Chapter 20 – Reflection and Refraction of Light

(A) Basic Concepts of Light

1. What is light a form of?

- A form of energy.

2. In what form does light energy travel from the Sun?

- In the form of waves.

3(a) Does light need a medium for travelling?

- No.

(b) Thus, can light travel in a vacuum?

- Yes.

Comments:

√ *Vacuum is "empty space". It does not contain matter.*
√ *Evidence that light can travel through vacuum:*
  - *Sunlight reaching the Earth, even though most of the space between the Sun and Earth has no matter.*

4. Fill in the blanks:

(a) Light travels in _____ lines.

- straight

(b) The path along which light travels is called a _____.

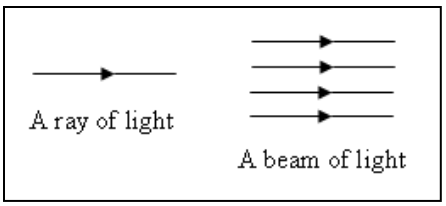
- ray

(c) _____ are drawn on light rays to show the direction in which light travels.

- Arrows

(d) A _____of light consists of a bundle of light rays.

- beam



5. State the speed of light in vacuum.

- 3×10^8 m/s

(A1) Light Vs Nature of Surface

6. State the three effects that light experiences when it falls on a surface.

- When light falls on a surface, it can be:

  I. Reflected
  II. Transmitted / Refracted
  III. Absorbed

Comments:

√ *Examples of the above:*

- *When light falls on mirror → Light will be reflected. (I.e. light "bounces" back).*
- *When light falls on glass → Light will be transmitted. (I.e. light passes through it.)*
- *When light falls on wood → Light will be absorbed.*

√ *Our focus in this chapter will be on effects I (reflection) and II (refraction).*

7. What is the factor that will determine whether light is absorbed, transmitted or reflected when it falls on a surface?

- The nature of the surface that light falls on.

8. Give two examples each of

(a) Rough and dull surfaces

- Black curtains
- Paperboards

(b) Smooth and shiny surfaces

- Mirrors
- Polished metals

(A2) Regular Vs Diffused Reflection

9. The nature of surfaces can determine the type of reflection. State the type of surface that results in regular reflection and diffused (or irregular) reflection.

- Smooth and shiny surfaces result in regular reflection.
- Rough and dull surfaces result in diffused (or irregular) reflection.

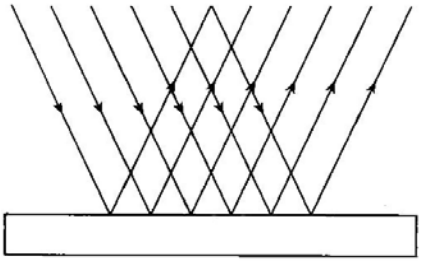
10(a) Distinguish between regular and diffused reflection.

- ❖ In regular reflection, parallel light rays remain parallel after falling on a smooth and polished surface.
- ❖ In contrast, in diffused reflection, parallel light rays are scattered in different directions after falling on a rough surface.

(b) Draw diagrams to illustrate

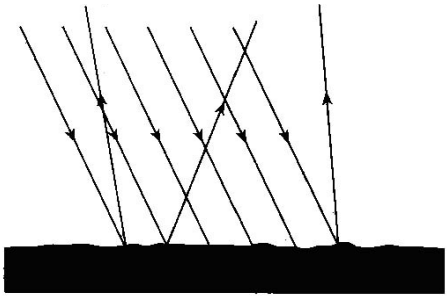
(i) Regular reflection,

❖ Answer:



(ii) Diffused reflection.

❖ Answer:



11. What does regular reflection lead to when an object is placed in front of the reflecting surface?

- ❖ Leads to the formation of an image

Comment:

√ *Regular reflection and the images formed will be covered in detail in the next section.*

(B) Reflection

12. Fill in the blank:

Reflection is the _____ of light off a surface.

- ❖ bouncing

13. Fill in the blanks:

(a) _____ ray is the ray of light striking a surface.

- ❖ Incident

(b) _____ ray is the ray of light reflected from a surface.

- ❖ Reflected

(c) _____ is an imaginary line perpendicular to the surface where the reflection occurs.

- ❖ Normal

(d) Angle of incidence is the angle between _____ and the _____.

- ❖ incident ray
- ❖ normal

(e) Angle of reflection is the angle between _____ and the _____.

- ❖ reflected ray
- ❖ normal

(B1) Laws of Reflection

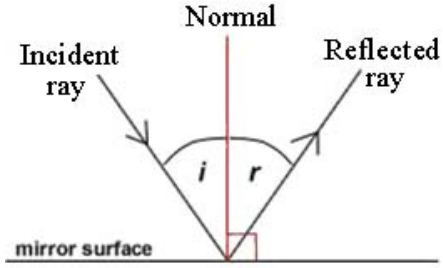
14. State the two laws of reflection at plane surfaces.

- ❖ The angle of incidence is equal to the angle of reflection.
- ❖ The incident ray, reflected ray and the normal at that point all lie on the same plane.

15. Draw a diagram to illustrate the reflection of light off a mirror, clearly labelling the following parts:

- **Incident and reflected rays**
- **Angles of incidence, i and reflection, r**
- **Normal**
- **Mirror surface.**

❖



where i = r

16. Fill in the blanks:

(a) The normal is always _____ to the mirror. I.e. it is at _____ to the mirror.

- ❖ perpendicular
- ❖ 90°

(b) The angles of incidence and reflection are always measured relative to the _____.

- ❖ normal

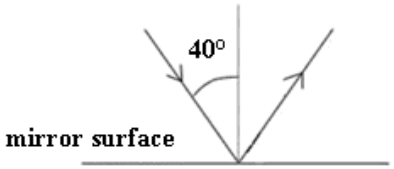
Comments:

- √ *Students tend to make the mistake of measuring angles of incidence and reflection relative to the mirror surface.*
- √ *The correct way is to measure these angles with respect to the normal (i.e. the line perpendicular to the mirror surface.)*

Eg

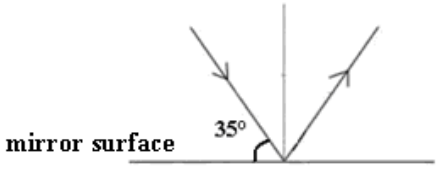
17. Write down the angle of incidence and angle of reflection based on the diagrams below:

(a)



- ❖ Angle of incidence = 40°
- ❖ Angle of reflection = 40°

(b)

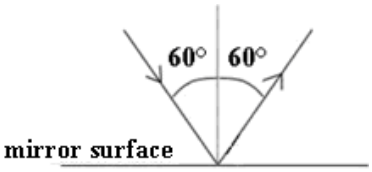


- ❖ Angle of incidence = 90° - 35°
  = 55°
- ❖ Angle of reflection = 55°

18. Draw ray diagrams to show reflection off plane mirrors with:

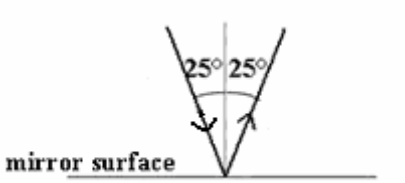
(a) Angle of incidence equal to 60°

- Answer (not to scale):



(b) Angle of reflection equal to 25°

- Answer (not to scale):



(B2) Plane Mirror

19. Fill in the blank:

A plane mirror is one with a _____surface.

- flat

20. State five characteristics of the image formed by a plane mirror.

- The image is of the same **s**ize as the object.
- The image is laterally **i**nverted.
- The image is virtual *(i.e. not **r**eal).*
- The perpendicular **d**istance of the image from the mirror is the same as the perpendicular distance of the object from the mirror.
- The image is **u**pright.

Memory Help:

√ *The underlined alphabets form the words "Sir Du". When asked to list the images of reflection, simply think of "Sir Du", and it will be easy to recite the answer.*

21. What is meant by "laterally inverted"?

- The left side of an object appears as the right side of the image and vice versa.

22. The words "SMASHING EXAMS" are flashed in front of a mirror. Which of the alphabets will become laterally inverted?

- ❖ S, N, G, E.

23. What is a virtual image?

- ❖ A virtual image is one which cannot be formed on a screen placed behind the mirror.

Comment:

√ *Virtual means "not real"; cannot be captured.*

24. A man sitting on a chair looks into a plane mirror which is 2.5 m away from him. He sees the image of a chart which faces the mirror and is 0.5 m behind him.

(a) How far away from his eyes does the chart appear to be?

- ❖ Distance of chart from mirror = 2.5 m + 0.5 m
  = 3.0 m

  Distance of image of chart from man = 3.0 m + 2.5 m
  = 5.5 m

(b) Is the chart seen by the man real or virtual? Explain your answer.

- ❖ The chart seen by the man is virtual.
- ❖ This is because the image formed cannot be captured by a screen placed behind the plane mirror.

25. State two uses of plane mirrors.

- ❖ Used for personal grooming.
- ❖ Used in periscopes for seeing over walls or above water surfaces when used in submarines.

(B3) Convex Mirror

26. Fill in the blank:

A convex mirror is one with its reflecting surface curved _____.

- ❖ outwards

27. State one difference between the image formed by a convex mirror and that by a plane mirror.

- ❖ The image formed by a convex mirror is smaller in size compared to the object.
- ❖ In contrast, the image formed by a plane mirror is of the same size compared to the object.

28. Relative to a plane mirror, what is the field of vision covered by a convex mirror?

- ❖ A convex mirror covers a wider field of vision relative to a plane mirror.

Comment:

√ *This partly explains why the image formed by a convex mirror is smaller in size – Since a convex mirror has to cover a wider field of vision (i.e. a bigger scope / area), the images captured by the convex mirror will be smaller.*

29. State three uses of convex mirrors.

- ❖ Used at traffic junctions to enable drivers to see blind spots.
- ❖ Mounted on cars' wing mirrors to help drivers park their car.
- ❖ Used in security mirrors.

(B4) Concave Mirror

30. Fill in the blank:

A concave mirror is one with its reflecting surface curved _____.

- ❖ inwards

31. State one difference between the image formed by a concave mirror (held near to the object) and that by a plane mirror.

- ❖ The image formed by a concave mirror is magnified in size compared to the object.
- ❖ In contrast, the image formed by a plane mirror is of the same size compared to the object.

32. State three uses of concave mirrors.

- ❖ Used as a small make-up mirror.
- ❖ Used as dentists' mirrors.
- ❖ Used in microscopes.

(C) Refraction

33. Define refraction.

- ❖ Refraction is the bending of light when it passes from one medium to another medium of different optical density, caused by a change in the speed of light.

Comment:

√ *The definition of refraction is much more important than that of reflection and is sometimes asked for in tests / exams.*

34. Fill in the blanks:

(a) _____ ray is the ray of light striking a surface.

- ❖ Incident

(b) _____ ray is the bent ray as a result of passing from one optical medium to another.

- ❖ Refracted

(c) _____ is an imaginary line perpendicular to the surface where the refraction occurs.

- ❖ Normal

(d) Angle of incidence is the angle between the _____ and the _____.

- ❖ incident ray
- ❖ normal

(e) Angle of refraction is the angle between the _____ and the _____.

- ❖ refracted ray
- ❖ normal

(C1) Laws of Refraction

35. State one law of refraction.

- ❖ The incident ray, refracted ray and the normal at that point all lie on the same plane.

36. State and explain how the path of light will change when it travels from:

(a) A less dense medium to a denser medium

- ❖ Light will bend towards the normal.
- ❖ This is due to the decrease in the speed of light.

(b) A denser medium to a less dense medium.

- ❖ Light will bend away from the normal.
- ❖ This is due to the increase in the speed of light.

Memory Help:

√ *Think of "**D**esign & **T**echnology". Thus, D & T are "paired together", and "denser and towards" are linked / closer together.*
⇨ *Hence, less dense to **d**enser medium, light bends **t**owards the normal.*

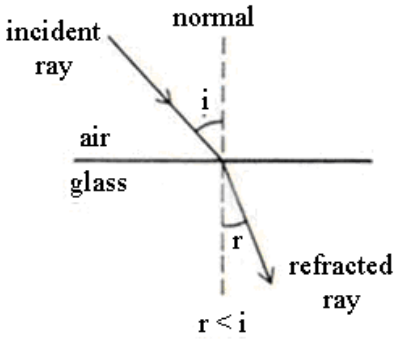
37. Give two examples of mediums that are denser than air.

- ❖ Water
- ❖ Glass

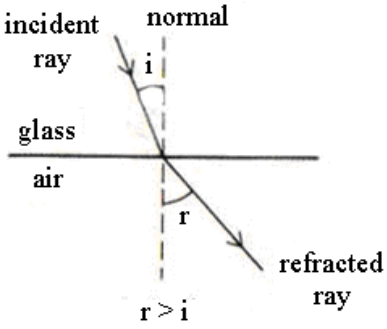
Eg

38(a) Using diagrams, show the refraction of light as it passes from

(i) Air to glass



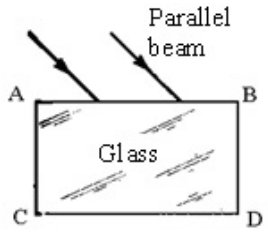
(ii) Glass to air



(b) Explain why the light rays bend as such.

- ❖ Glass is a denser medium compared to air.
- ❖ When light travels from a less dense medium (air) to a denser medium (glass), it slows down and bends towards the normal [and hence the diagram in part (a)(i) above].
- ❖ In contrast, when light travels from a denser medium (glass) to a less dense medium (air), it speeds up and bends away from the normal [and hence the diagram in part (a)(ii) above].

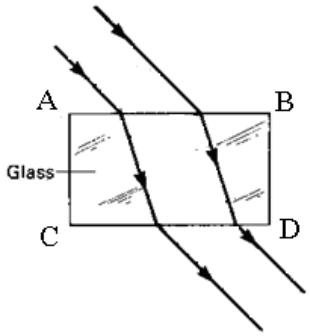
39(a) The figure below shows two parallel beams of light incident from air at 45° on the surface AB of the glass block ABCD.



Complete the figure by sketching the approximate path of the light ray

i. travelling in the glass,
ii. after emergence from CD.

❖ Answer:



Comments:

√ *The emergent ray is the "ray that emerges / comes out of the medium".*
√ *Note that the emergent beam must be parallel to the incident beam.*

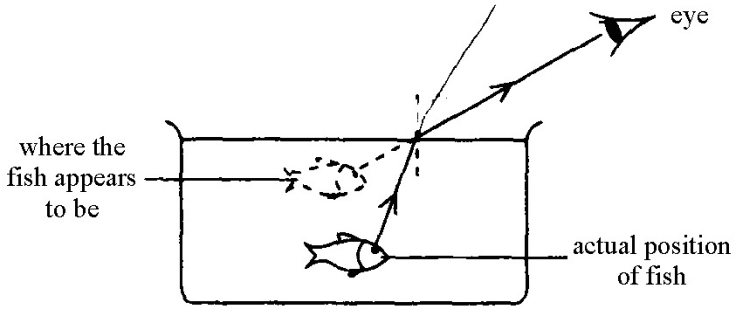
(b) Explain why the direction of travel of the light ray changes on entering the glass, and then upon leaving the glass.

❖ The direction of travel changes because the speed of light in glass is less than that in air.
❖ On entering the glass, the light ray is moving from a less dense medium (air) to a denser medium (glass), and thus bends towards the normal.
❖ On leaving the glass, the light ray is moving from a denser medium (glass) to a less dense medium (air), and thus bends away from the normal.

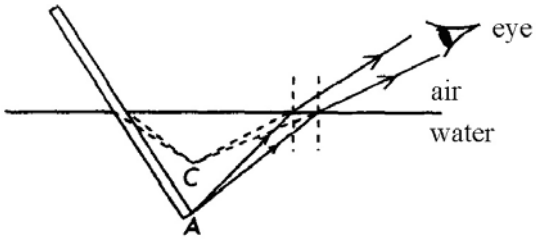
(C2) Effects of Refraction

40. State three effects of refraction, illustrating with diagrams.

- "Shallow pools" – Water pools appear shallower than they actually are, or objects appear nearer to the surface than they should be.

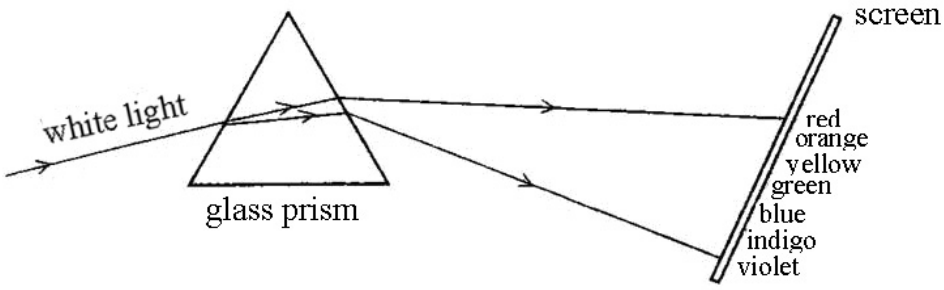


- "Bent sticks" – Objects (e.g. straight sticks) appear bent when placed in a glass of water.



Point A is the actual position of the end of the stick;
Point C is the position as seen by the eye.

- Dispersion – White light being split into its seven component colours.



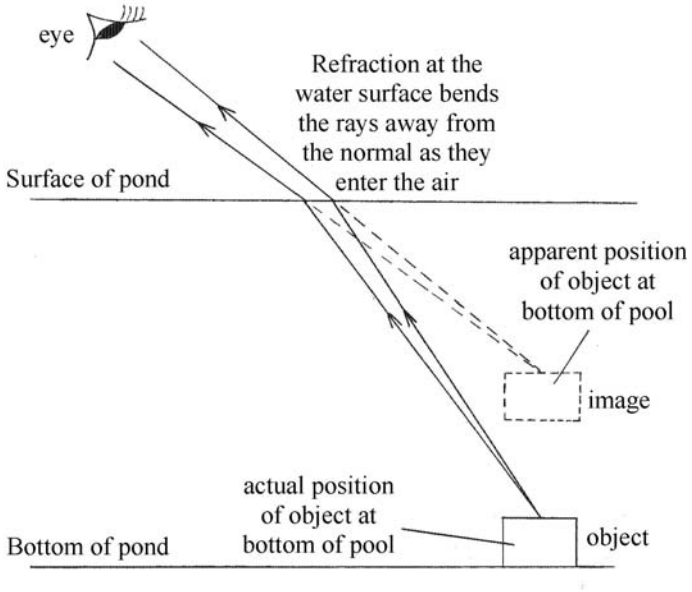
Comment:

√ *The terms "shallow pools" and "bent sticks" are written here for easy reference and to enhance students' ability to recall the concepts. In tests / exams, students should write the full statements "Water pools appear shallower than they actually are" and "Objects (e.g. straight sticks) appear bent when placed in a glass of water" when asked for the effects of refraction.*

(C2.1) Shallow Pools

41. With the help of a diagram, explain why a pool of water appears shallower than it actually is.

- Answer:



- Light travels faster in air than in water.
- As light rays from the bottom of the pool leave the water, they are refracted (bend away from the normal) as shown in the diagram above.

Comment:

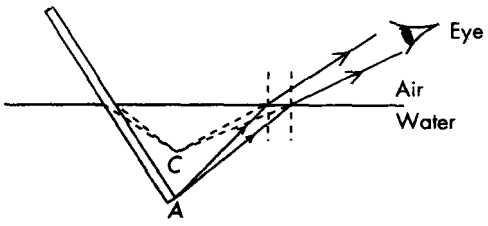
√ *You should use the above diagram (in question 41) when asked to illustrate the effect of "shallow pools". The diagram with the fish (in question 40) is meant more for your understanding; it is not as clear when it comes to explaining the concept.*

(C2.2) Bent Sticks

42. Fill in the blanks:

(a) Based on the same principle that light travels at different _____ in different _____, a straight stick will appear bent when placed in a glass of water.

- speeds
- mediums



(b) Light rays from point A (in the diagram) are _____ at the _____ boundary.

- ❖ refracted
- ❖ water-air

(c) The _____ light rays will appear to have come from point C to the eye, thus resulting in the stick appearing bent.

- ❖ refracted

(C2.3) Dispersion of White Light

→ *Dispersion will be covered in the next chapter under "Colours".*

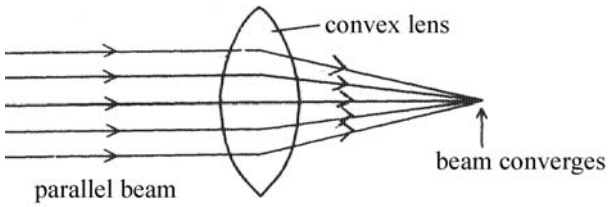
(C3) Applications of Refraction

43. State one area where the effects of refraction are being applied to.

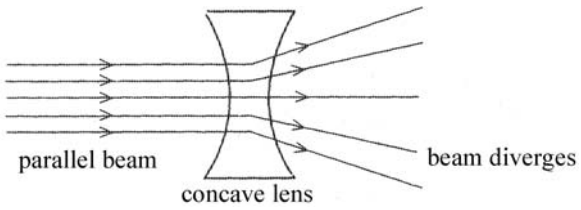
- ❖ Lenses.

44. Draw a diagram to show the refraction of light rays through:

(a) a convex lens



(b) a concave lens



45. State three uses of convex lens.

- ❖ Spectacles for correction of long-sightedness.
- ❖ Camera.
- ❖ Magnifying glass.

46. State one use of concave lens.

- ❖ Spectacles for correction of short-sightedness.