On Reflexion

A.C. Norman
anorman@bishopheber.cheshire.sch.uk

Warm-up problems

1. Copy out and complete:

   "Light travels in *straight* lines, which are drawn as lines called *rays*."

2. The angle between an incident ray and a plane mirror is 30 degrees.

   (a) What line do physicists measure the angles of incidence and reflexion from?
   The normal, which is at 90° to the surface.

   (b) What is the angle of incidence in this case?
   60°

   (c) What will the angle of reflexion be?
   60°

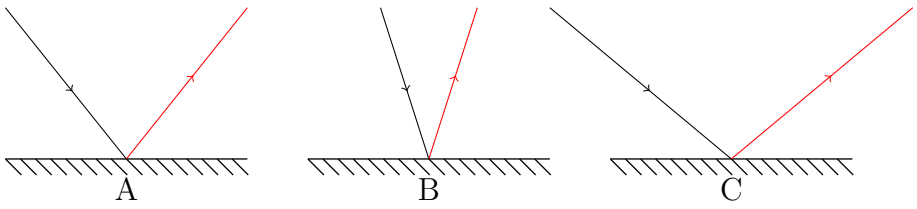
3. Copy out and complete the following:

   The law of reflexion says

   "The angle of *reflexion* equals the angle of *incidence*."

Regular problems

4. Copy out and complete the following diagrams, showing the reflected ray. Don't forget to include the direction (arrow) on the reflected ray.

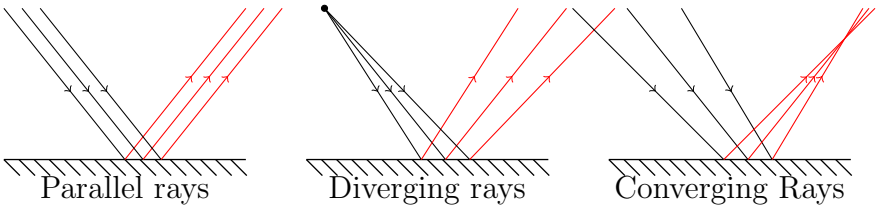


5. A laser beam can be bounced off the Moon (from a retro-reflector left by astronauts). The light travels there and back in 2.6 s. If light travels at 300 000 000 m/s, calculate the distance to the moon.

$$\begin{aligned}\text{speed} &= \frac{\text{distance}}{\text{time}} \\ \text{distance} &= \text{speed} \times \text{time} \\ &= 3 \times 10^8\,\text{m}\,\text{s}^1 \times 1.3\,\text{s} \\ &= 3.9 \times 10^8\,\text{m} = 390\,000\,\text{km}\end{aligned}$$

NB I used 1.3 s as this is the amount of time to get *there* (as 2.6 s is the time for light to get *there and back*).

6. (a) Copy out and complete the following diagrams, showing the reflected rays.



   (b) Label your diagrams to show which diagram has
      i. converging rays after reflexion,
      ii. parallel rays after reflexion,
      iii. diverging rays after reflexion.

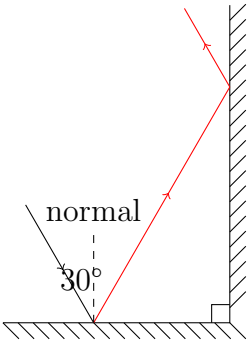
7. Where would you see the sign below, and why is it written that way?

AMBULANCE

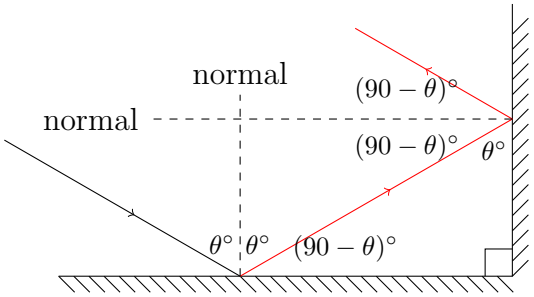
   This would be written on the front of an ambulance to enable drivers in front (viewing the image of the ambulance in their rear-view mirror) to read the word ambulance.

Extension problems

8. (a) Copy the diagram below, and complete the path of the ray



   (b) Prove that, for any incoming angle, light will reflect back on itself.
   Let's see how the reflection happens at an angle θ to the normal:



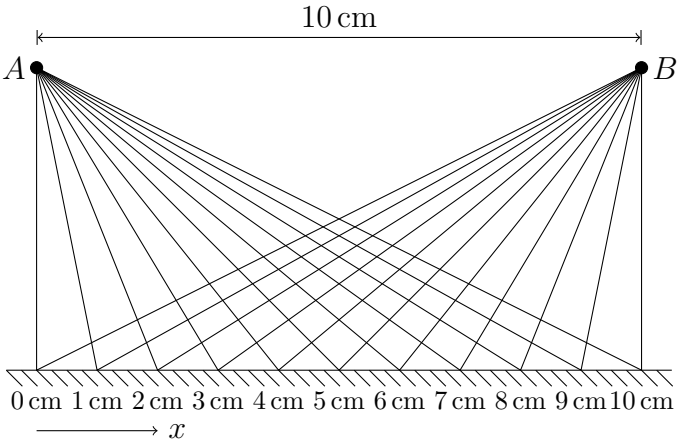
If you add up the angles on the inside of the rays, they come to

$$(90-\theta)^\circ + \theta^\circ + (90-\theta)^\circ + \theta^\circ = 180^\circ.$$

This means a light ray aimed into this setup of mirrors at *any* angle will be reflected back in the opposite direction to the incident direction.

(c) Such a setup is known as a *retroreflector*. Where do you think such a system might be useful, and why do you think that the Apollo astronauts left a retroreflector on the moon?
This is part of the (ongoing) Lunar Laser Ranging Experiment, which fires a laser at the Moon to measure the Earth-Moon distance. Lasers on Earth are aimed at retroreflectors planted on the Moon during the Apollo program (11, 14, and 15), and the time for the reflected light to return is determined.

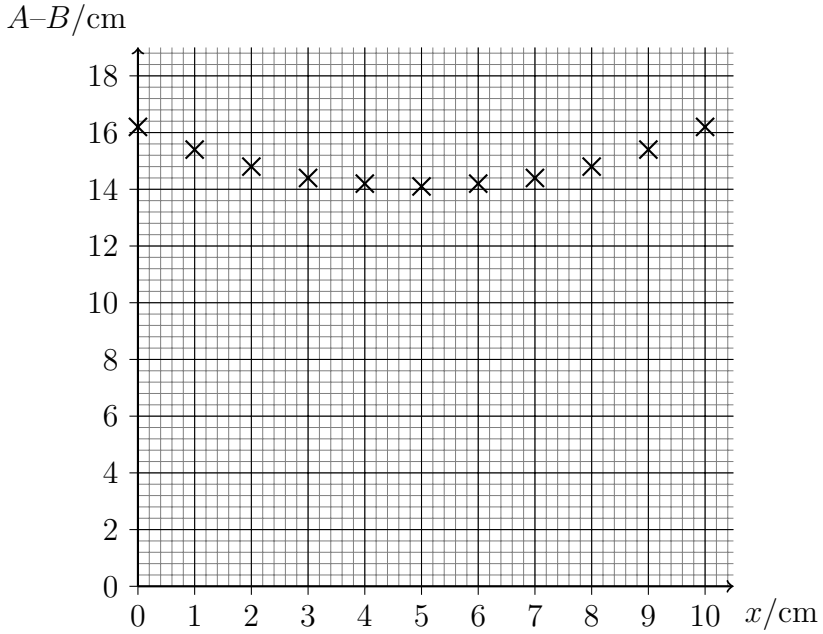
9. The diagram below shows various paths, all of which travel from A to B via a mirror.



(a) Copy the diagram out full size, and measure the path lengths A–B for the various paths from A to B in the diagram below, as the position x along the mirror is varied, and record your results in a table.

x/cm	A-B/cm
0.0	16.2
1.0	15.4
2.0	14.8
3.0	14.4
4.0	14.2
5.0	14.1
6.0	14.2
7.0	14.4
8.0	14.8
9.0	15.4
10.0	16.2

(b) Plot a graph of the length A–B on the y-axis and the position x on the x-axis.



(c) What can you say about the path that light would follow, according to the law of reflexion?
Light follows the path for which the angle of reflexion is equal to the angle of incidence. This is the path that hits the mirror at $x = 5\,\text{cm}$. The graph shows that this is also the shortest path from A–B which hits the mirror, so light has cunningly followed the shortest route (which *takes the least time*)!