct path of refracted ray is:



Answer:
(b)
Explanation:
Denser to rarer and away from the normal.

Question 15:
When light passes from rarer medium to denser medium, the light will bend:
(a) towards the normal
(b) away from normal
(c) depends on thickness of glass slab

(d) depends on the angle of incidence.

Answer:

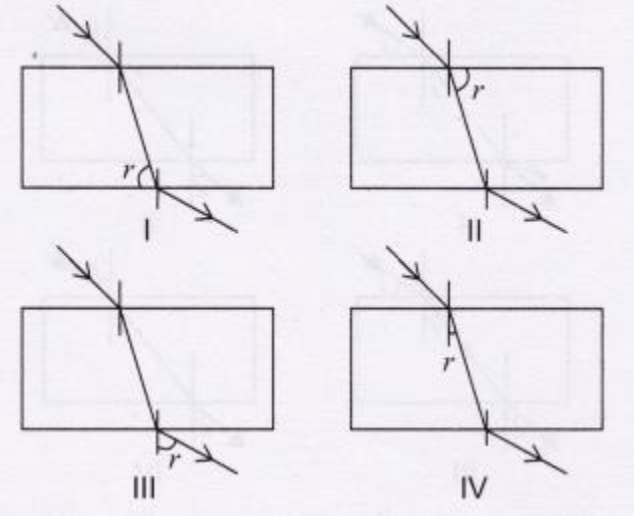
(a)

Explanation:

(RDTN) The ray from rarer to denser medium bends towards the normal.

Question 16:

In these diagrams, the angle of refraction r is correctly marked in which diagram?



(a) I **(b)** II **(c)** III **(d)** IV

Answer:

(d)

Explanation:

Angle r is between the normal and the refracted ray.

Question 17:

A student traces the path of a ray of white light through a rectangular glass slab and marks the angles of incidence (∠i), refraction (∠r) and emergence (∠e) as shown in the figure. Which angle or angles has he NOT marked correctly?

(a) ∠i only **(b)** ∠i and ∠r

(c) ∠i and ∠e **(d)** ∠r and ∠e

Answer:

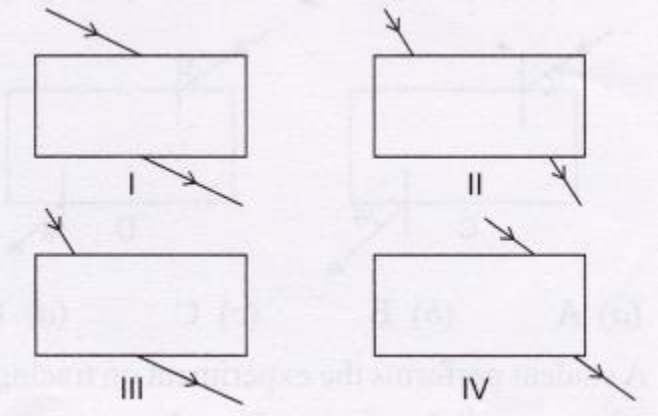
(c)

Explanation:

Angle should be between the normal ray and the incident ray, the normal and the emergent rays.

Question 18:

Four students showed the following traces of the path of a ray of light passing through a rectangular glass slab.



The trace most likely to be correct is that of student:

(a) I **(b)** II **(c)** III **(d)** IV

Answer:

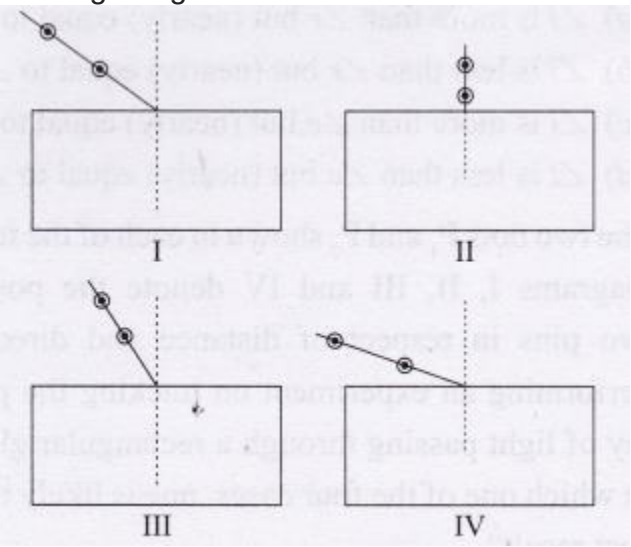
(c)

Explanation:

The shift of I and E rays is appropriate.

Question 19:

Select from the following the best set-up for tracing the path of a ray of light through a rectangular glass slab:



(a) I **(b)** II **(c)** III **(d)** IV

Answer:

(a)

Explanation:

The angle of incidence and distance between two points is appropriate.

Questions based on Reporting and Interpretation Skills

Question 20:

In an experiment to trace the path of a ray of light passing through a rectangular glass slab, four students tabulated their observations as given below:

Students	A	B	C	D
∠i	30°	30°	30°	30°
∠r	18°	20°	17°	21.5°
∠e	32°	32.5°	30°	34.5°

Which student performed the experiment correctly?

(a) A **(b)** B **(c)** C **(d)** D

Answer:

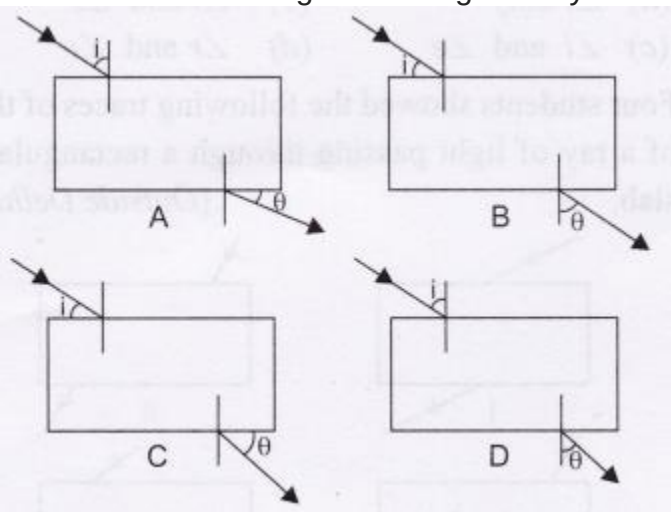
(c)

Explanation:

∠i and ∠e are same and angle r is less than angle i.

Question 21:

A student does the experiment on tracing the path of a ray of light through a rectangular glass slab for different angles of incidence. He can get a correct measure of the angle of incidence and the angle of emergence by following the labelling indicated in figure:



(a) A **(b)** B **(c)** C **(d)** D

Answer:

(d)

Explanation:

The angle is measured between the normal ray and the incident ray.

Question 22:

A student performs the experiment on tracing the path of a ray of light passing through a rectangular glass slab for different angles of incidence. He measures the angle of incidence ∠i, angle of refraction ∠r and angle of emergence ∠e for all his observations. He would find that in all cases

(a) ∠i is more than ∠r but (nearly) equal to ∠e

(b) ∠i is less than ∠r but (nearly) equal to ∠e

(c) ∠i is more than ∠e but (nearly) equal to ∠r

(d) ∠i is less than ∠e but (nearly) equal to ∠r

Answer:

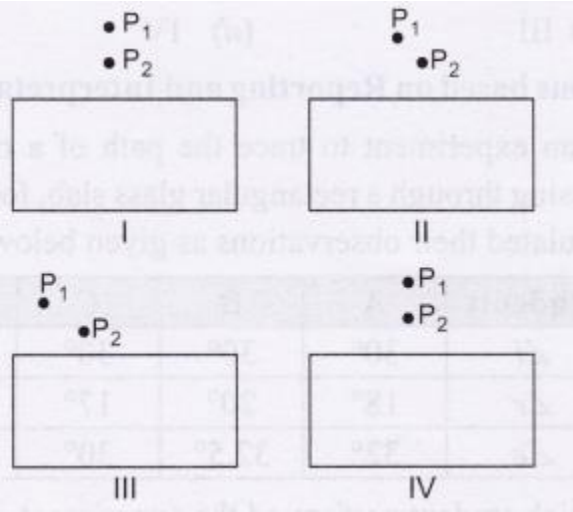
(a)

Explanation:

∠i and ∠e are same and angle r is less than angle i.

Question 23:

The two dots Pt and P2 shown in each of the following diagrams I, II, III and IV denote the position of two pins in respect of distance and direction for performing an experiment on tracking the path of a ray of light passing through a rectangular glass slab. In which one of the four cases, one is likely to get the best result?



(a) I **(b)** II **(c)** III **(d)** IV

Answer:

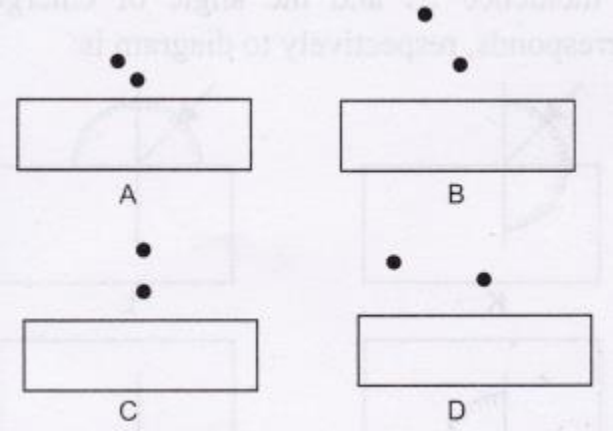
(c)

Explanation:

Dots P and P, should be on incident ray making an angle of 30 to 60 degree with the normal.

Question 24:

Out of the four set-ups shown for carrying out the experiment to trace the path of a ray of light through a rectangular glass slab, the best set-up is



(a) A **(b)** B **(c)** C **(d)** D

Answer:

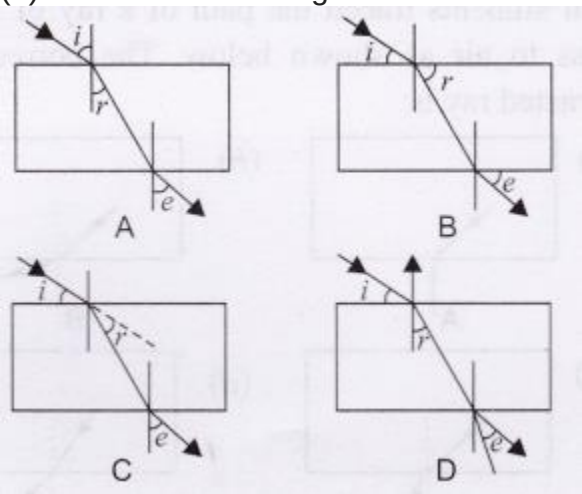
(b)

Explanation:

Dots should be on incident ray making an angle of 30 to 60 degree with the normal.

Question 25:

In an experiment to trace the path of a ray of light passing through a rectangular glass slab, the correct measurement of angles of incidence (i), refraction (r) and emergence (e) is shown in the diagrams.



(a) A **(b)** B **(c)** C **(d)** D.

Answer:

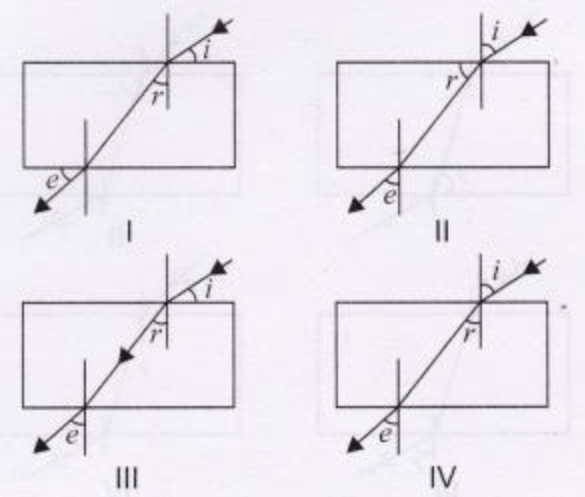
(a)

Explanation:

$\angle i = \angle e$, $\angle i > \angle r$.

Question 26:

The path of a ray of light passing through a rectangular glass slab was traced and angles measured. Which one out of the following is the correct representation of an angle of incidence (i), angle of refraction (r) and angle of emergence (e) as shown in the diagrams:



(a) I **(b)** II **(c)** III **(d)** IV

Answer:

(d)

Explanation:

The angle is always formed between the normal and the ray (incident/refracted/emergent).

Question 27:

An experiment to trace the path of a ray of light through a glass was performed by four students A, B, C and D. They reported the following measurements of angle of incidence i, angle of refraction r and angle of emergence e.

Student	∠i	∠r	∠e
A	30°	30°	20°
B	40°	50°	40°
C	40°	30°	48°
D	40°	30°	40°

student performed the experiment correctly?

(a) A **(b)** B **(c)** C **(d)** D

Answer:

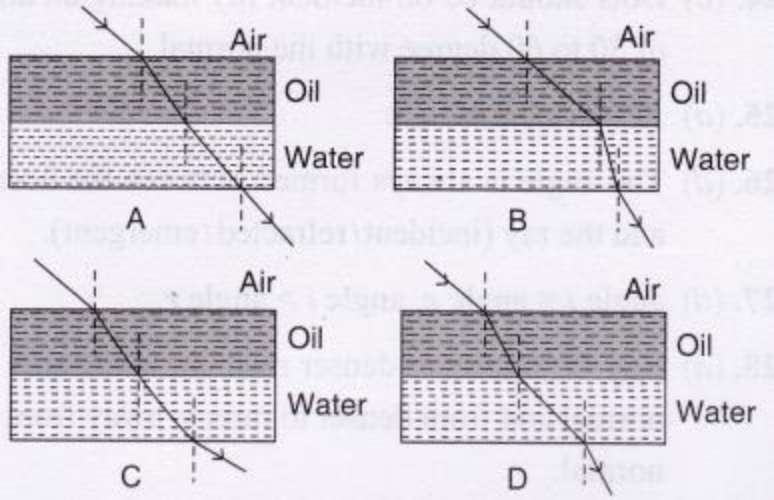
(d)

Explanation:

angle i = angle e, angle i > angle r.

Question 28:

The correct path of a ray of light passing from air to kerosene oil and from kerosene oil to water is



(a) A **(b)** B **(c)** C **(d)** D

Answer:

(a)

Explanation:

Ray from rarer to denser medium is towards the normal and from denser to rarer is away from the normal.

Question 29:

A ray of light enters air from water and experiences refraction, then

(a) $\angle i = \angle r$ **(b)** $\angle i < \angle r$

(c) $\angle i > \angle r$ **(d)** $\angle i / \angle r = 0°$.

Answer:

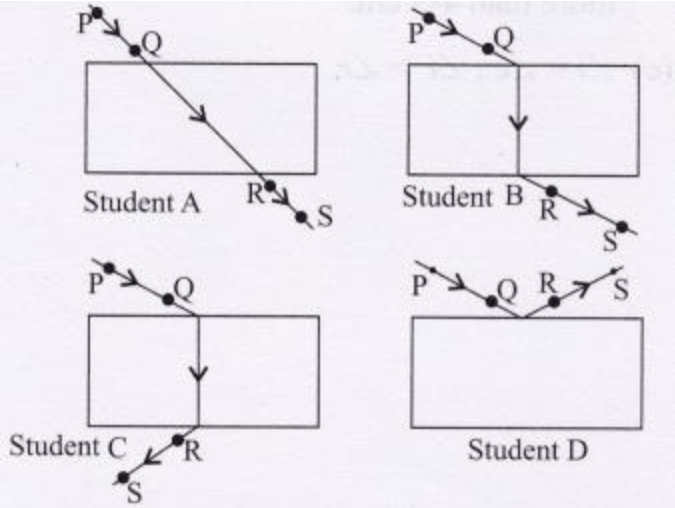
(b)

Explanation:

Light is passing from denser to rarer medium.

Question 30:

Four students A, B, C and D traced the paths of incident ray and the emergent ray by fixing pins P and Q for incident ray and pins R and S for emergent ray for a ray of light passing through a glass slab.

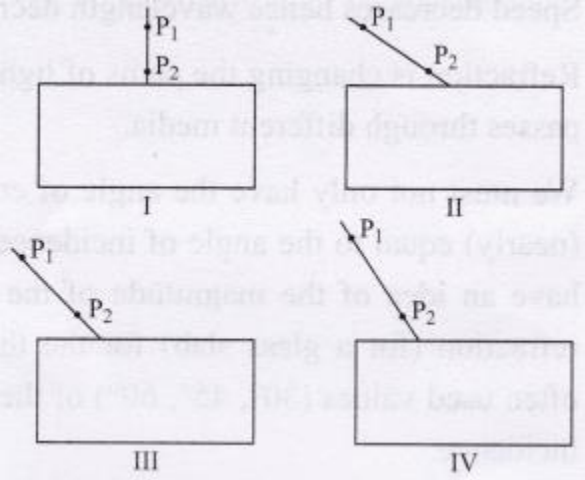


The correct emergent ray was traced by the student:
(a) A **(b)** B **(c)** C **(d)** D
Answer:
(b)
Explanation:
The bending of light is correct (DRAN) and (RDTN).

Question 31:
A ray of light is incident normally, the angle of incidence is:
(a) 90° **(b)** 60° **(c)** 180° **(d)** 0°.
Answer:
(d)
Explanation:
No angle is made as the incident and the normal rays are straight and same lines.

Question 32:
A student traces the path of a ray of light through a rectangular glass slab for four different angles of incidence. He very cautiously measures the angle i, angle r and the angle e. On analyzing his measurements, he is likely to draw the following conclusion:
(a) ∠i = ∠e < ∠r **(b)** ∠i > ∠r > ∠e
(c) ∠i = ∠ r < ∠e **(d)** ∠i = ∠e > ∠r
Answer:
(d)
Explanation:
Angle i = angle e, but angle of refraction is always less than both the other angles.

Question 33:
Study the following four experimental set-ups I, II, III and IV for the experiment, “To trace the path of a ray of light through a rectangular glass slab”.



Which of the marked set-ups is likely to give best results (P_1 and P_2 are the positions of pins fixed on the incident ray)?

(a) I **(b)** II **(c)** III **(d)** IV

Answer:

(d)

Explanation:

The distance between the two pins should be more than 4-5 cm.

Question 34:

After tracing the path of a ray of light passing through a rectangular glass slab for four different values of the angle of incidence, a student reported his observations in tabular form as given below:

S.No.	∠i	∠r	∠e
I	30°	19°	29°
II	40°	28°	40°
III	50°	36°	50°
IV	36°	40°	59°

The best observation is:

(a) I **(b)** II **(c)** III **(d)** IV

Answer:

(c)

Explanation:

∠i = ∠e , ∠i > ∠r.