Light

Reflection & Refraction

Topics

- Reflection
  - characteristics of image
  - ray diagrams
- Refraction
  - refractive index
  - n = sin i / sin r
  - 1/n = sin i / sin r
  - n = c / v
- Total Internal Reflection
  - critical angle

How do we see light?
How do we see the colours around us?

Light

- We see **red colour** from an apple because the apple absorbs all colours of light from the sun and reflects only red colour back to our eyes.

SPEED OF LIGHT?

Cheetah
31.0 m/s

Jetplane
350 m/s

Fastest supersonic plane (X15)
1361 m/s

Sound in air
330 m/s

Earth in orbit around the Sun
29,780 m/s

Light in vacuum
300,000,000 m/s

Characteristics of light

- It has a speed of approx $3.0 \times 10^8 \mathrm{ms}^{-1}$ in vacuum

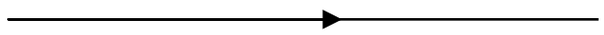
- It travels in a straight line. (Ray)

  - When light hits an object, it can undergo reflection or refraction or both

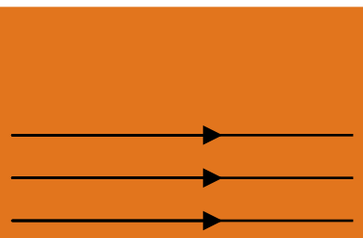
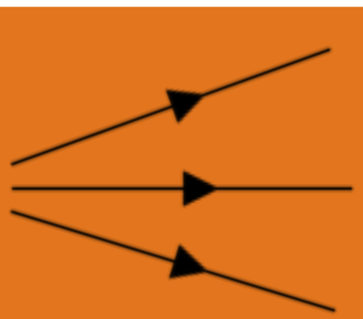
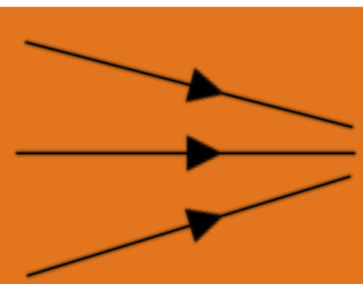
  - Light is a form of energy

RAYS AND BEAMS

A light ray can be represented by drawing a straight line with an arrow.

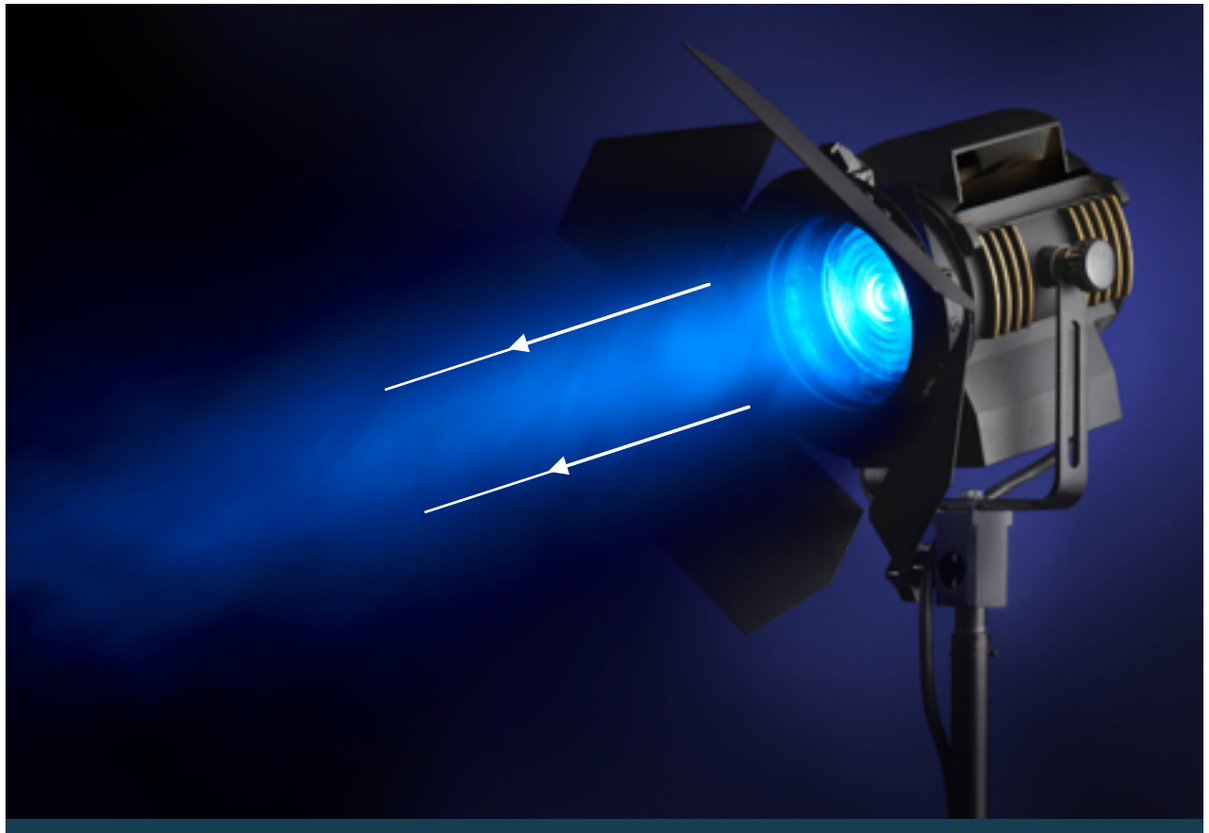


A bundle of light rays is called a **beam of light**, which can be:

		
parallel	divergent (fan outwards)	convergent (merge to a point)

RAYS AND BEAMS

A lighthouse produces divergent beams.

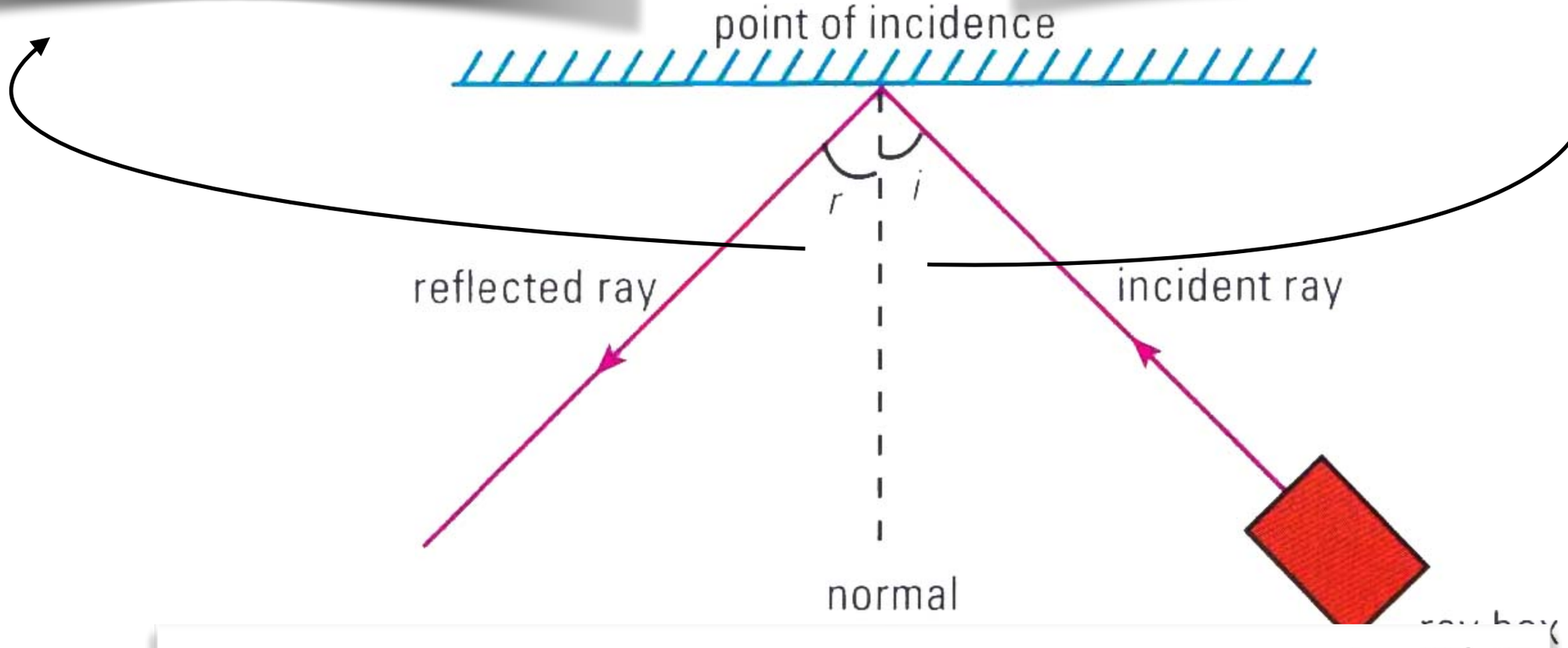


A spotlight produces parallel beams.

Reflection of Light

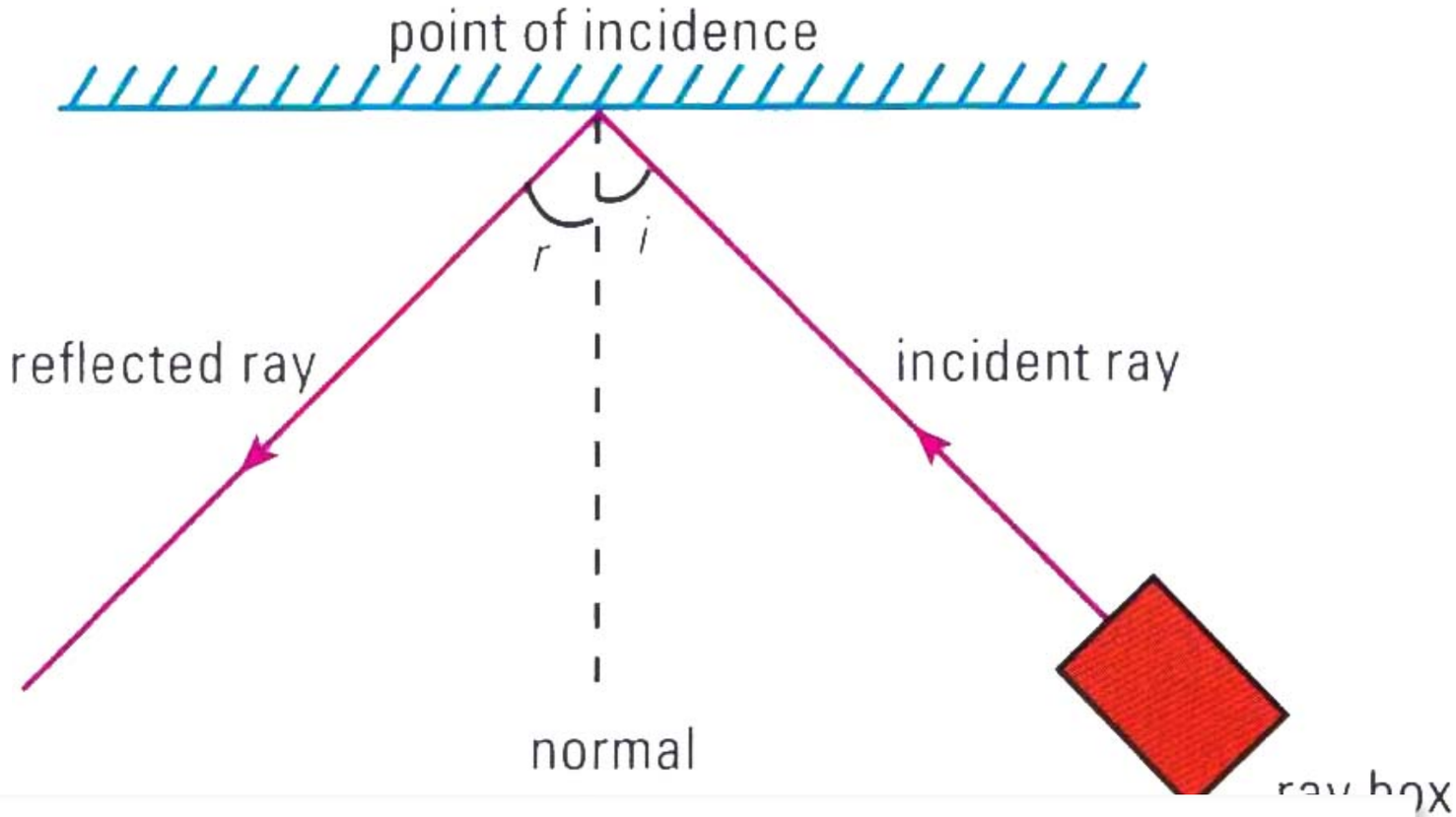
The angle of reflection is the angle which the reflected ray makes with with the normal

The angle of incidence is the angle which the incident ray makes with with the normal



Normal: The imaginary line that is perpendicular to the surface of incidence, at the point of incidence.

Reflection of Light



The angle of incidence is equal to the angle of reflection

Worked example 1

GLM BOOK

pg 213 2(c)

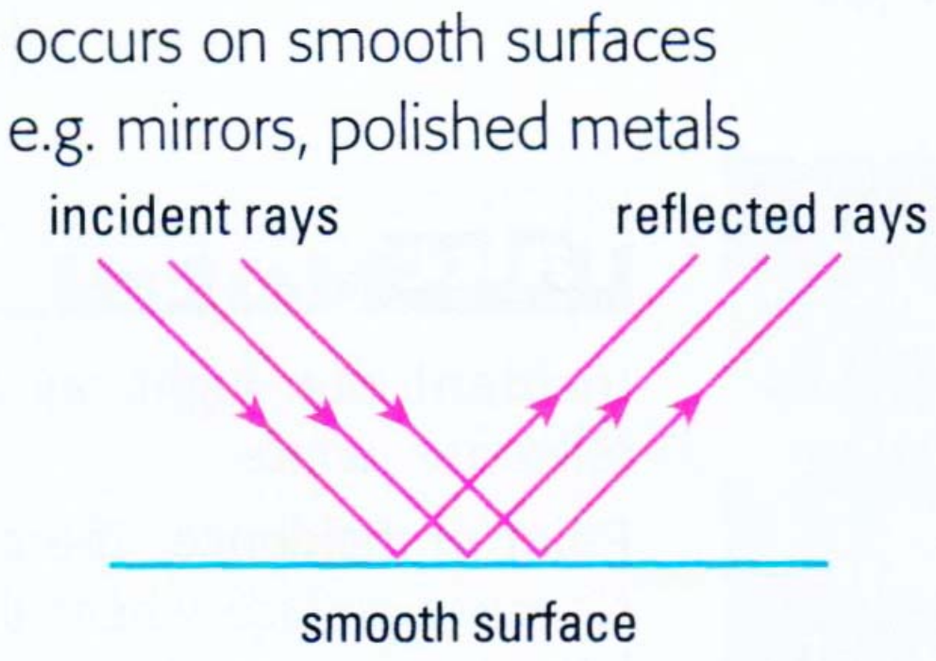
Does the law of reflection apply to rough surfaces too?

Types of Reflections

Regular reflection

— occurs on smooth surfaces

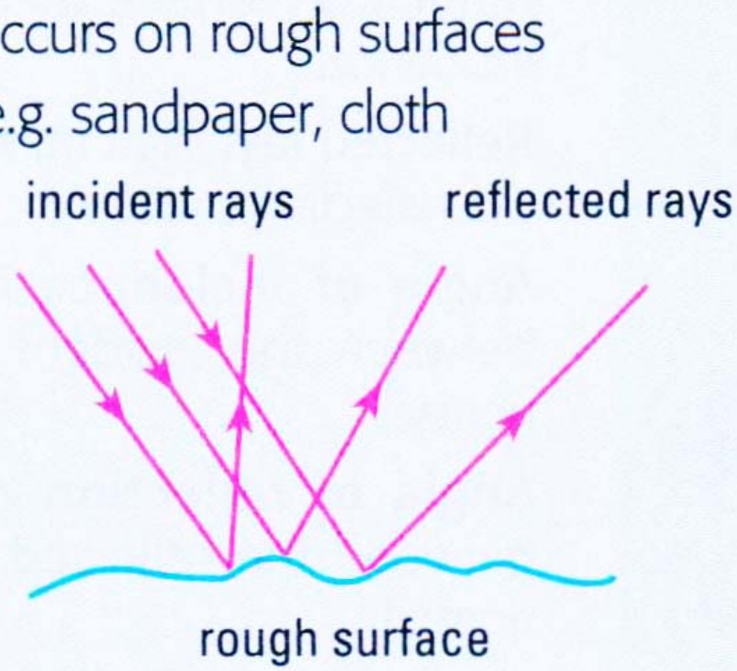
e.g. mirrors, polished metals



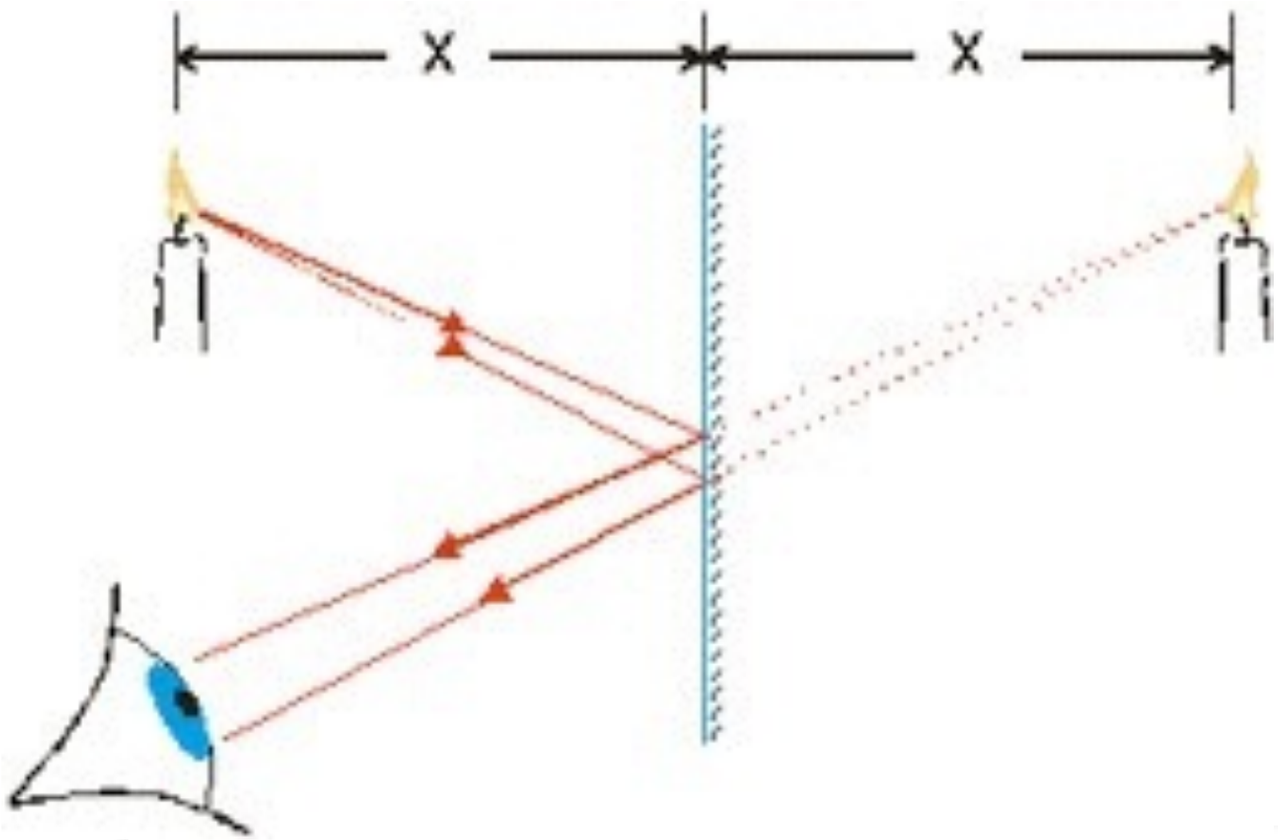
Irregular reflection

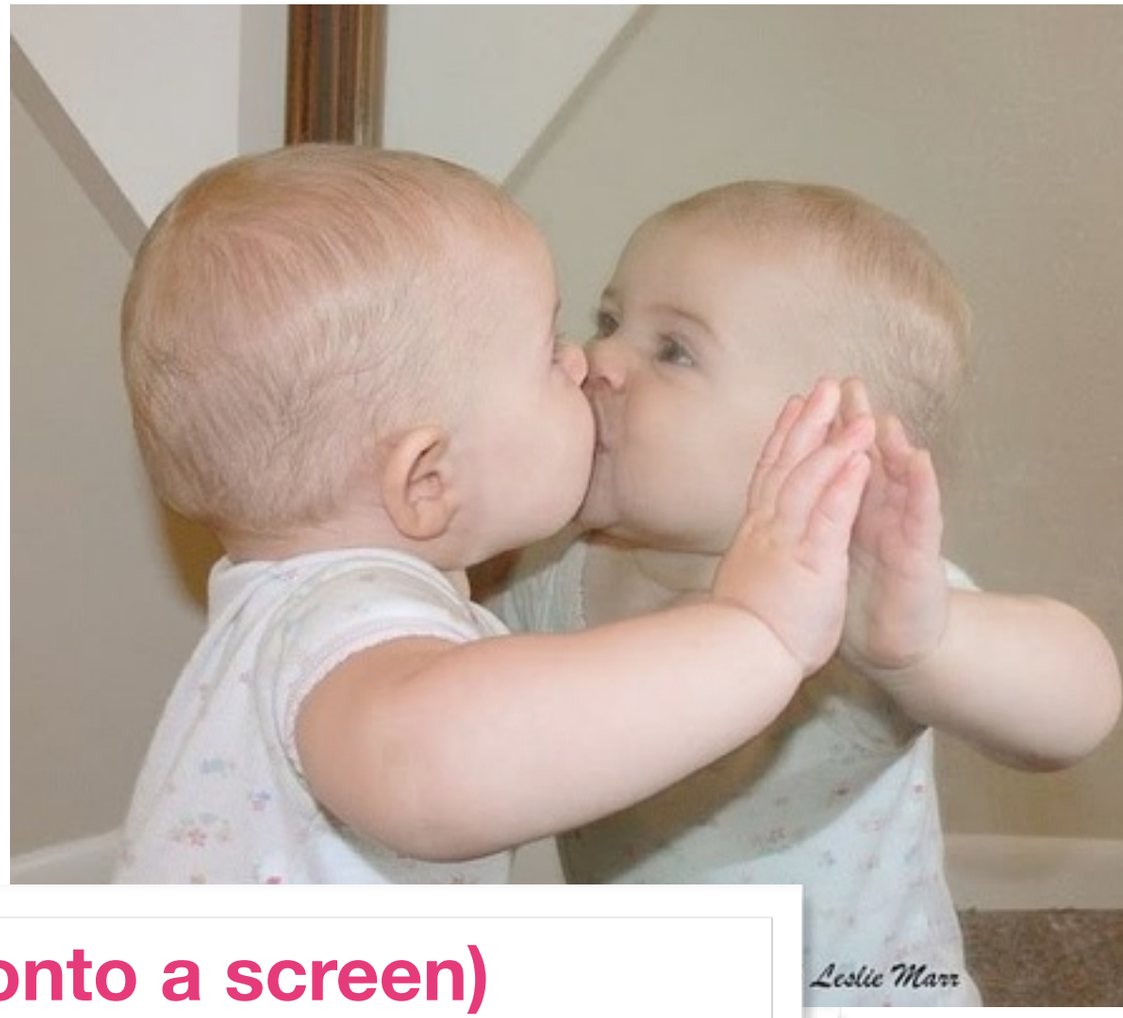
— occurs on rough surfaces

e.g. sandpaper, cloth



Characteristics of an image

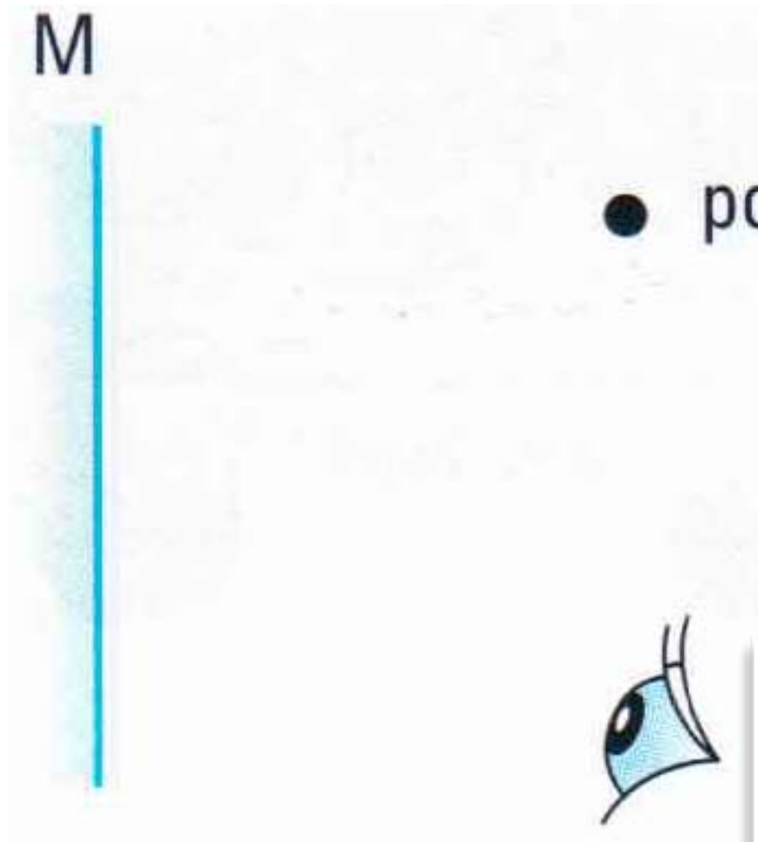




2. Virtual (cannot be projected onto a screen)

3. Upright
4. Same size as object
5. Same distance behind mirror as the object in front of the mirror.

Ray diagrams - 1 mirror



Step 1: Measure accurately the perpendicular distance between object O and the mirror surface.

Step 2: Mark off the same distance behind the mirror to locate the image I.

Step 3: Use dotted lines for to indicate that the rays coming from behind the mirror is virtual. Use bold lines to indicate rays reflected from the mirror is real

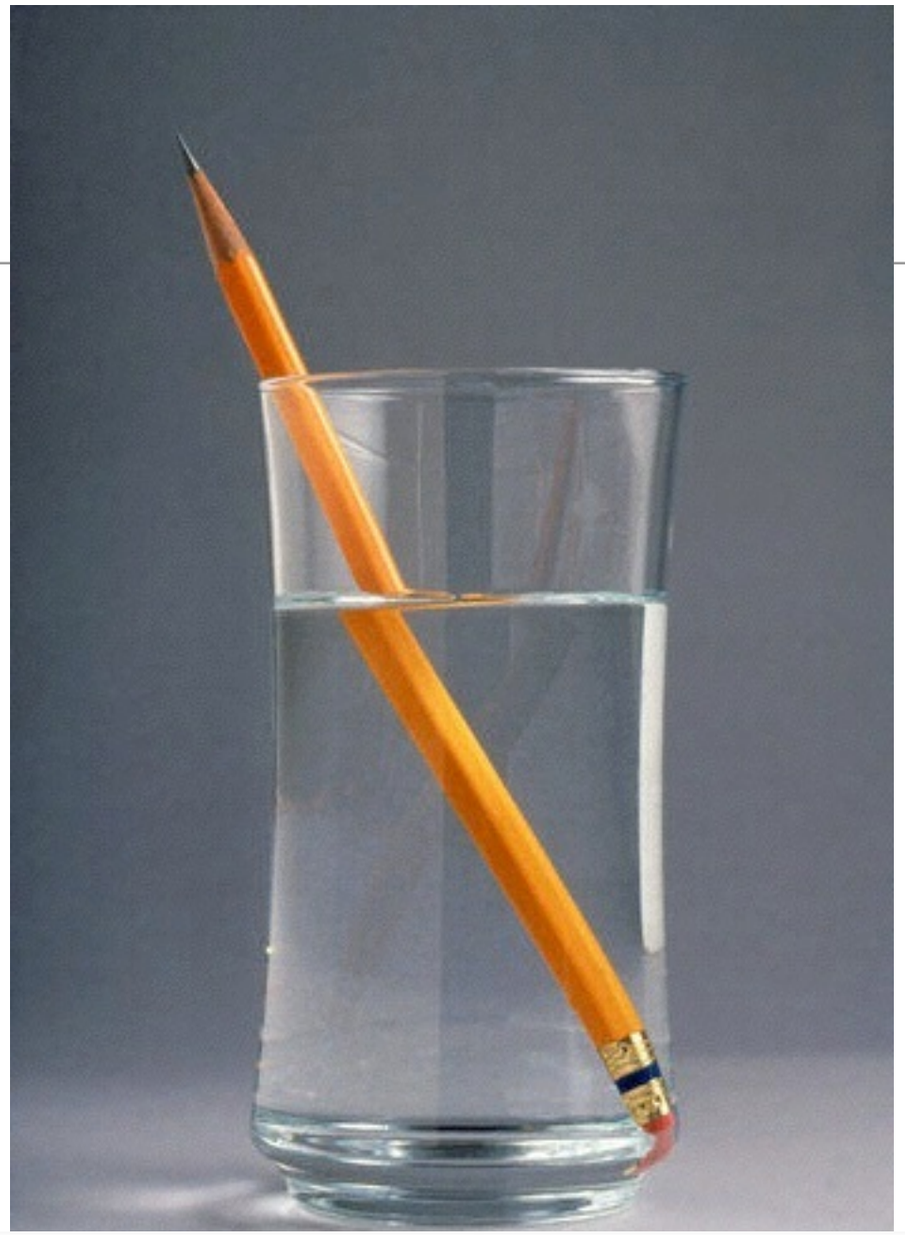
Step 4: Join Object O to the points of incidence on the mirror surface

Do we need to use a protractor?

Practice Task for reflection

- GLM pg 228
- Q2
- Q6
- Q7
- Q9

Light: Refraction

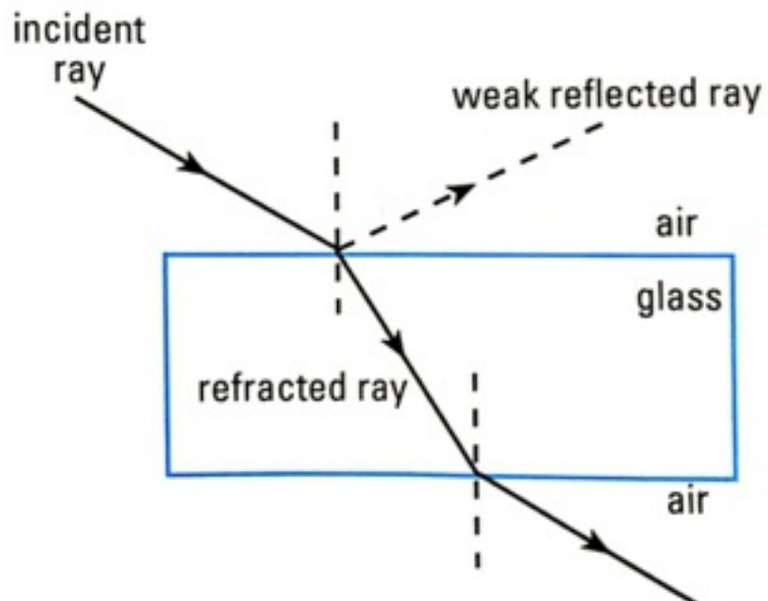


Pencil appears to be broken

Gives the illusion that there is much more rootbeer float than there actually is

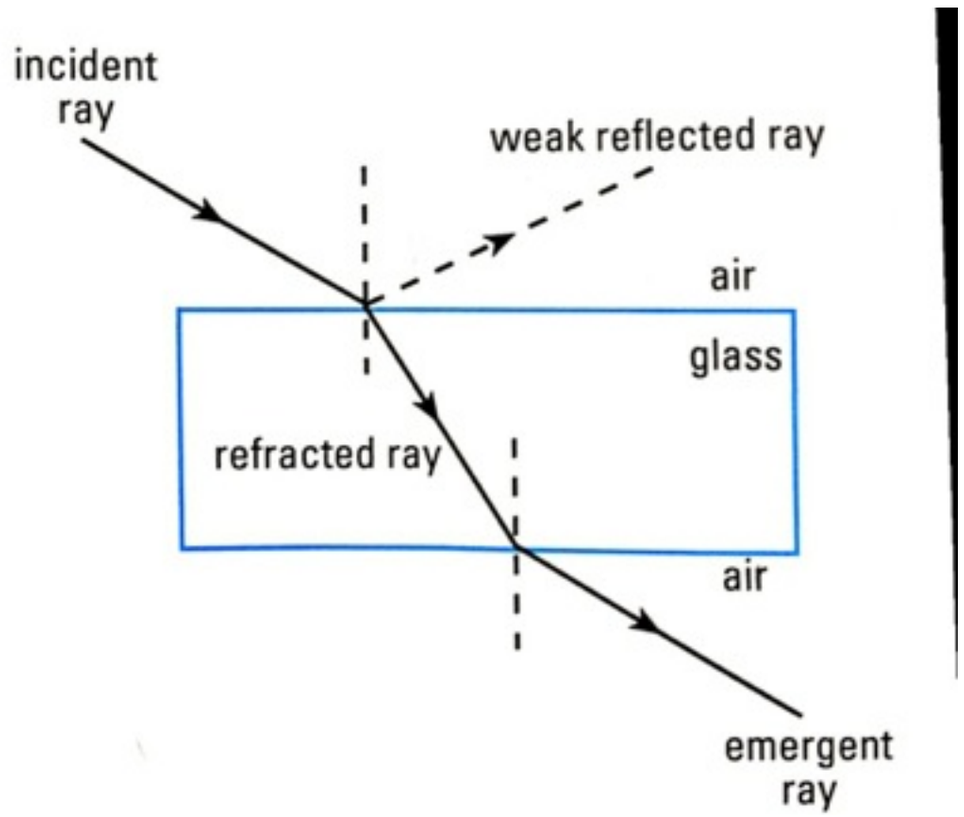
What is a refraction?

- **Refraction is the bending of light when it travels from one transparent medium to another, of different optical densities.**
- 1. Light bends towards the normal as it travels from a less dense medium to a denser medium
- 2. Light bends away from the normal as it travels from a denser medium to a less dense medium



What is a refraction?

- **This bending of light is caused by the change in speed.**
- **1. Light moves slower in a denser medium, so it bends towards normal.**
- **2. Light moves faster in a less dense medium, so it bends away from normal.**



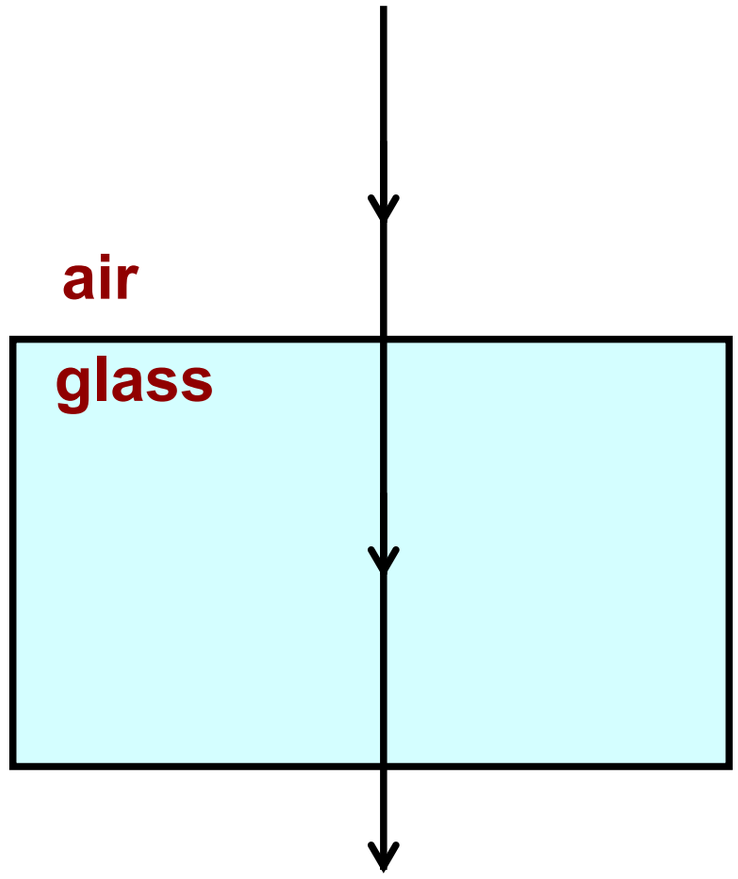
Optical density vs physical density

	diamond	flint glass
physical density/ g cm	3.3	7.62
optical density	2.4	1.65

- If a medium is physically denser than the other, it does not mean that it is optically denser than the other.
- OPTICAL DENSITY NOT = DENSITY

Refraction

- No refraction occurs when light travels **perpendicular** to the boundary of the mediums.



Practice Task

- GLM
- pg 228 Q3, Q4
- pg 231 Q5a

Refractive index

- Refraction occurs because there is a **difference in the speed of light** as it enters from air to medium.
- So there is a ratio of their speeds in each medium.
- This ratio is known as the refractive index of the medium.
- **Refractive index *n* is defined as the ratio of speed of light in vacuum/air and in a medium.**
- ***n = c / v***

Refractive index

- Refractive index is a property of the medium in which light rays enter from air.
- It tells us the light-bending ability of the medium as the rays enter from air.

$$n = \frac{c}{v}$$

Medium	Refractive index *n*
Diamond	2.40
Glass	1.50*
Perspex	1.50
Water	1.33
Ice	1.30
Air	1.00

Refractive index

- The larger the refractive index of a medium, the slower the speed of light in that medium.
- The more it bends towards the normal.
- Refractive index indicates the amount of bending

Medium	Refractive index *n*	Speed of light ($\times 10^8$ m s^{-1})
Diamond	2.40	1.25
Glass	1.50*	2.00
Perspex	1.50	2.00
Water	1.33	2.25
Ice	1.30	2.30
Air	1.00	3.00

Worked Example 1

- Given that light travels in diamond and glass at a speed of 1.25×10^8 ms^{-1} and 2.00×10^8 ms^{-1}, find the refractive indexes of both mediums.

Refractive index

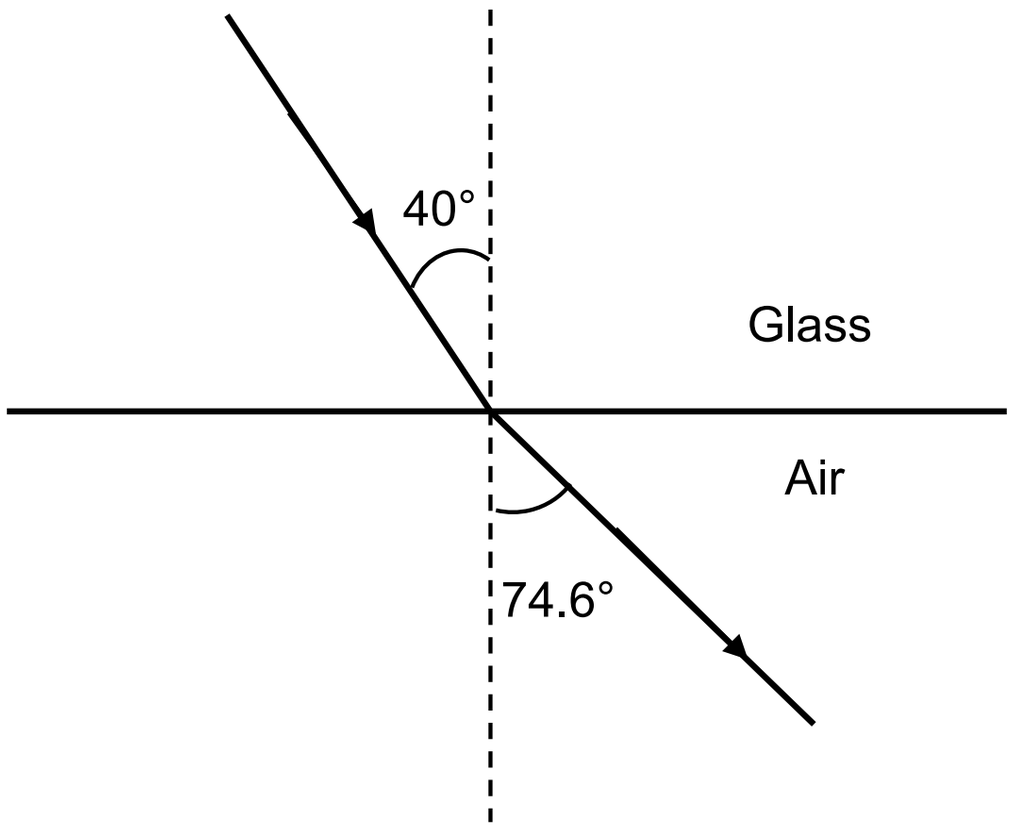
- Since *n* tells us the amount of bending, it can also be expressed as a ratio of the sine of angles.

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

- *1. from* **air to denser medium**
  - use **n = sin i / sin r**
- *2. from* **denser medium to air**
  - use **1/n = sin i / sin r**

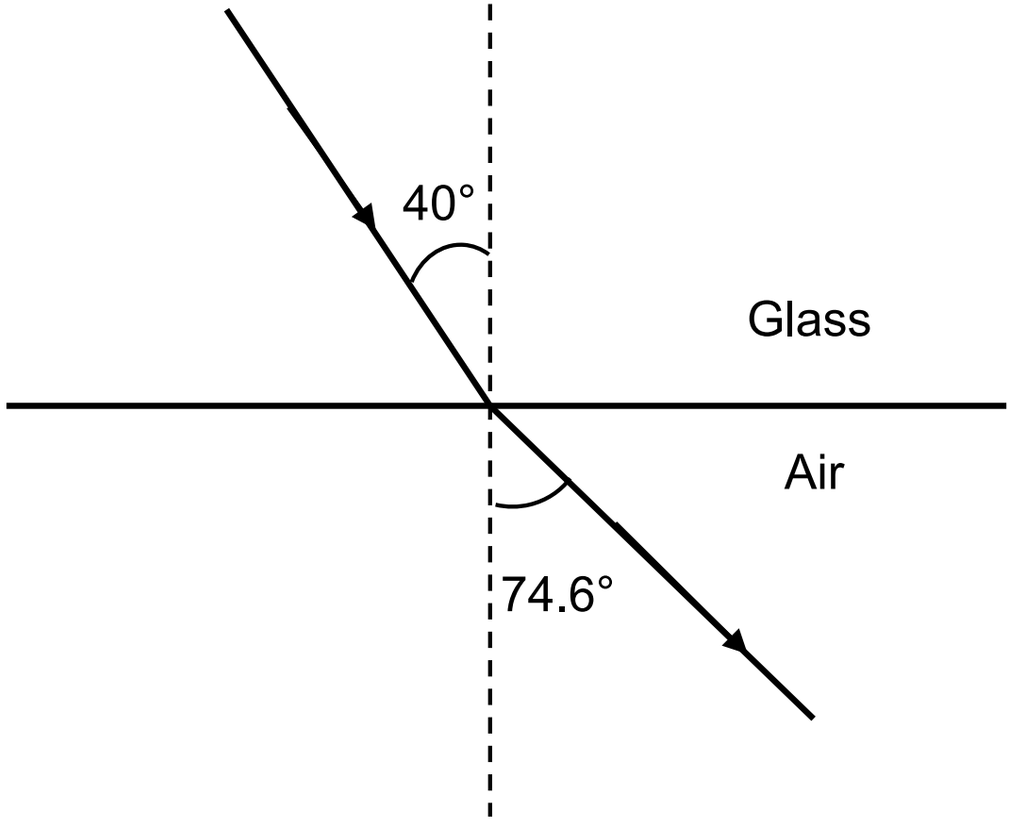
Worked Example 2

- Calculate the refractive index of the glass if light enters and refract as shown in the diagram.



Reversibility of light

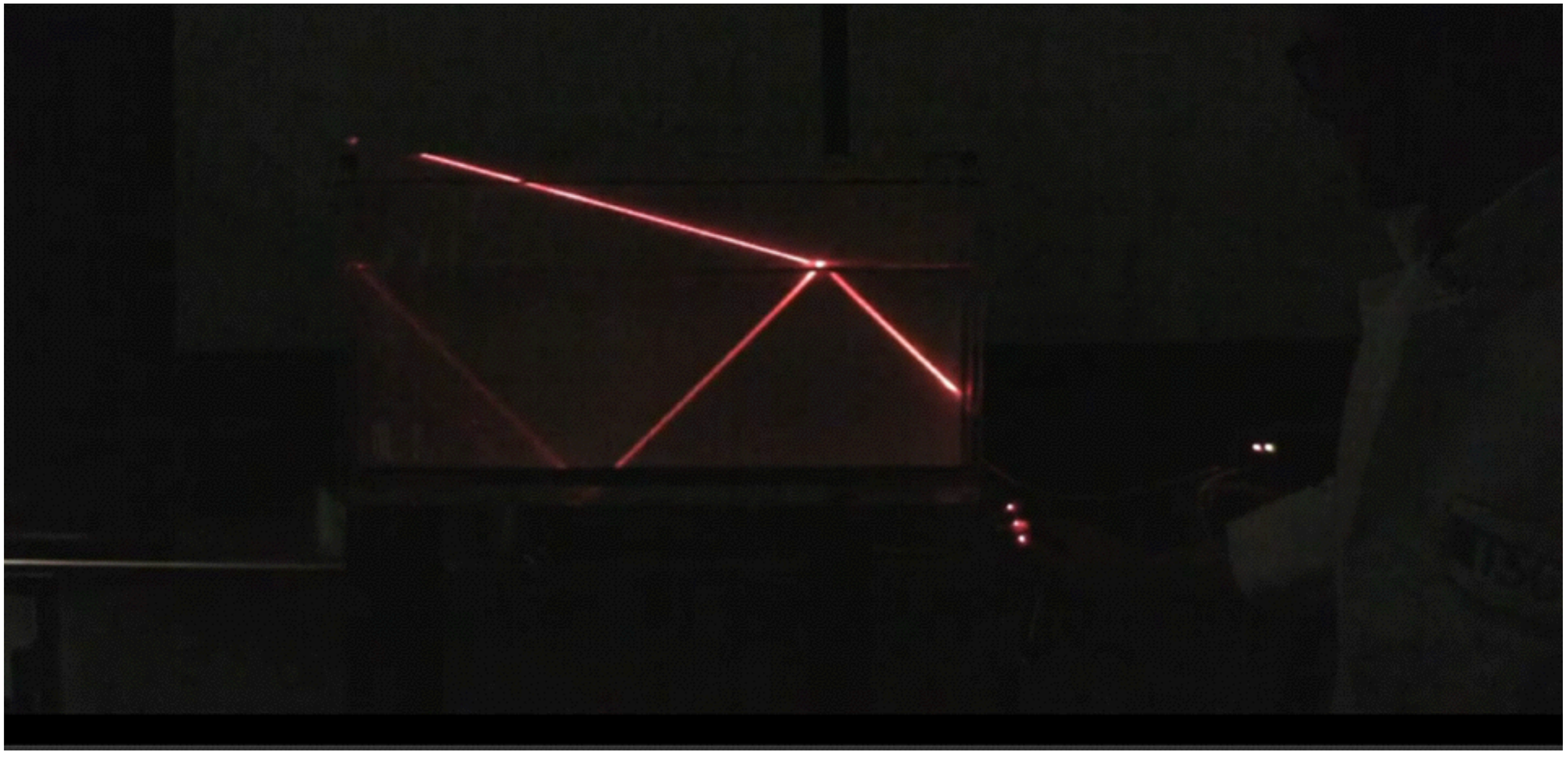
- If light exits glass at enters air as shown, light can also exit air with *i* = 74.6 degrees and enter glass with a *r* = 40 degrees.



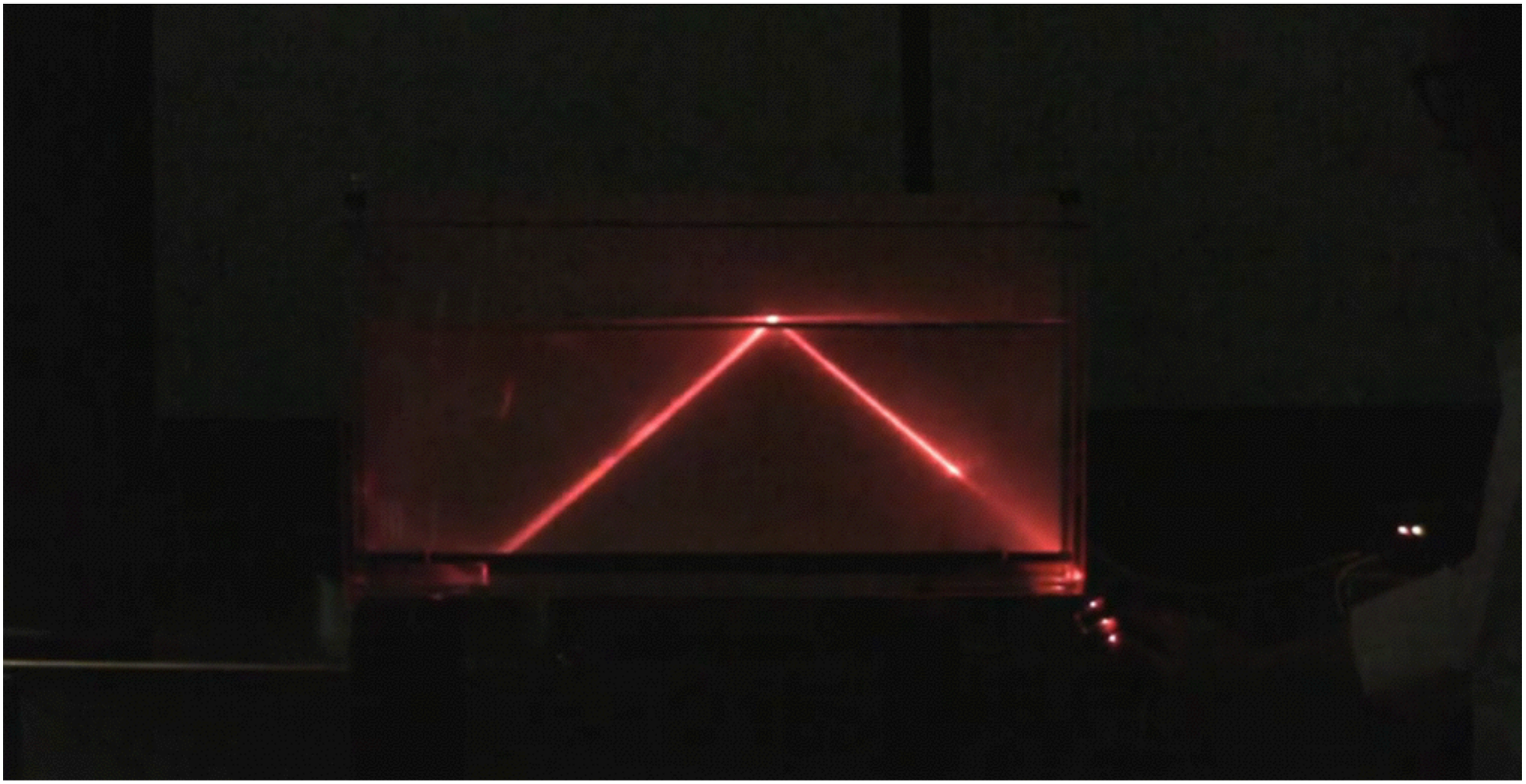
Practice Task

- GLM
- pg 222 Q 2 (b)(i) & (ii)

Laser light shining from beneath the water surface is refracted at a larger angle in air.



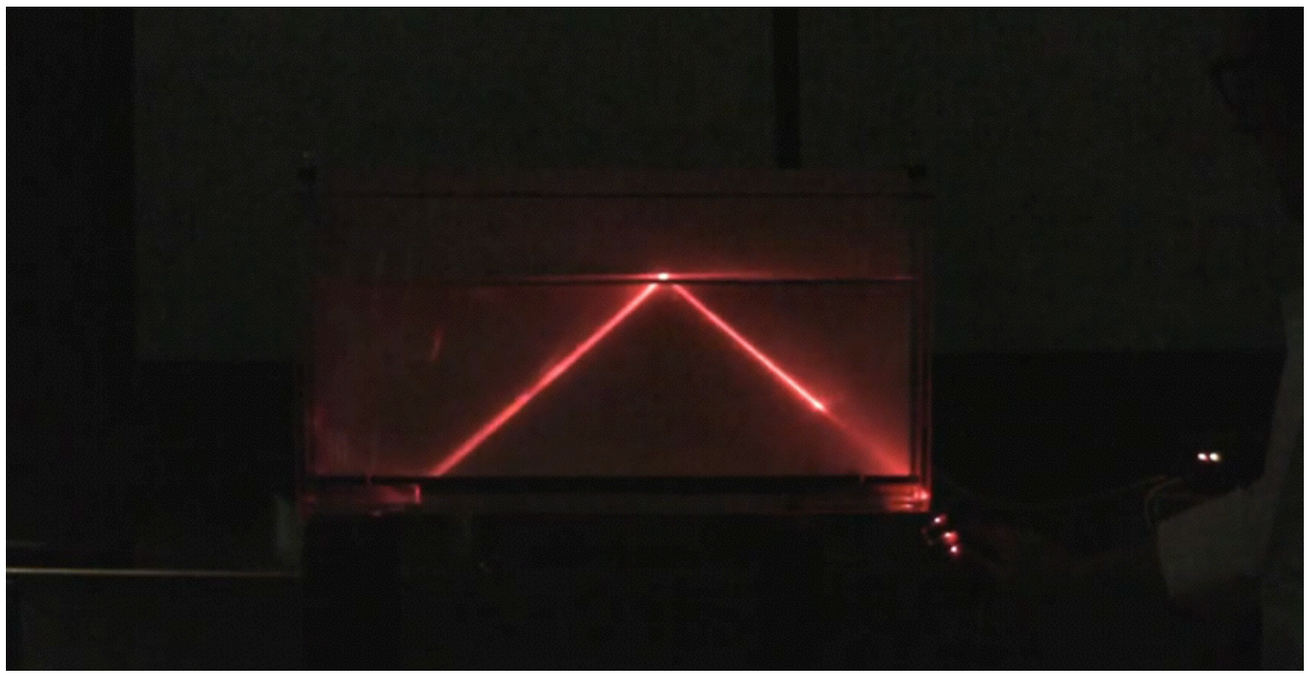
At a certain angle of incidence, light is totally reflected! (Light does not leave the water)



Total internal reflection

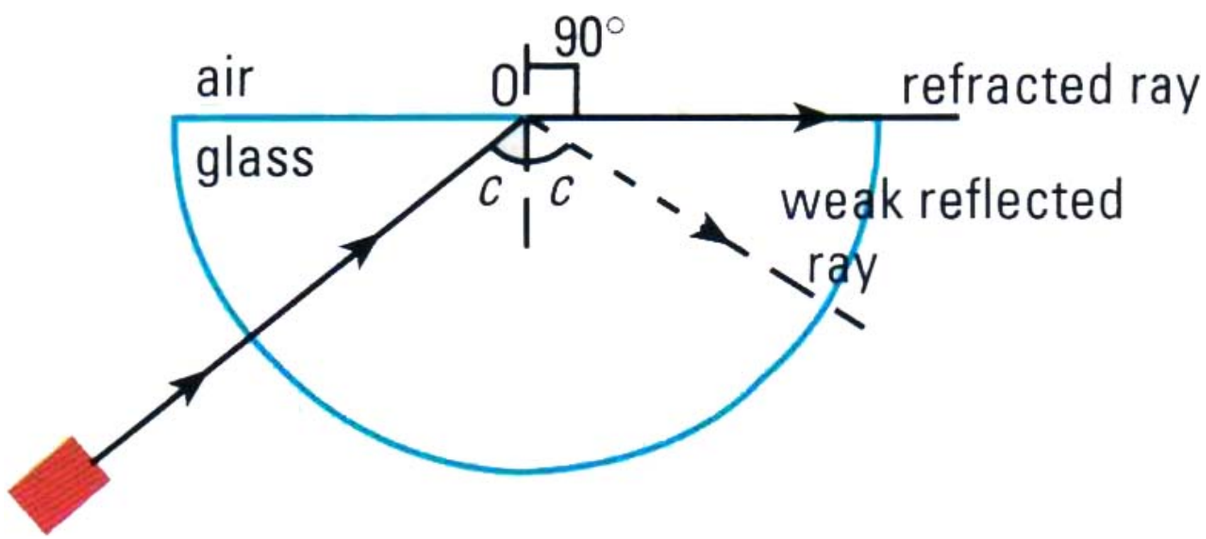
- This phenomena is known as total internal reflection.
- Total internal reflection only occurs when light passes from an optically **denser** medium to an optically **less dense** medium.

- **Just like normal reflection, it obeys the law of reflection**
- **angle i = angle r**



Critical angle

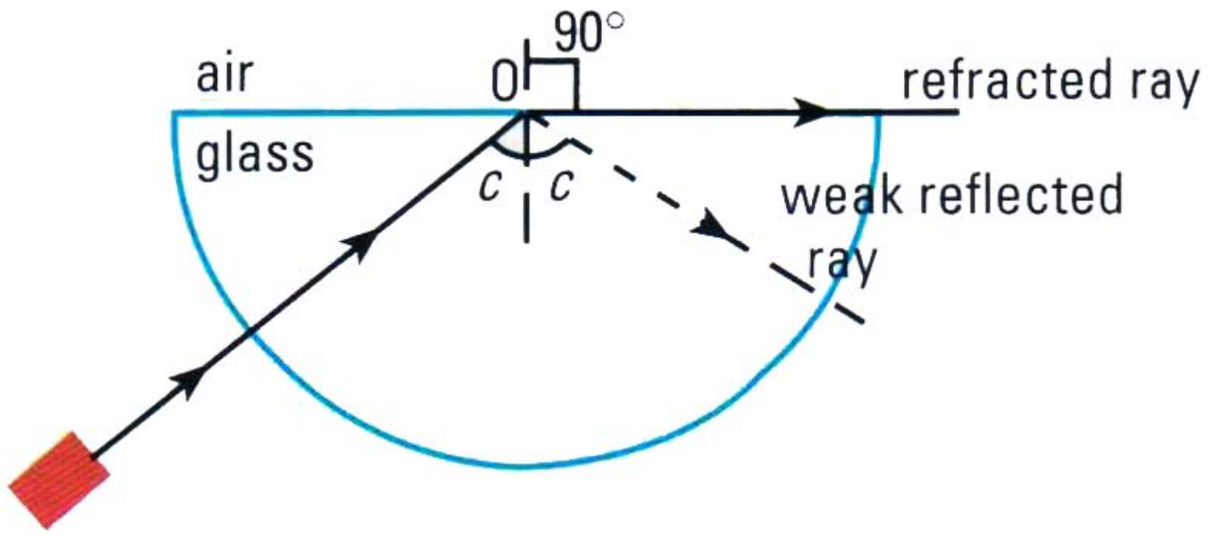
- How does total internal reflection happen?
- We need to first understand what critical angle is.
- **Critical angle is the <u>angle of incidence</u> in the denser medium for which the <u>angle of refraction is 90º.</u>**



Critical angle

- Each medium has its own critical angle.
- E.g. Diamond has a critical angle of about 24.6º and glass has a critical angle 41.8º.

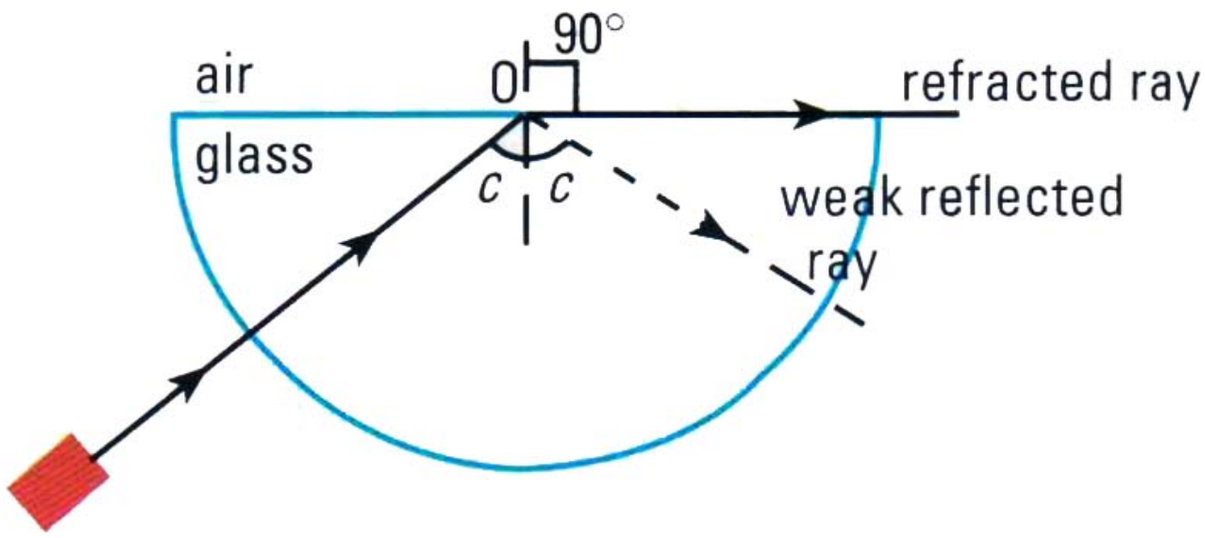
- The critical angle can be calculated using this formula:
- **sin c = 1/n**



Worked Example 3

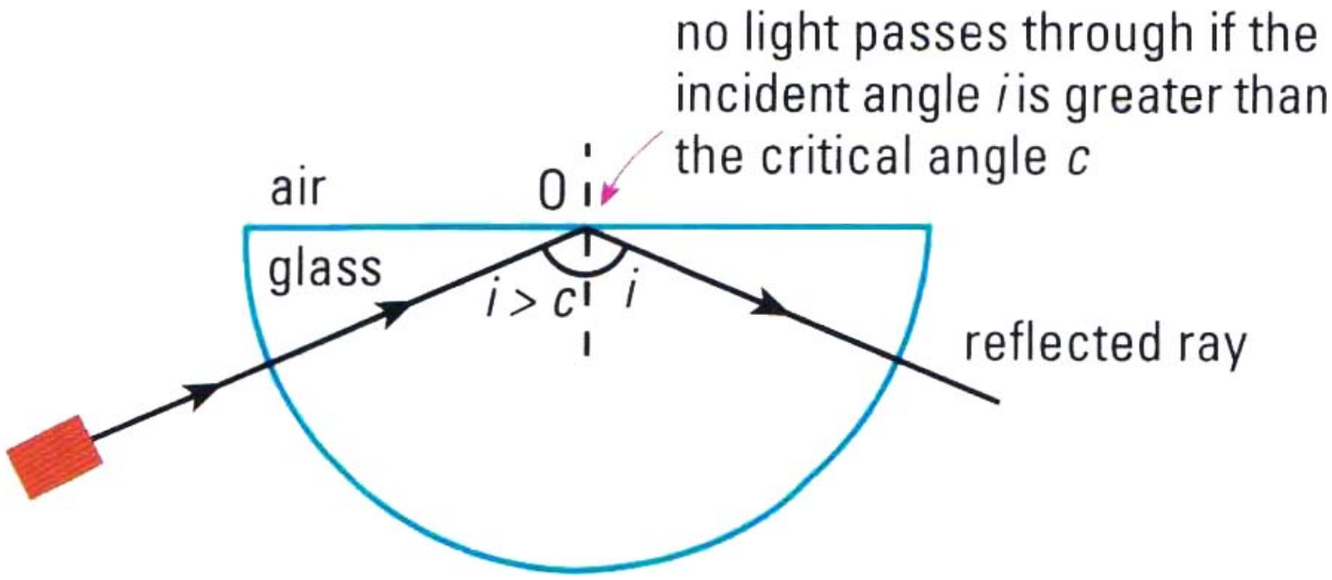
- Show that diamond has a critical angle of about 24.6º and glass has a critical angle 41.8º.

- Given that their refractive indexes are 2.40 and 1.50 respectively.



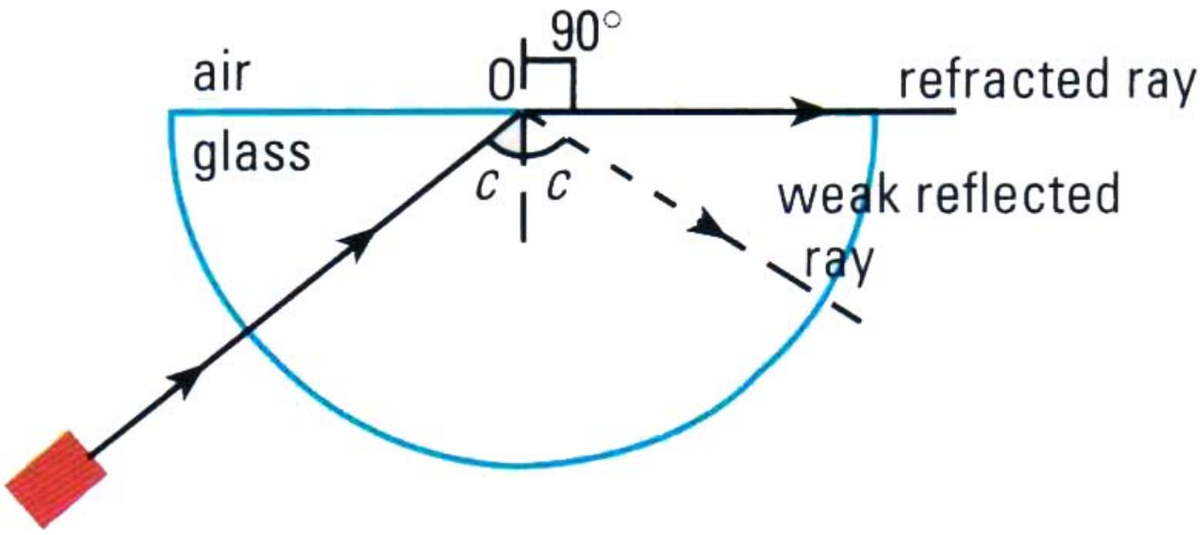
Total Internal Reflection

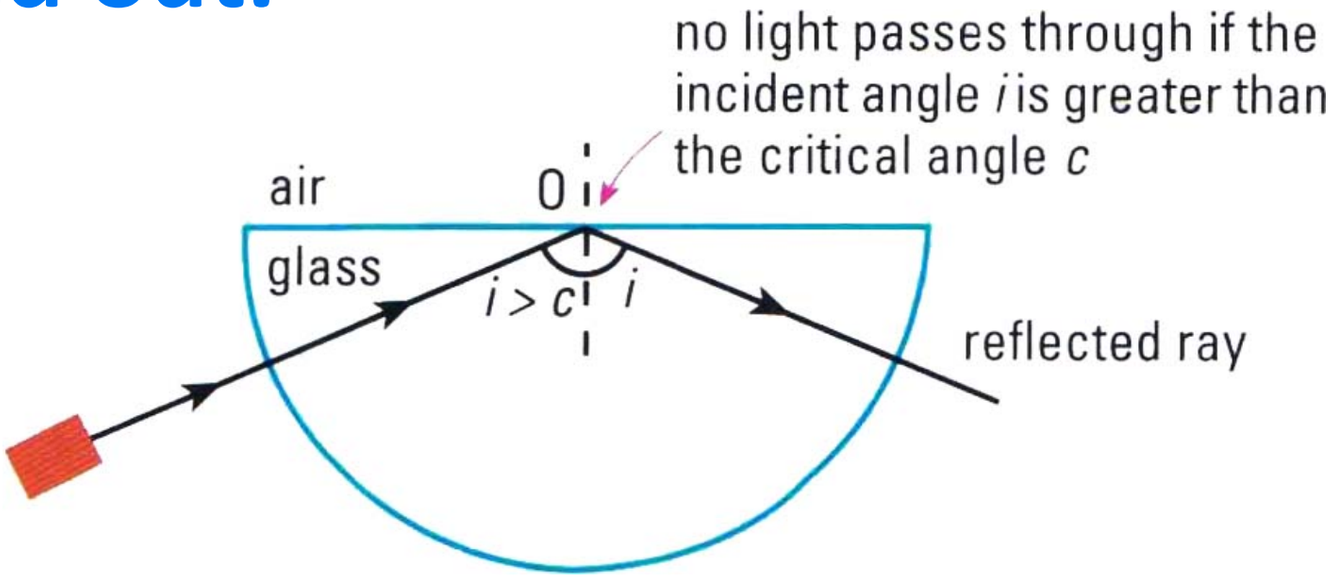
- **Definition:**
- It is the complete reflection of a light ray inside an optically denser medium at its boundary with an optically less dense medium.



Total Internal Reflection

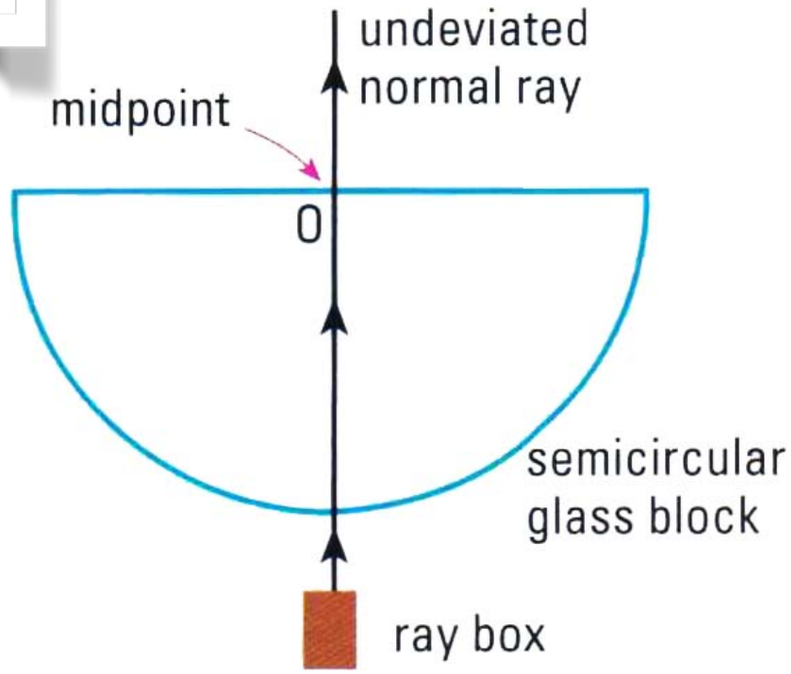
- **Once the angle of incidence in the denser medium becomes larger than the critical angle, i > c,**
- **All the light rays undergo total internal reflection (within the denser medium)**
- **No light ray is refracted out.**



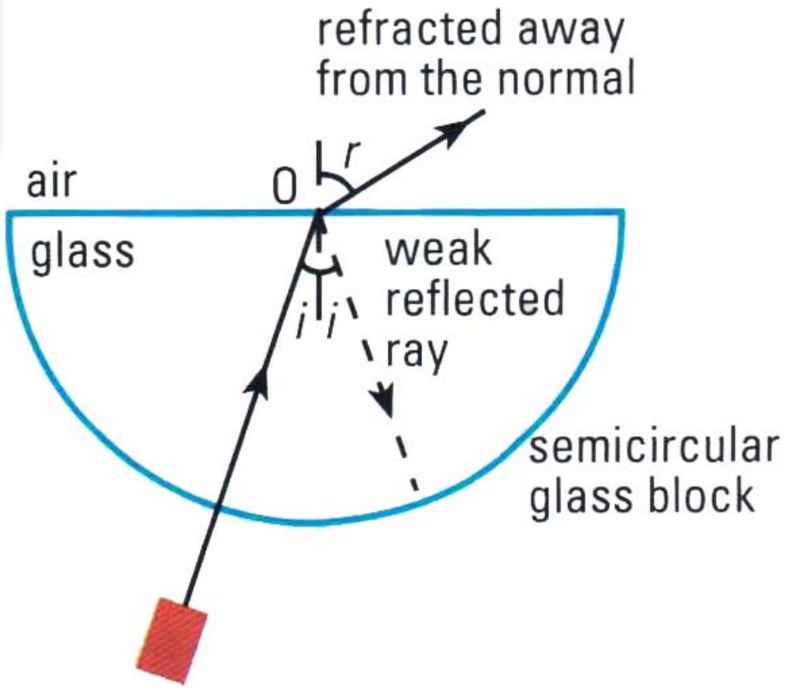


Total internal reflection

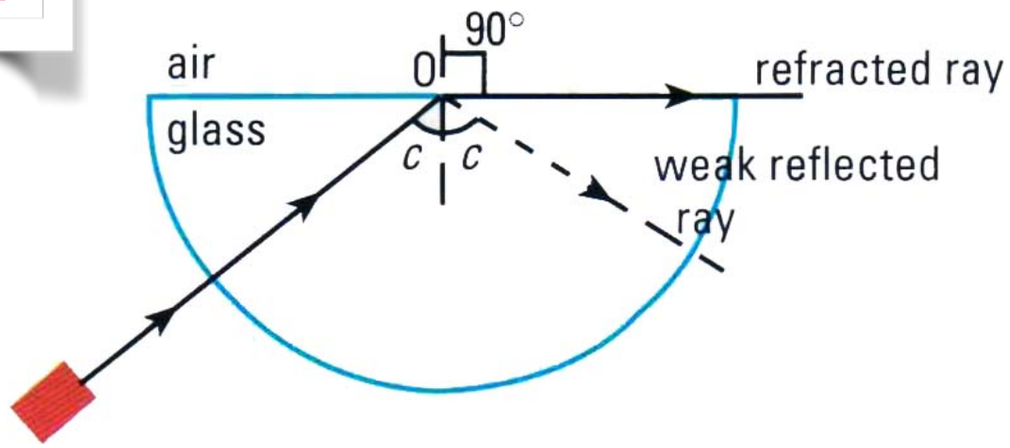
1.



2.



3.



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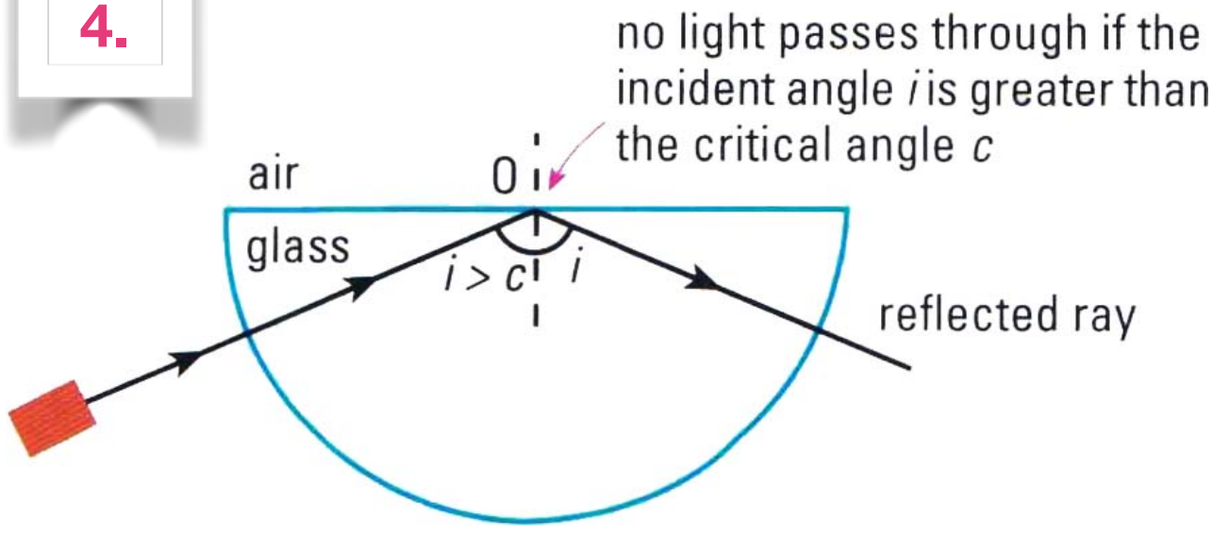
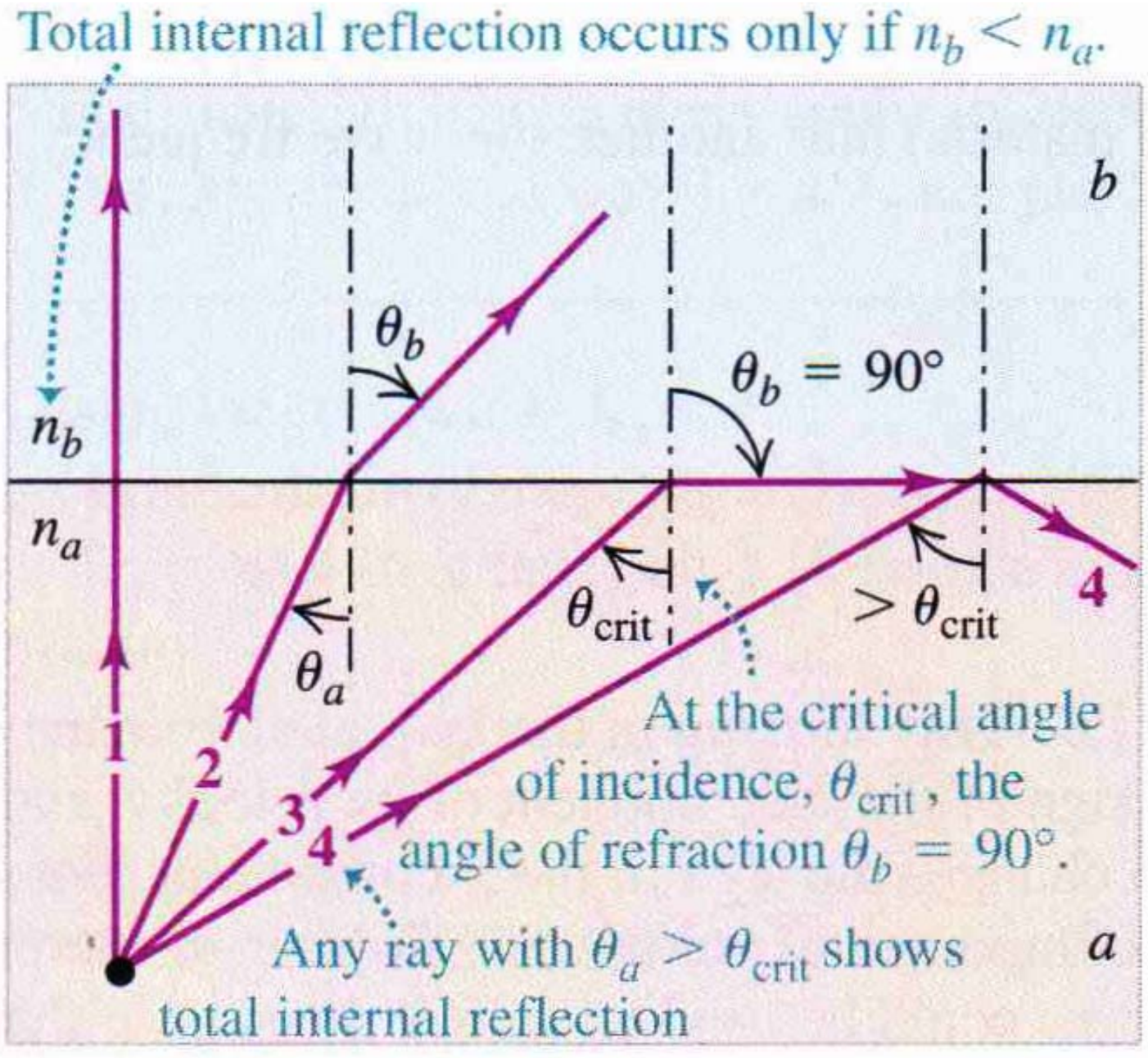
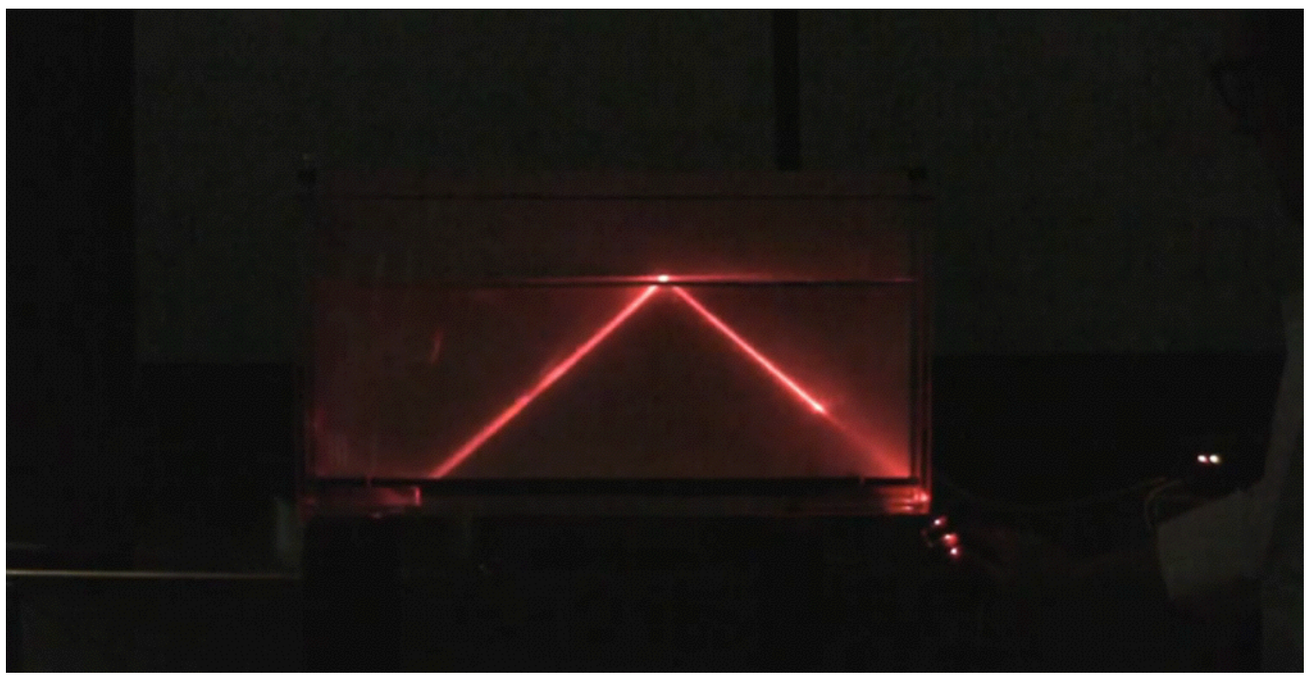


Total internal reflection



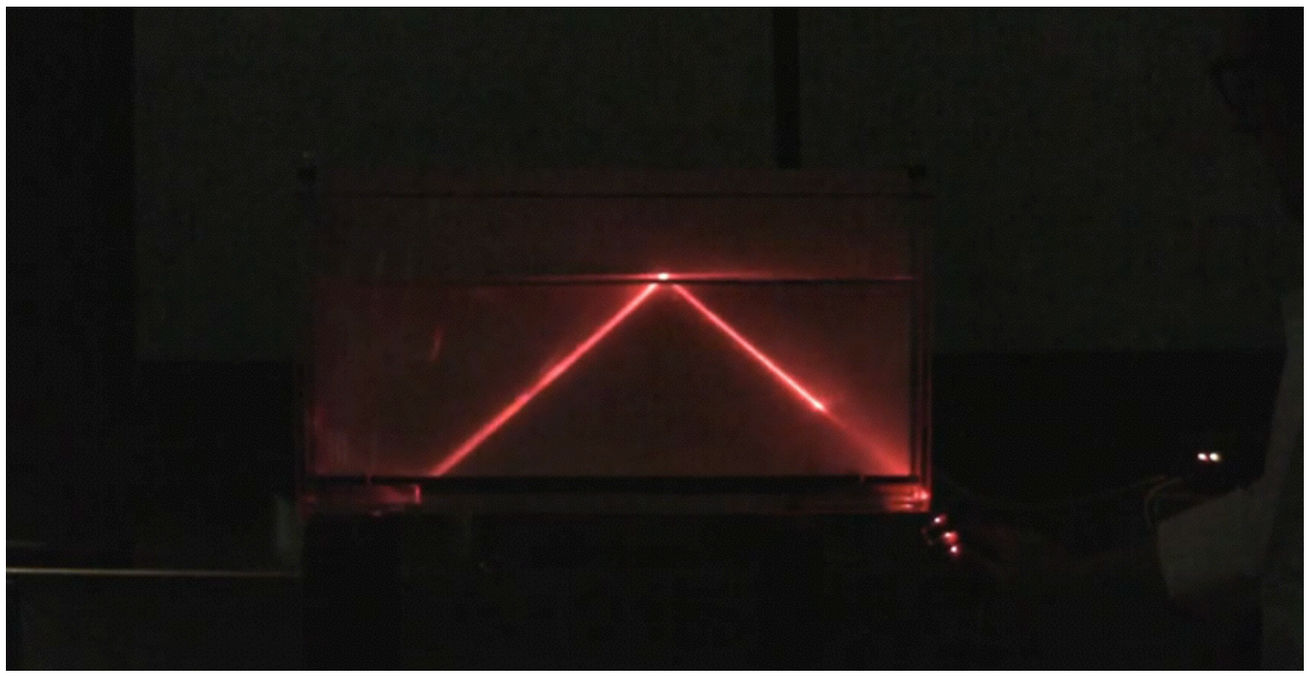
Conditions for total internal reflection

- It can only take place if:
- 1. The light is travelling from an **optically denser medium to a less dense medium**
- 2. The angle of incidence is **greater** than the critical angle



Practice Task

- GLM
- pg 222 Q3 (b) & (c)
- pg 231 Q4



Interesting: Total Internal Reflection

Instead of the sky, the bottom of the sea is being observed when the diver is looking upwards as light is reflected from the corals to the diver.

Interesting: Total Internal Reflection

Why do diamonds have such a brilliant sparkle?

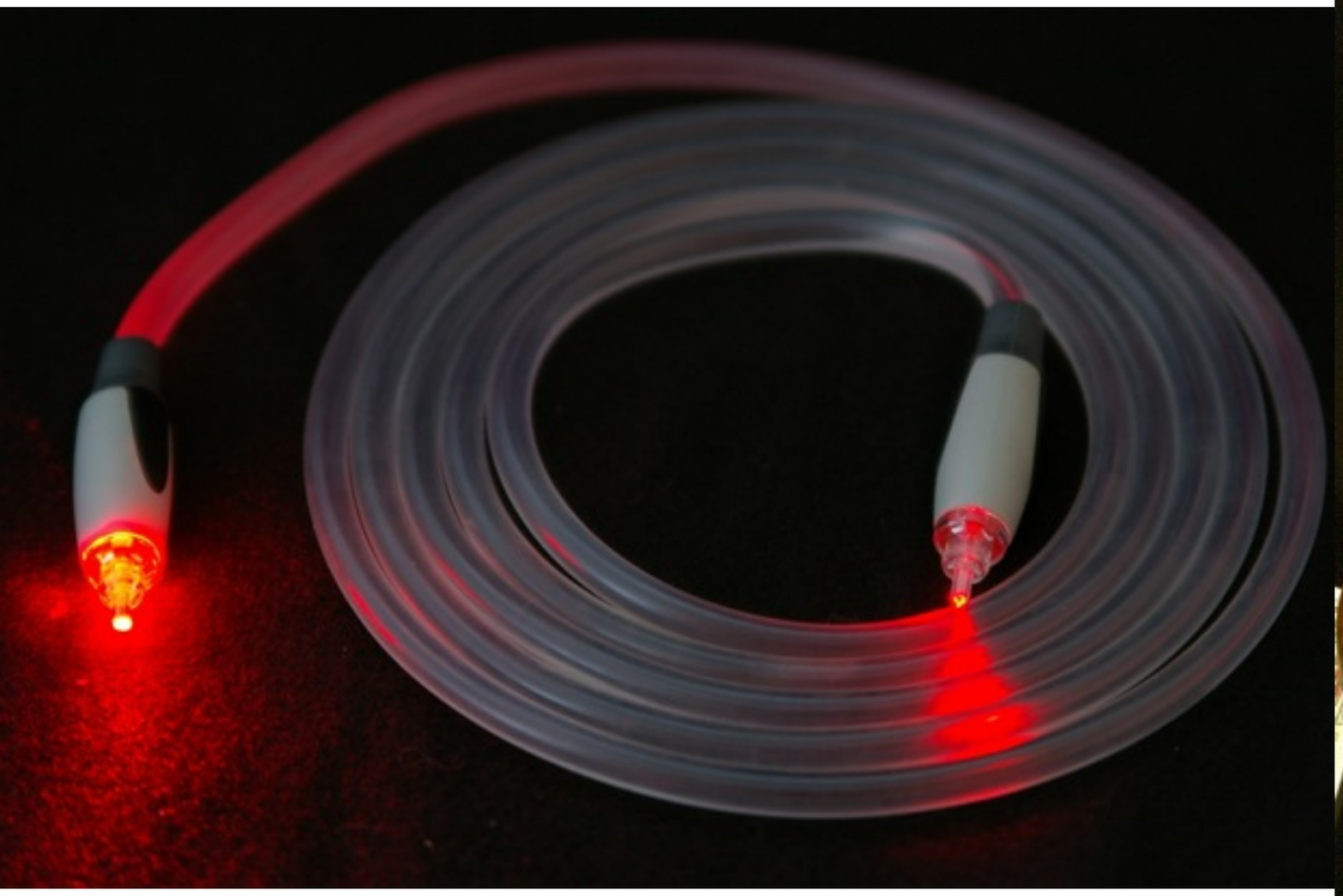
Medium	Refractive index *n*
Diamond	2.40
Glass	1.50*
Perspex	1.50
Water	1.33
Ice	1.30
Air	1.00

1. High refractive index. Small critical angle. <u>More light will be reflected internally.</u>

2. Due to the cut of the diamond. The surfaces of a diamond are angled such that when light enters, it will be reflected internally a number of times before it finally exits the diamond.

Optical Fibres

- Unlike copper wires, they transmit <u>light</u> instead of electric current

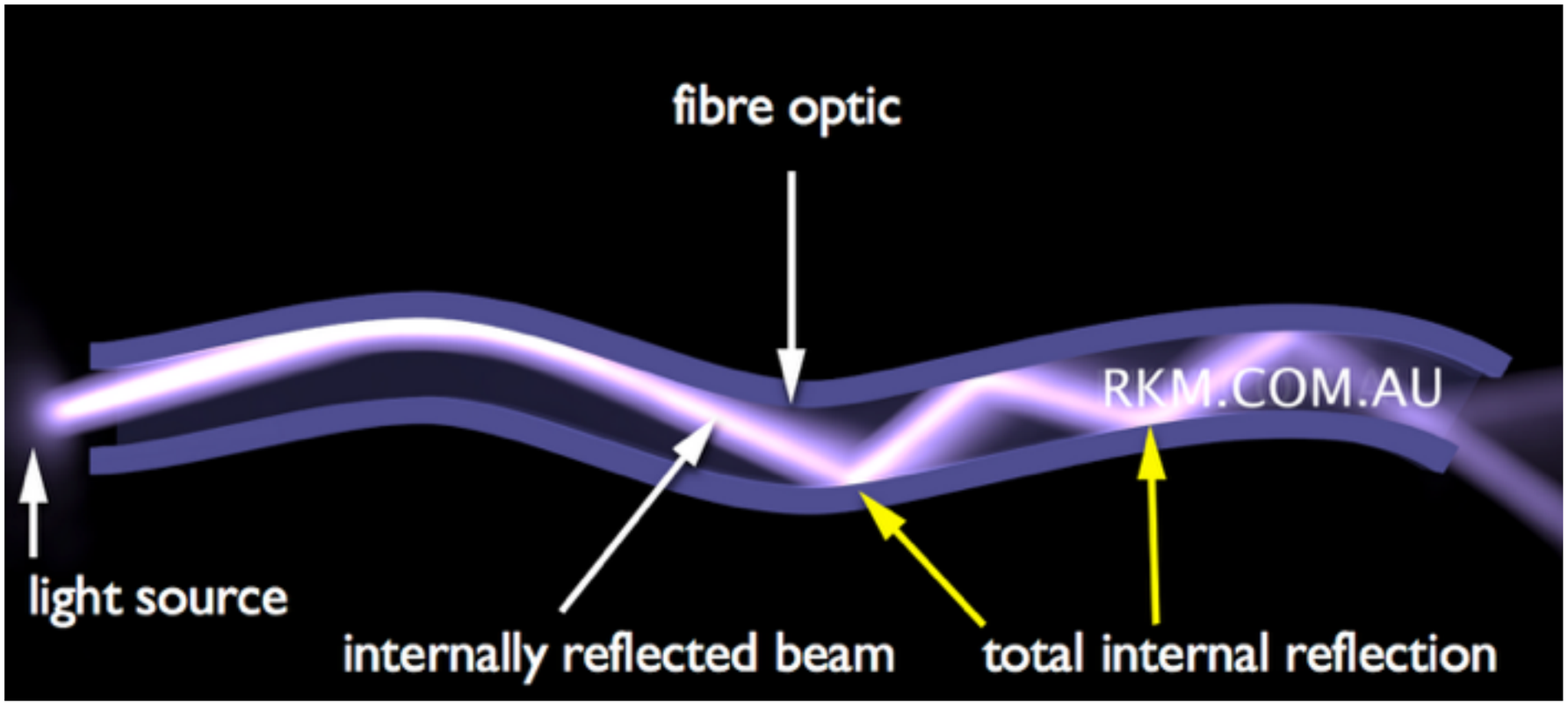


News: Fibre Broadband Price Wars

- On Thursday (Sep 11), M1 launched a promotional S$49-per-month 1Gbps fibre broadband plan – slashing its price by half to go head-to-head with MyRepublic's Ultra 1Gbps package, which the start-up is offering at S$49.99, and SingTel's S$69.90 Unlimited Fibre plan, which was put on the market only last month.
- In response to media queries, StarHub said it is revising its 1Gbps fibre broadband plan, but declined to elaborate. It has stopped selling its S $395.90 plan.

Optical Fibres

- They work on the principles of total internal reflection.
- 1. Light beam enters the plastic and incidents on the plastic to air boundary (denser to less dense)
- 2. Light incidents at an angle greater than the critical angle.

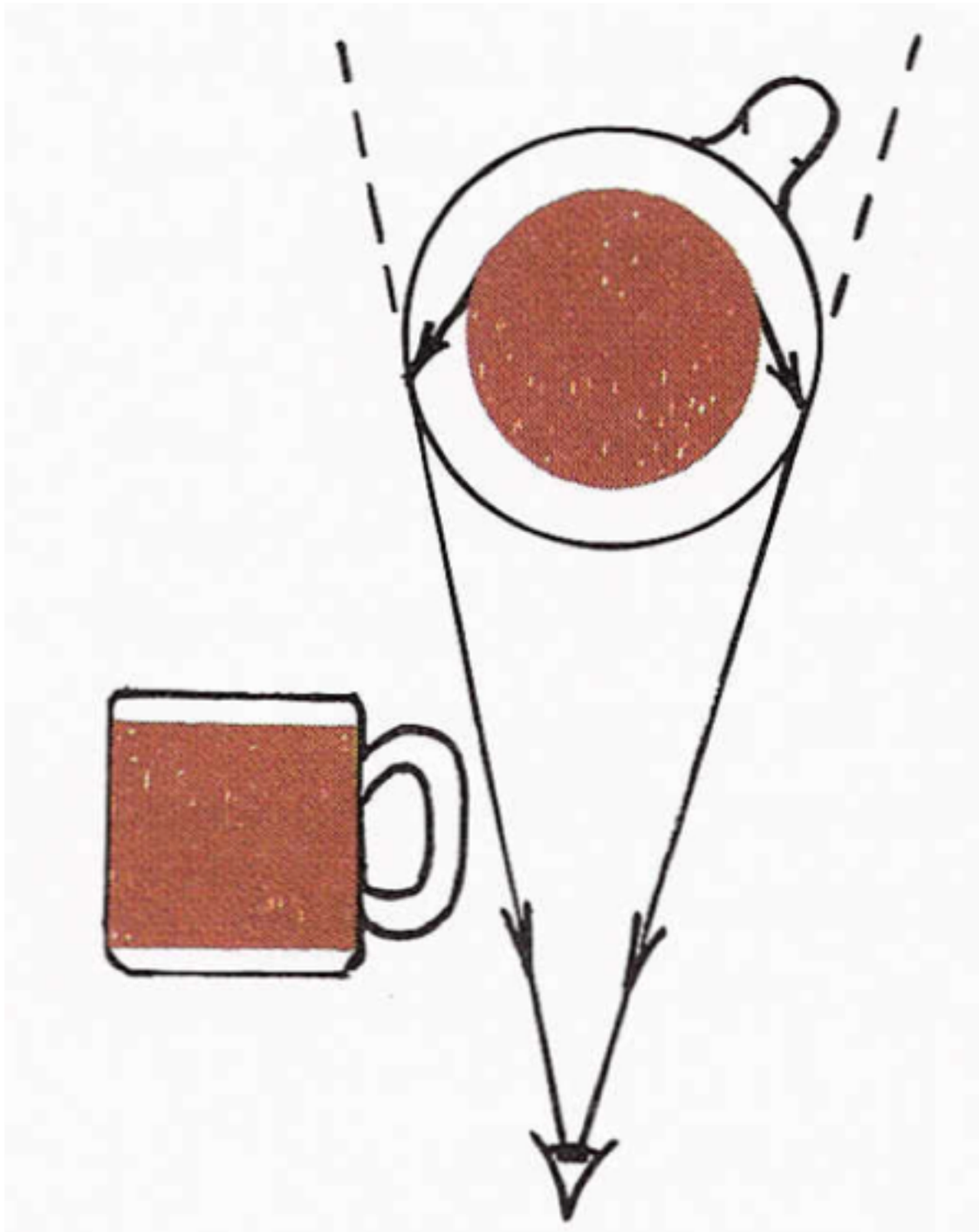


Optical Fibres vs Copper Wires

- Advantages of using them in telecommunication
- **1. Ability to transmit much more data than a copper wire. (More bandwidth)**
- **2. Very little signal loss during transmission. The data can move through greater distances and signal remains strong.**
- **3. It is less susceptible to temperature fluctuations than copper wires and less susceptible to many interferences that electric current can bring**

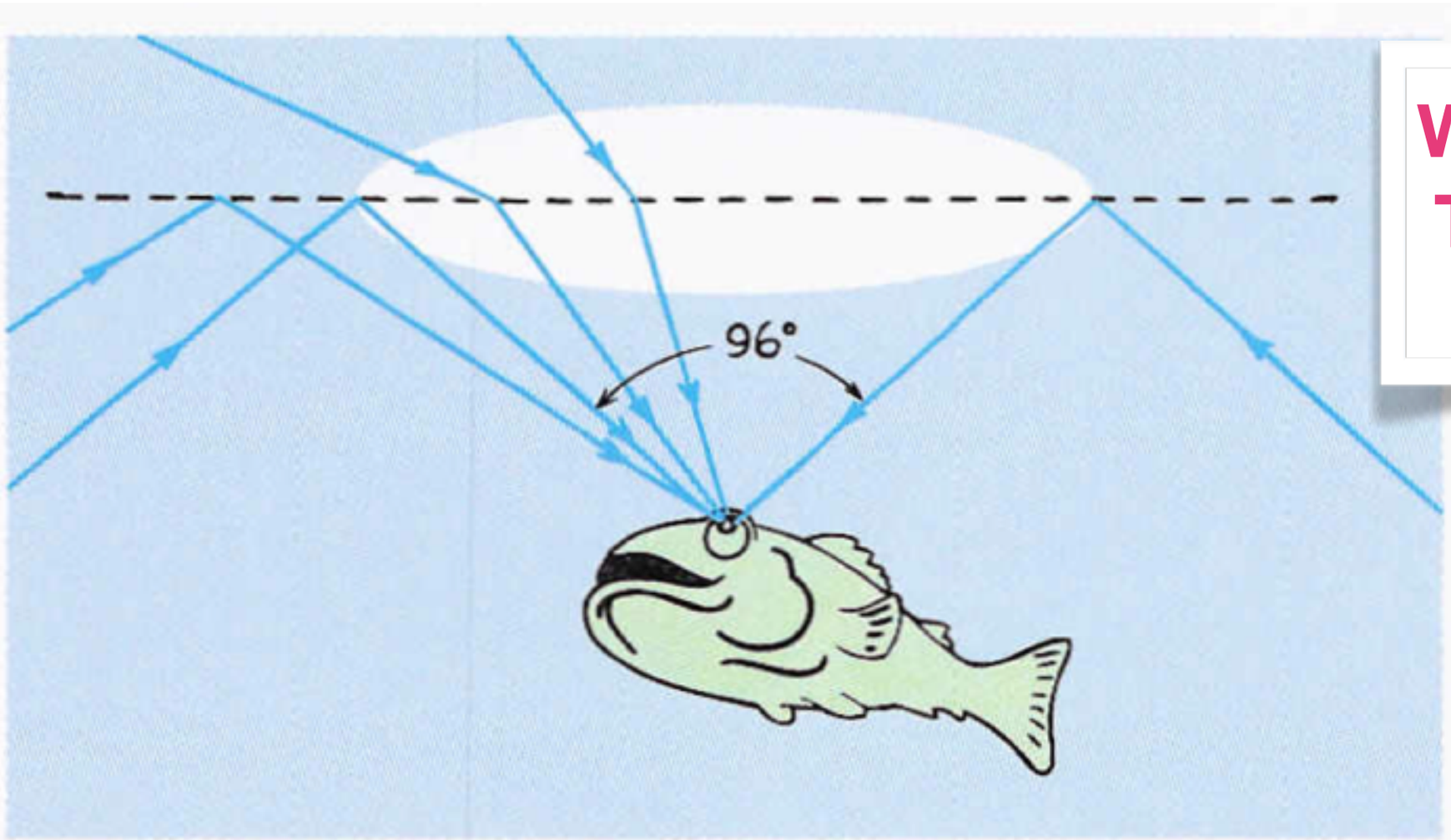
A&W Root Beer CHEAT

- Because of refraction, the full root beer mug appears to hold more root beer than it actually does



OMG this is so interesting

- An observer underwater sees a circle of light at the surface.
- Beyond a cone of 96 degrees, an observer sees a reflection of the water interior or bottom.

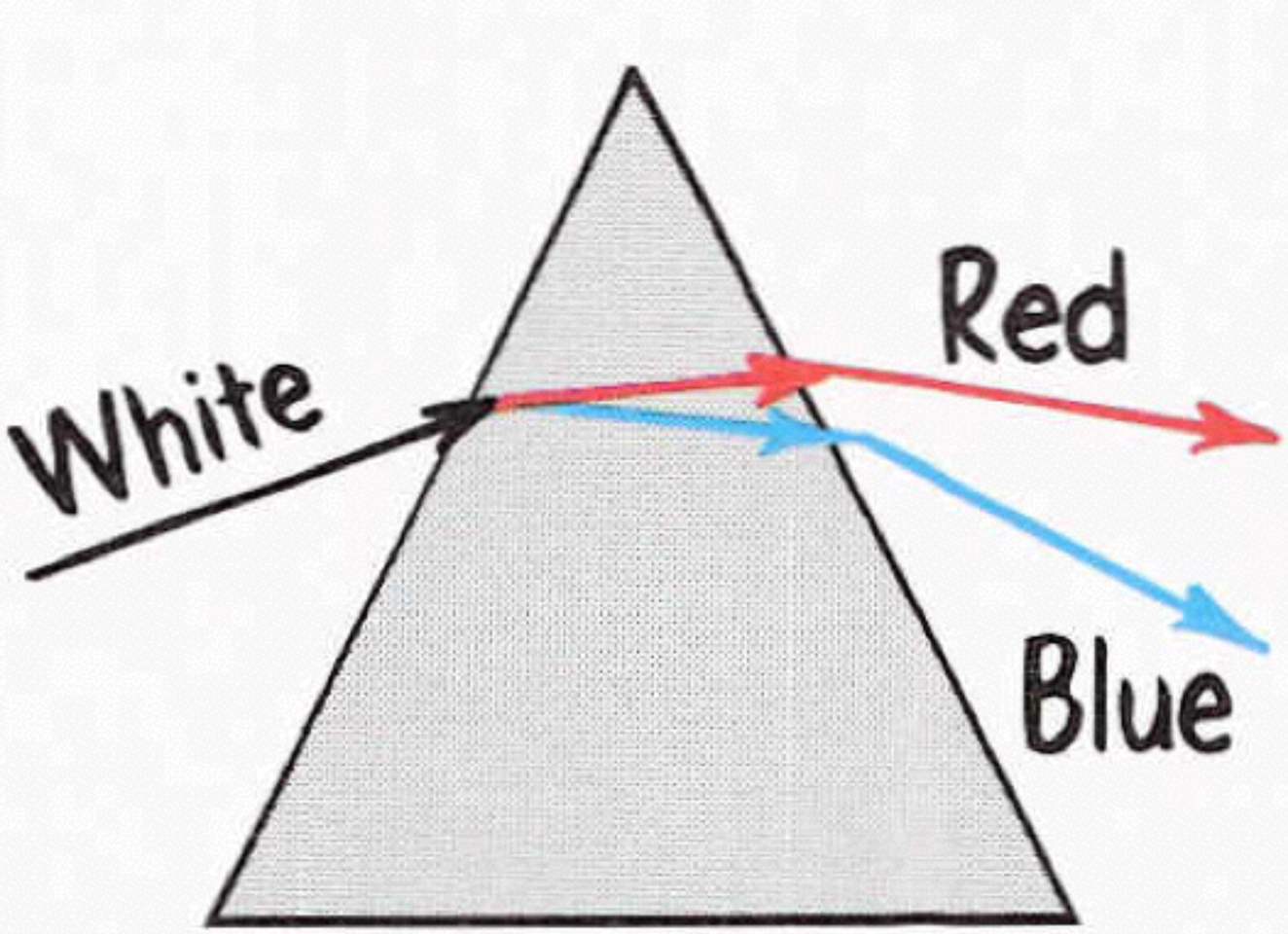


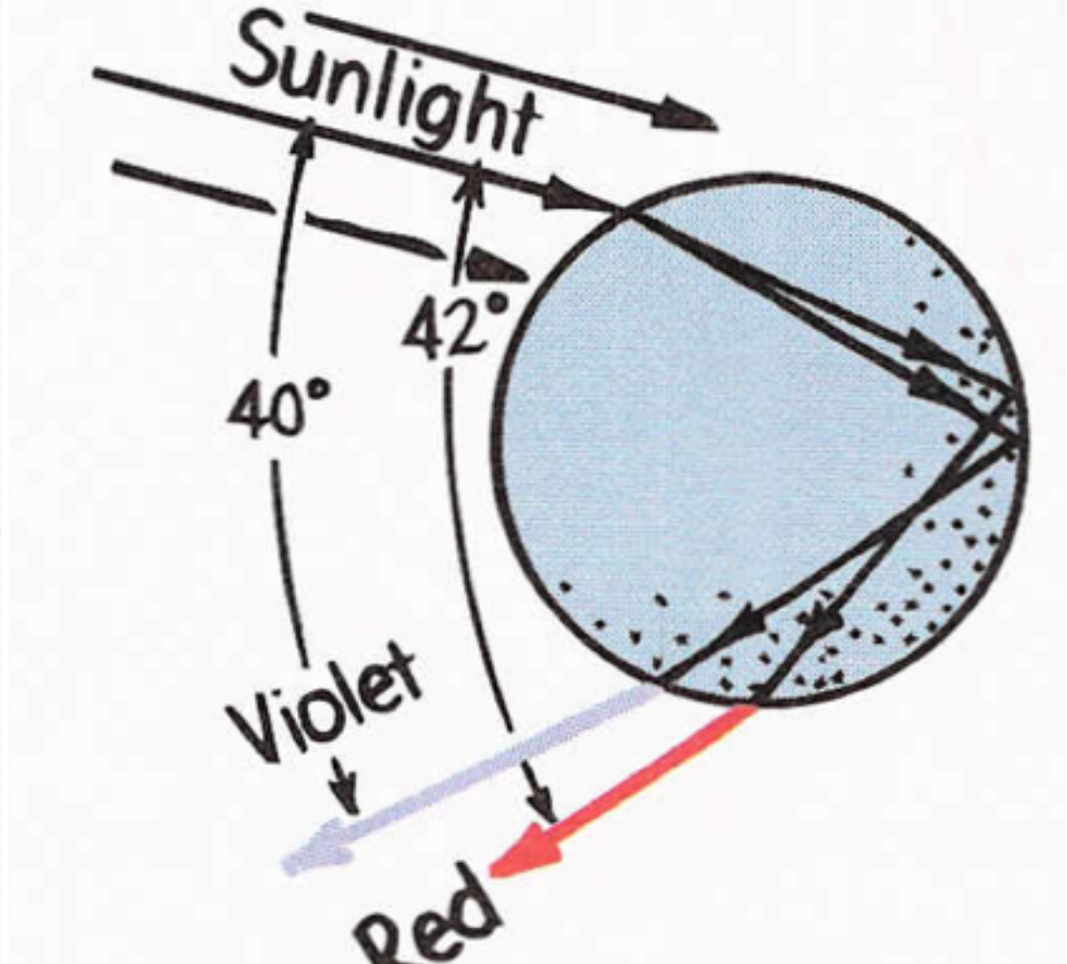
Why 96 degrees? Twice of water's critical angle

(NOT TESTED) Rainbows

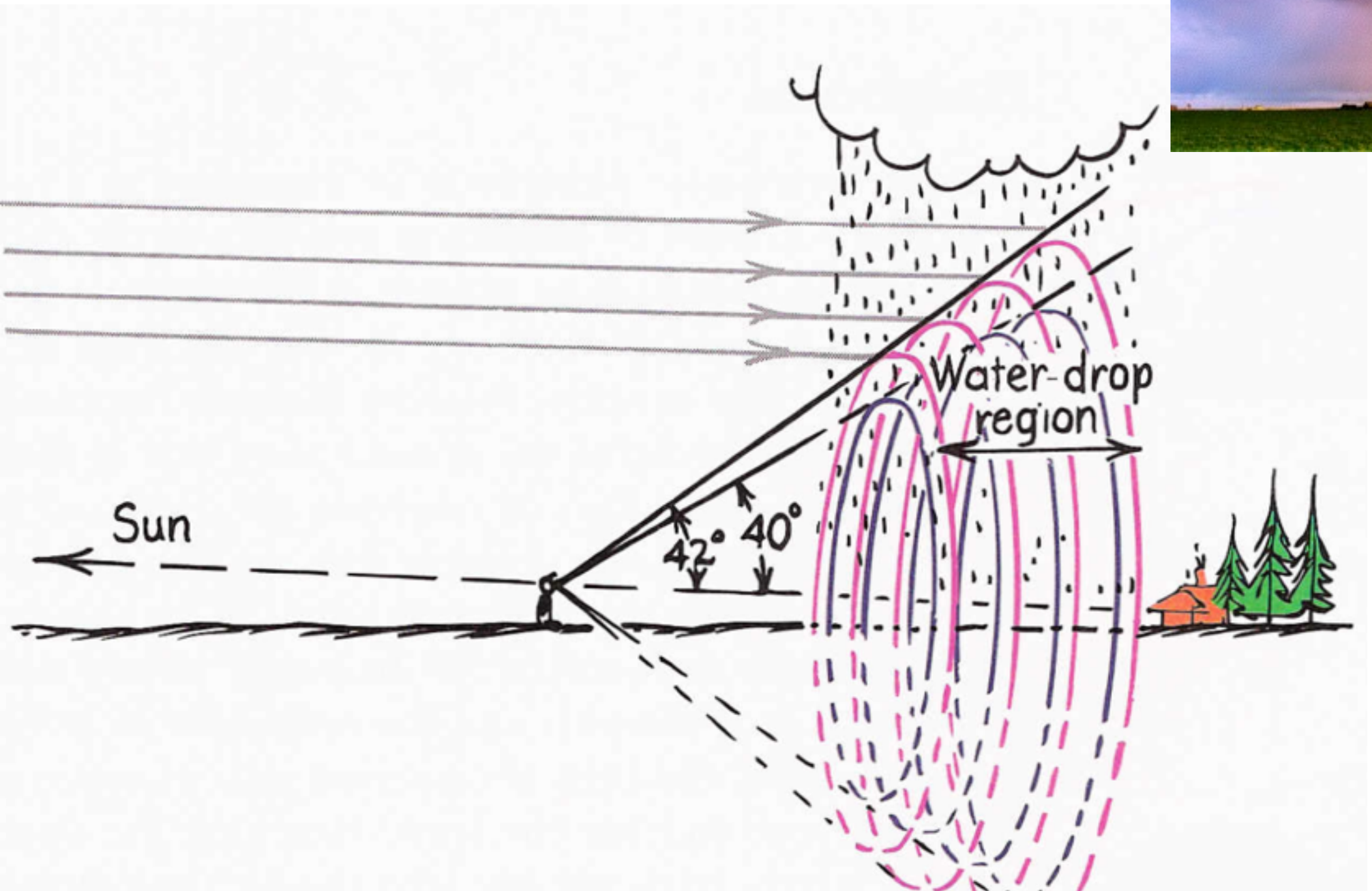
(NOT TESTED) Rainbows

- White light separates into a rainbow as it exits a prism or water droplet.
- Blue light travels slower than red light in optically denser medium.





(NOT TESTED) Rainb



Practice Task

- GLM Book
- Pg 232 Q2