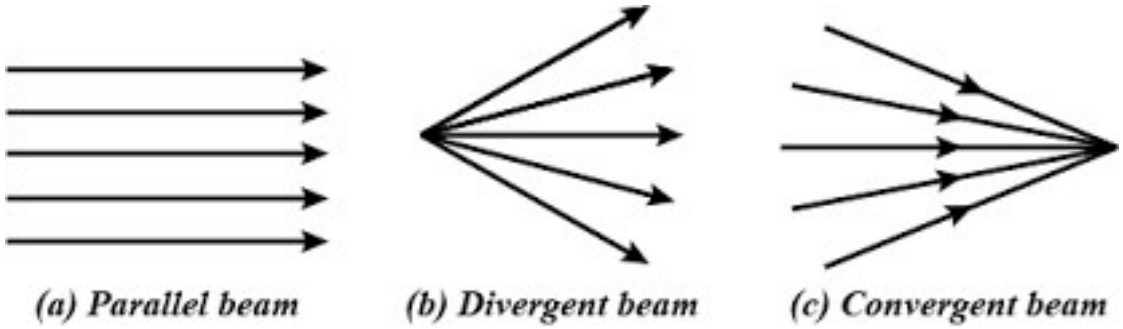
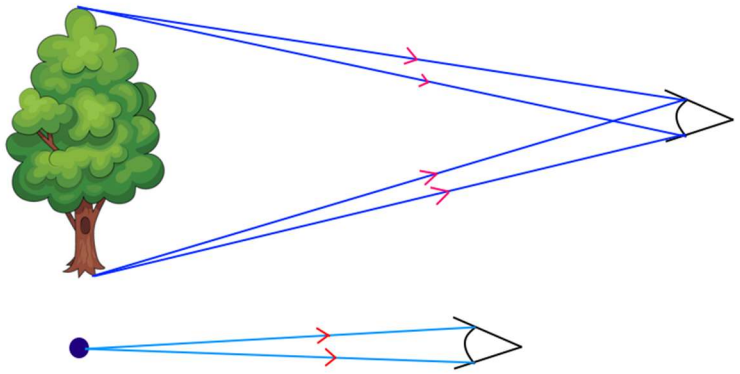
Converging, diverging and parallel:




Ray diagrams of looking at far and close objects:

- For any objects: Consider the top and bottom points (or left & right) only
- Draw lines from top (and bottom) of the object to the top and bottom of eye
- For point objects just draw a pair of lines



How does the man see the shoe on the ground?

# Plane mirror

**Angles of reflections:**

How to measure?

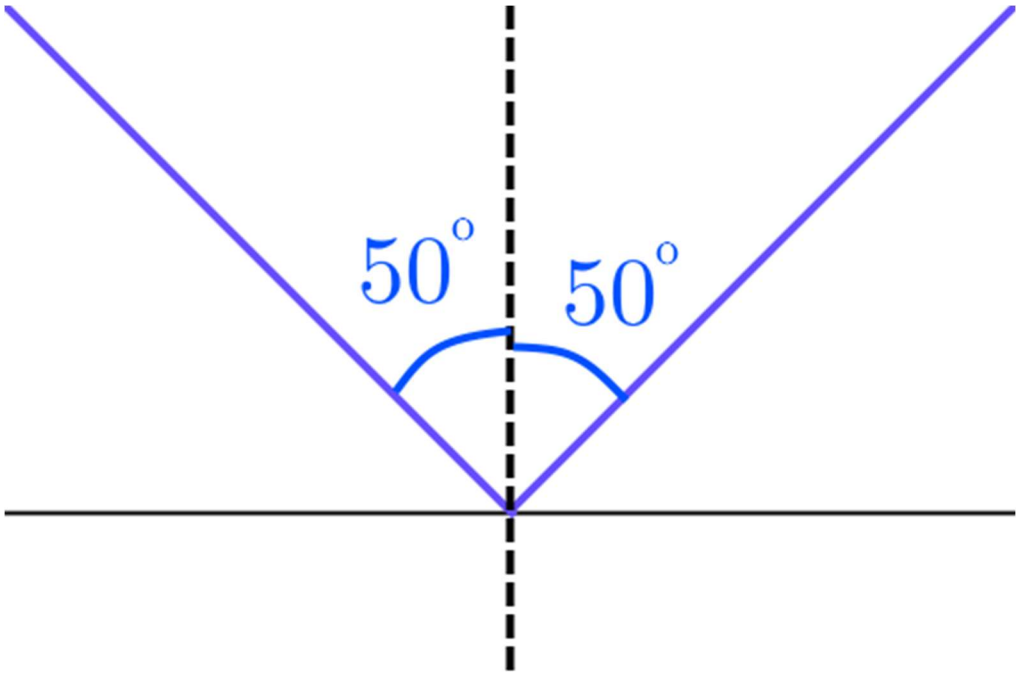
**Nature of plane mirror images:**

- **Upright →** Not flipped (上下沒有顛倒)
- **Laterally inverted** (左右調轉)
- **Virtual** – Cannot be captured/shown on a screen
- **Same size**

**Law of reflection:**

*The angle of incidence is the same as the angle of reflection.*

邊個角度入去就邊個角度出來




**** DOESN'T HAVE TO BE 50 DEGREES!!!

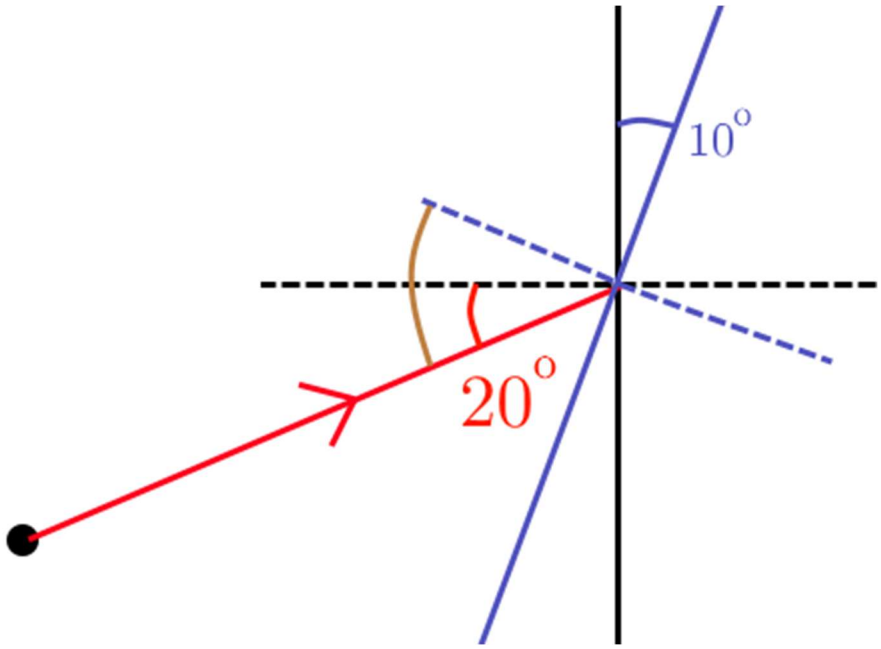
Dotted line: **Normal 法線** – Perpendicular to mirror surface

**Change of angle of incidence**

Usually questions go like this:

What is the new angle of incidence/reflection after the mirror is rotated in a certain direction by a certain angle.

1. Change in angle of incidence/reflection = angle rotated
2. Increase or decrease: Can be visually answered.




Angle of incidence (and reflection) has grown by 10 degrees.

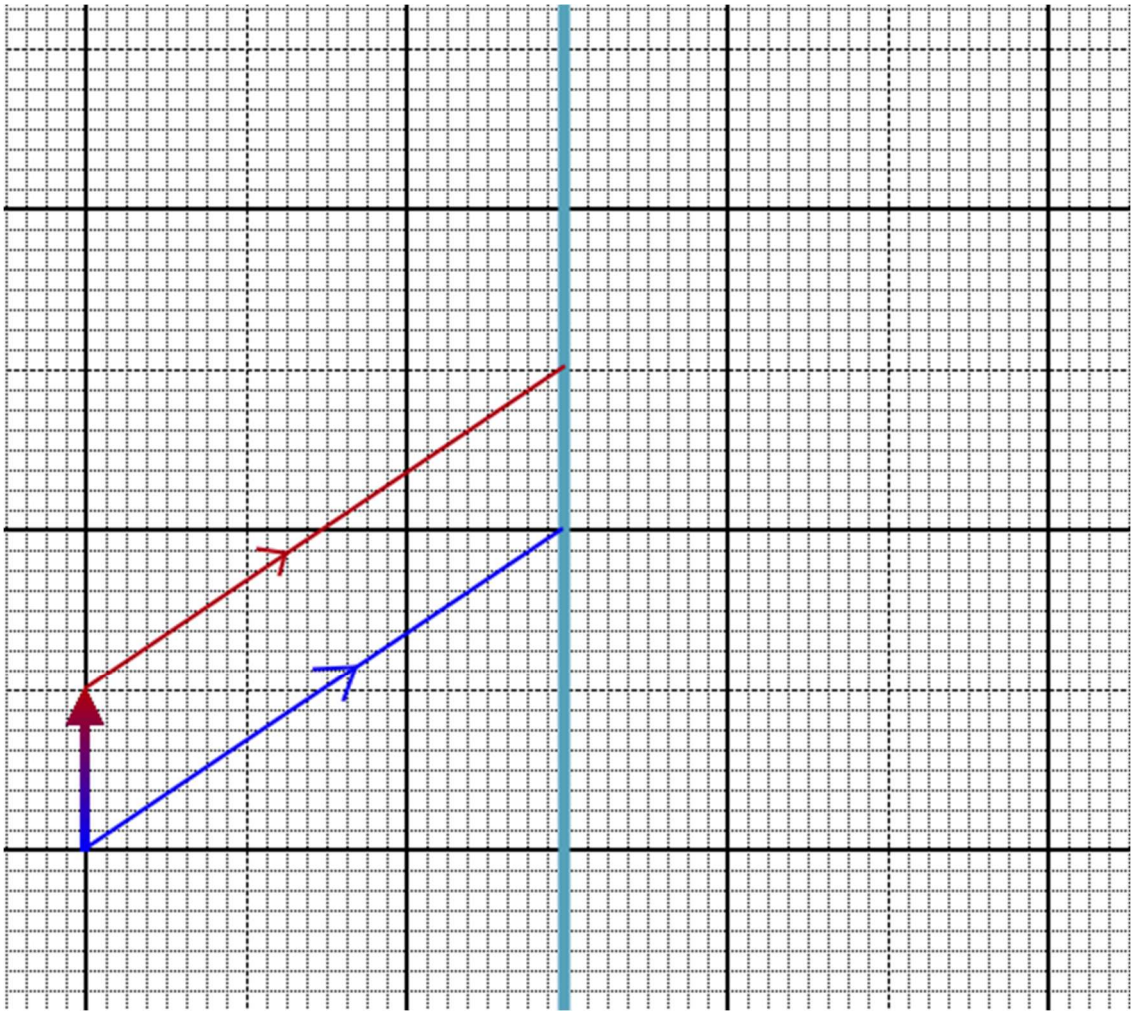
**Ray diagram construction of objects in mirrors**

1. Mirror the object on the other side of the mirror.
2. Draw the lines from the real object to the point on the mirror
3. From the virtual object, draw a dotted line to the same point on the mirror
4. Extend your dotted line to the real world, use a solid line
5. ADD ARROWS TO YOUR LINES!!!!!

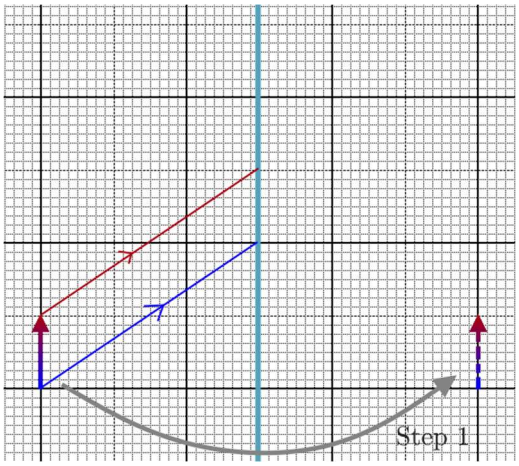
Or if you are drawing the lines to a person's eye:

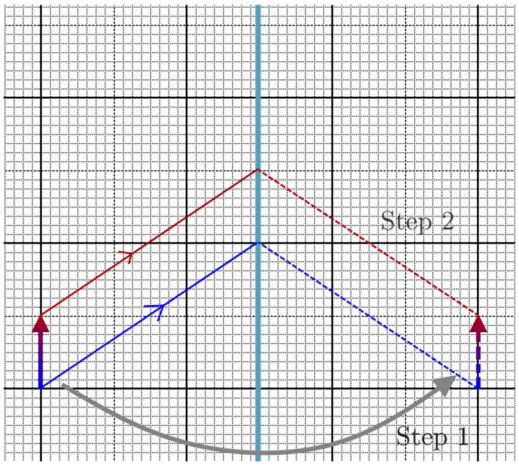
2. Draw lines from the virtual object to the person's eye (use dotted in virtual space and solid lines in real space)
3. Draw solid lines from the object to the points at which the virtual rays cross the mirror
4. Add arrows

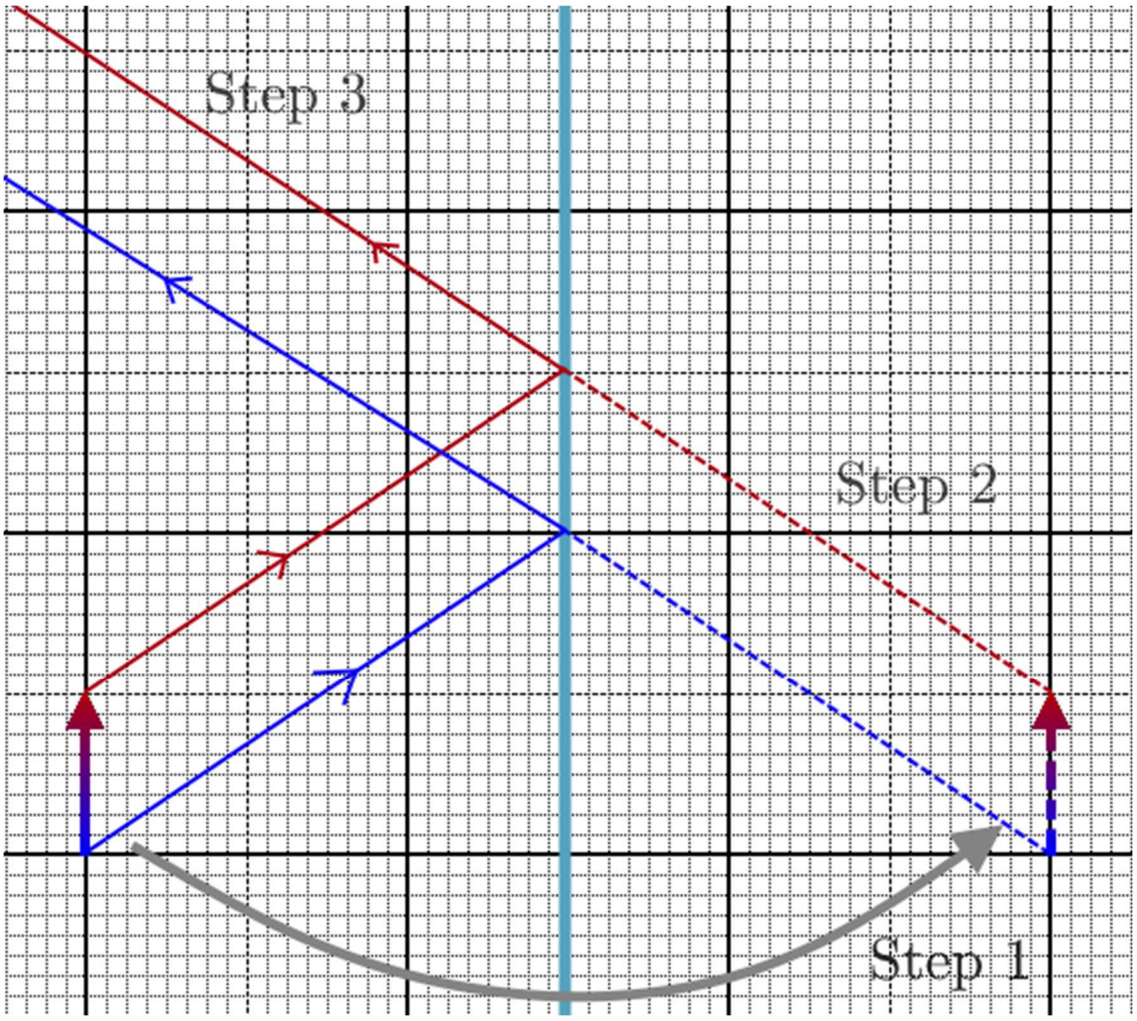
e.g. Complete the ray diagram:



Answer (in steps):

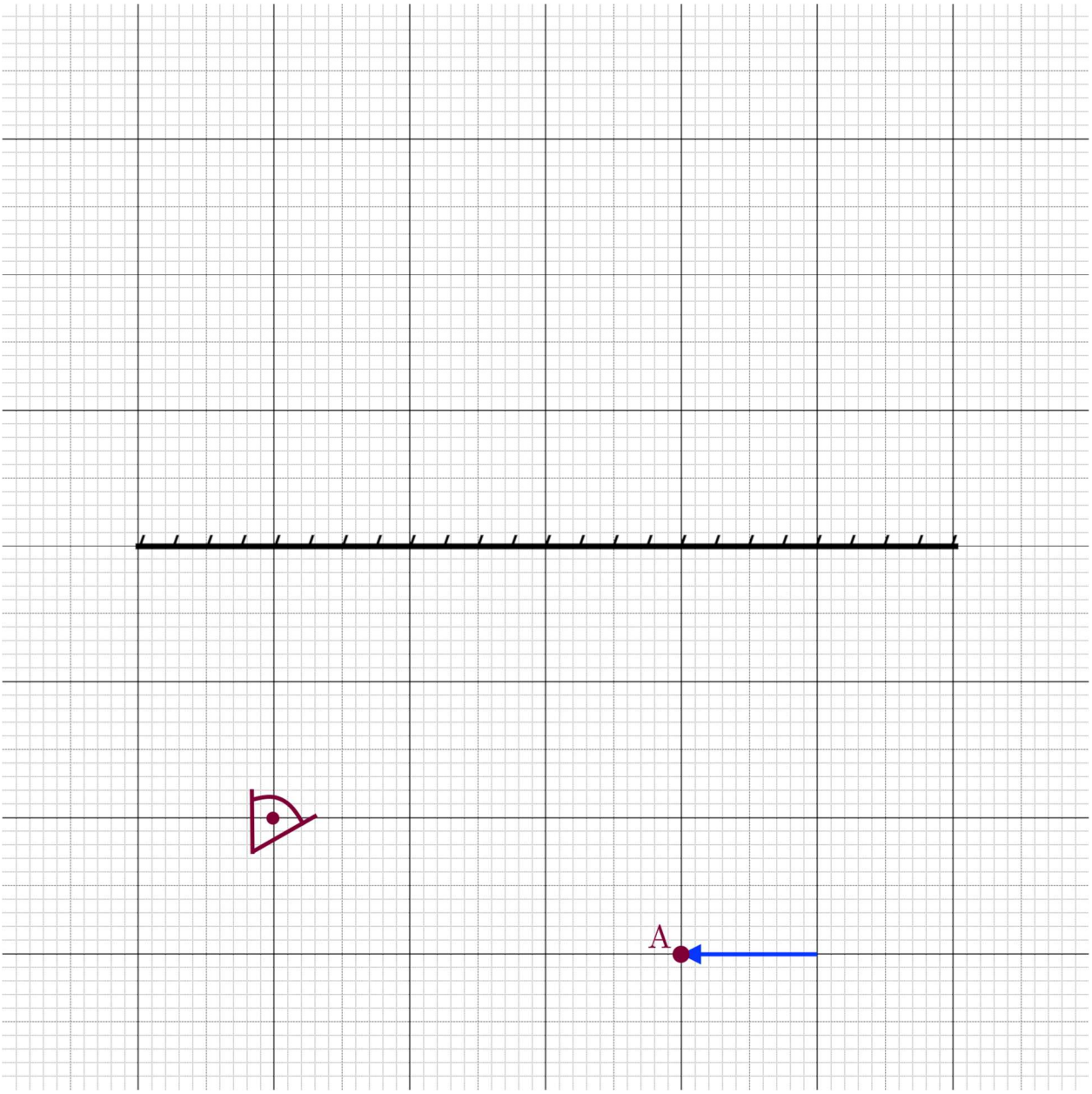



In exams you just need to provide this final drawing*

Questions:



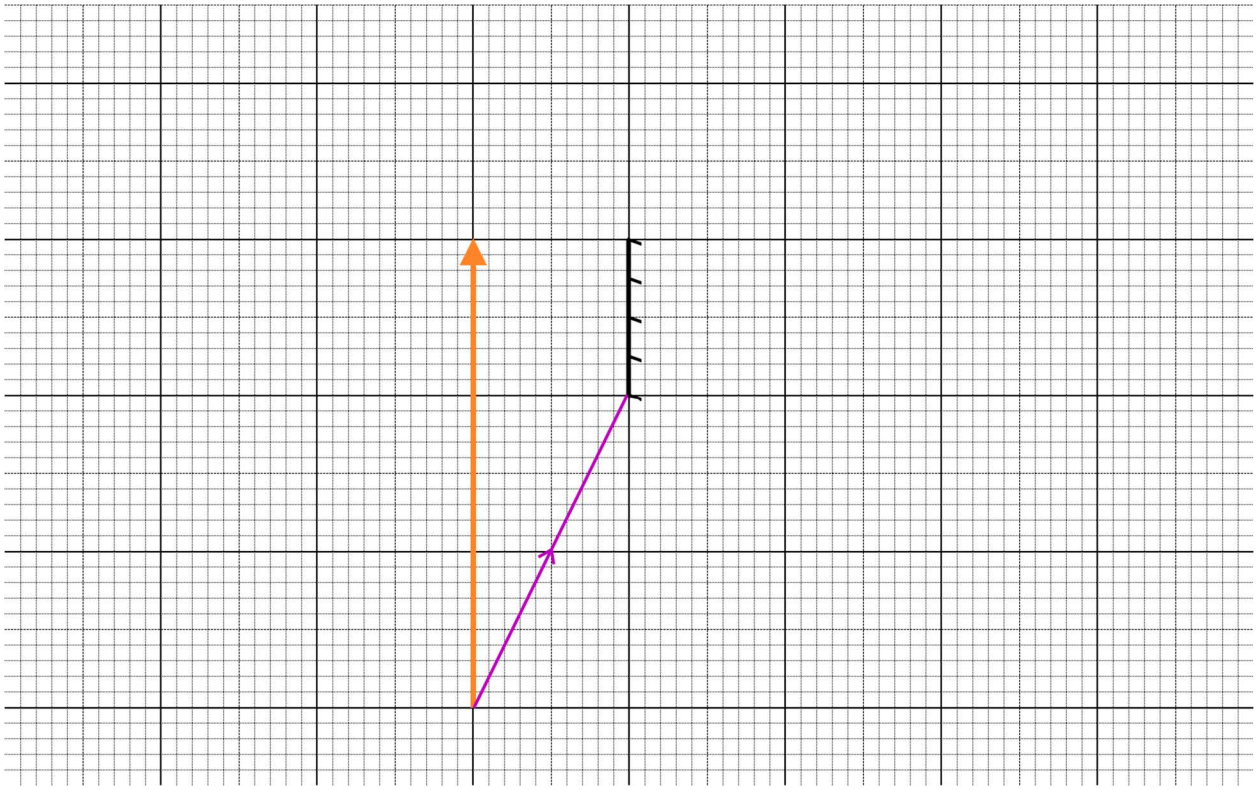

a) Complete the ray diagram to show how the man observes point A of the object through the mirror?

b) What is the size of the object? (1 big grid division is 10cm)

c) Can the image formed by the mirror be captured by the man's camera? EXPLAIN YOUR REASONING

Question 2:

A man stands in front of a mirror, each large grid is 50cm in length.

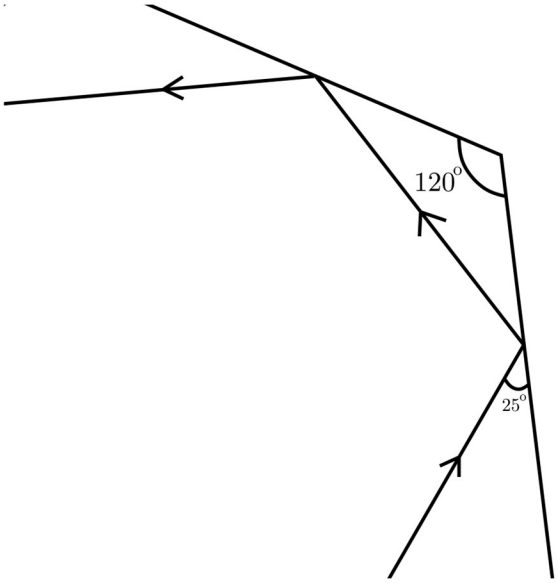


a) Complete the purple light ray and hence deduce whether the man can see his own feet in the mirror

b) By drawing a suitable light ray, determine how much the man should move the mirror downwards so he can see his feet. Assume he is still standing 50cm in front of the mirror as in (a)./

c) What is the horizontal distance between the man and his image?

Question 3




A light ray hits two mirrors (angled at 120 degree to one another as shown above). Find the angle of reflection of the second reflection.

## Refraction

**Some definitions:**

| Optical denseness | Refractive index ($n$) | Speed of light in medium |
|---|---|---|
| High density (optically dense) | High value of $n$ | Slower |
| Low density<br>(less optically dense) | Low value of $n$ | Faster |

Light is the fastest in air/vacuum, and all other mediums have a higher refractive index.
Refractive index of air = 1 (relative to air, which is what you encounter mostly)

**Snell's law of refraction**

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where the angles are angles of incidence and refraction, respectively.
For simplicity, always treat $n_1$ as your current medium and $n_2$ as your new medium.

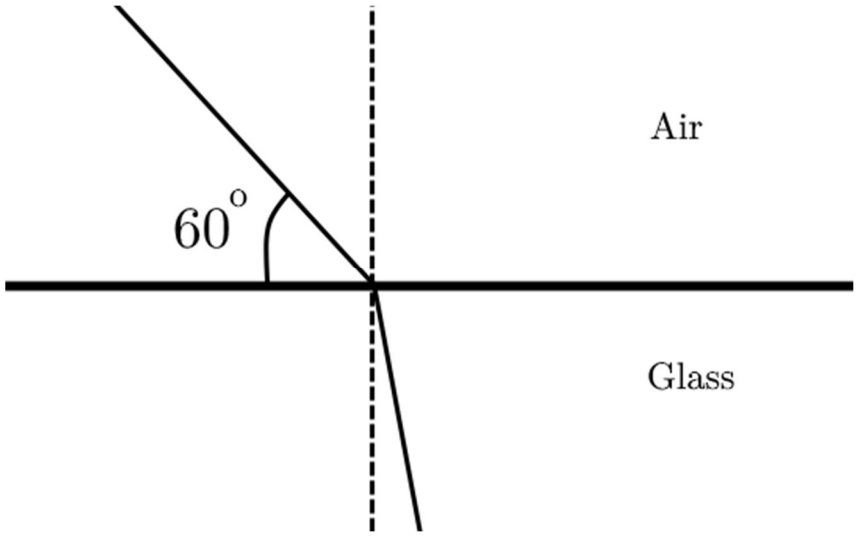
**If $n_2 > n_1$ ; going from less dense → dense; speed of light decreases**

- Then angle of refraction is smaller/larger than angle of incidence
- Light ray bends towards/away from normal.

**If $n_2 < n_1$ ; going from dense → less dense; speed of light increases**

- Then angle of refraction is smaller/larger than angle of incidence
- Light ray bends towards/away from normal.

Example questions:




1. Find the angle of refraction when the light ray travels into the glass. ($n_g = 1.5$)
(Also find what is missing in this ray diagram)

2. A light ray travels from diamond into air. The angle of incidence is 20°, and the angle of refraction is 49°, find the refractive index of diamond.

**Critical angle and total internal reflection**

Total internal reflection occurs when:

- **Travelling from optically dense to less dense medium** (speed of light increases)
- **Angle of incidence is larger than critical angle**

Critical angle:

- The largest angle of incidence at which refraction can occur
- Mathematically, this is defined as the largest $\theta$ where the snell's law can give a solution to the other angle
- Remember, supposing that $n_2 = 1$, $\sin\theta \leq 1$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- Set $\sin\theta_2 = 1$ and $n_2 = 1$,

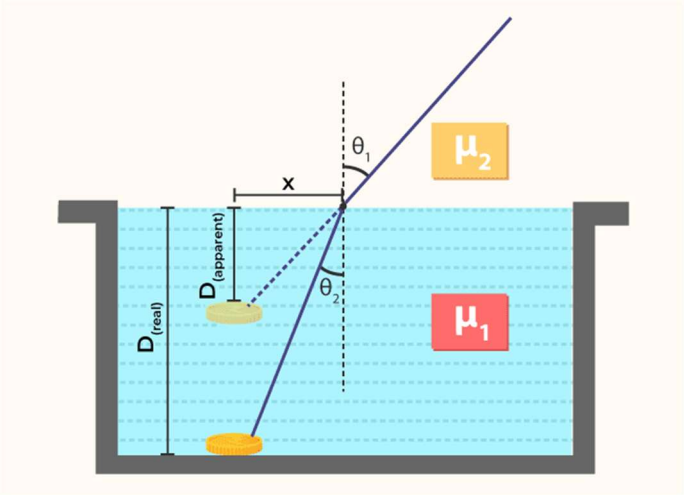
$$n_1 \sin\theta_c = n_2 \sin\theta_2 = 1$$

$$\boldsymbol{\sin\theta_c = \frac{1}{n_1}}$$

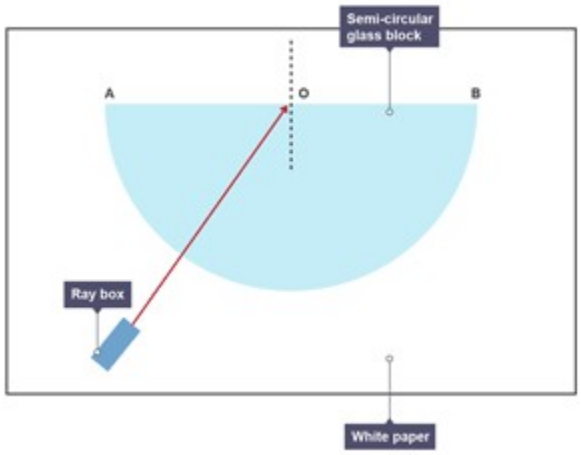
When total internal reflection occurs, the boundary between the medium acts like a mirror, and no ray goes out to the less dense medium.

**Raising effect**

Human eyes always assume light rays go straight!!! Objects can have less apparent depth.



Semi circular glass block to find refractive index




Setup

* You can also specify to add a piece of printable protractor beneath the glass block for easier angle measurement (which is what I will do)

- Setup as shown, with the printable protractor beneath.
- **Make sure the glass block and printable protractor are concentric** *(centers are overlapping)*, **and the horizontal side of the glass block is aligned with the 90 and 270 degrees on the protractor.**
- Using a ray box, shine a light ray **directed towards the center of the glass block,** measure the angle of incidence and the angle of refraction with the protractor.
    - We shine directly at the center to avoid light bending due to refraction at the first air → glass boundary since the angle of incidence is $0^{o}$.
- Change the angle of incidence. Take multiple measurements for both angle of incidence and refraction.
- **Plot a graph of sin(angle of refraction) against sin(angle of incidence).**
- **The slope of the resulting graph (best fit line) is 1/refractive index.**

Question:

A student tries to determine the refractive index of a transparent plastic block with the semi-circular block setup. The light ray reaches the center of the semi-circular plastic block at $\theta_i$, and travels into the air at $\theta_r$.

a) Complete the following table (all angles are in degrees)

| Angle of incidence $\theta_i$ | 0 | 10 | 20 | 30 | 35 |
|---|---|---|---|---|---|
| Angle of refraction $\theta_r$ | 0 | 16 | 32 | 54 | 67 |
| $\sin\theta_i$ | | | | | |
| $\sin\theta_r$ | | | | | |

b) Find the refractive index by plotting a suitable graph and using appropriate calculations.