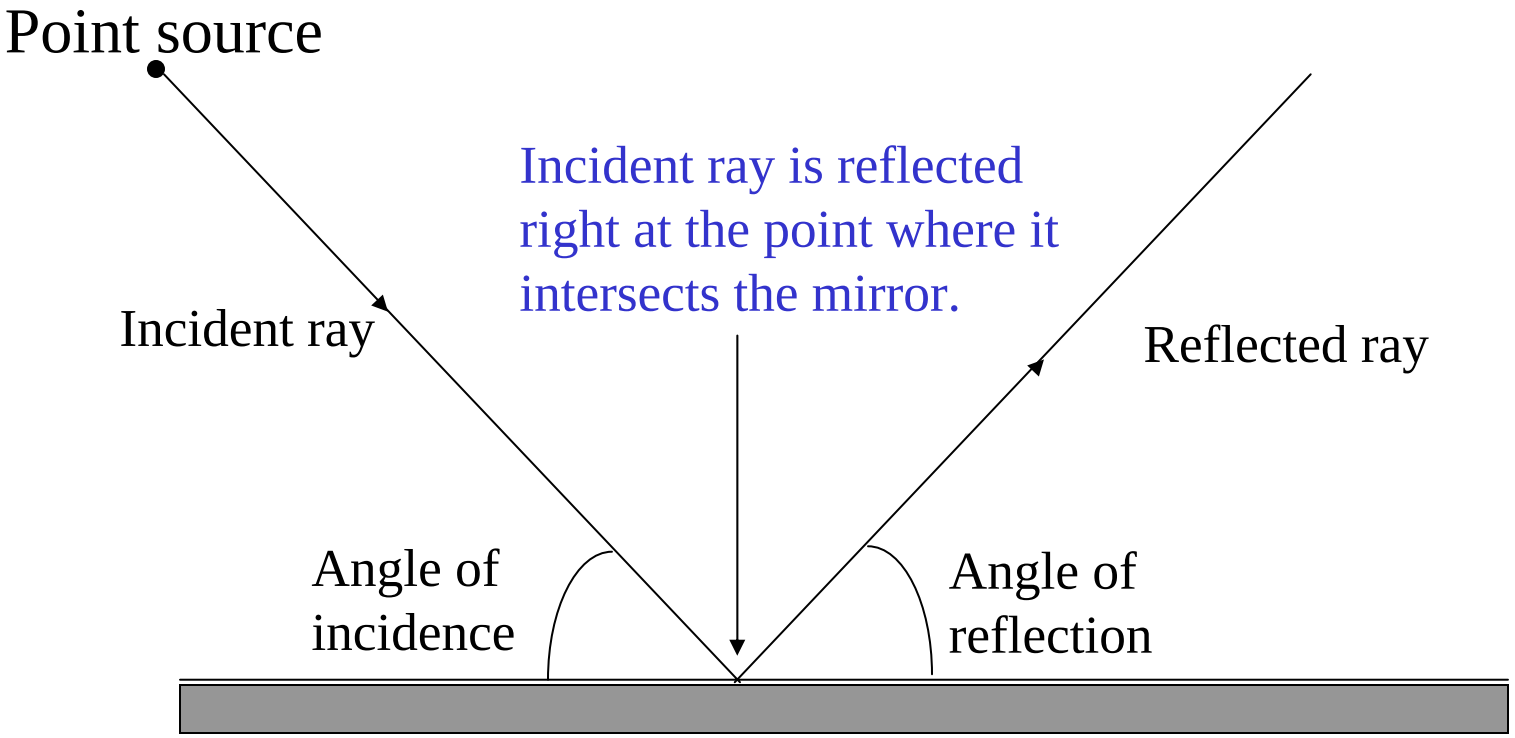
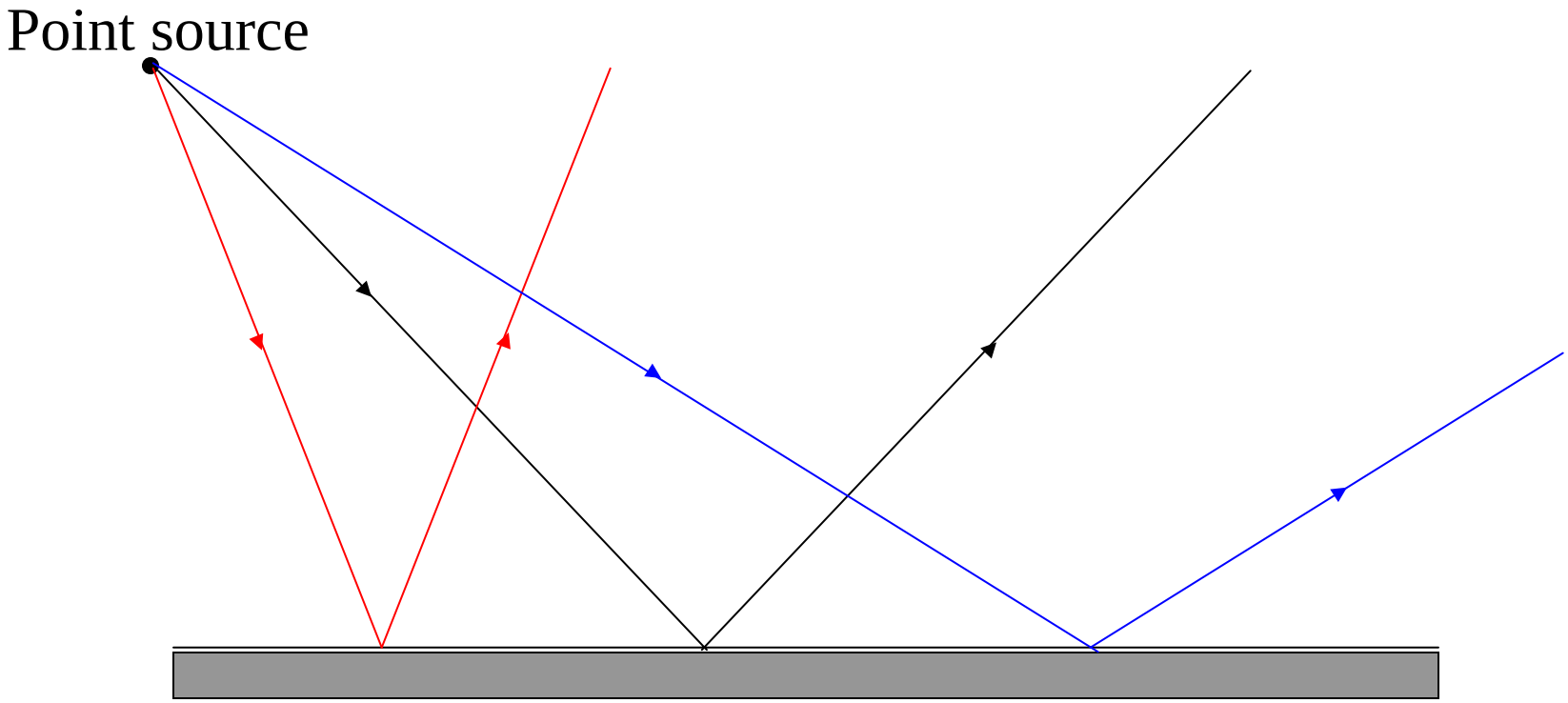
Law of Reflection



Angle of incidence = Angle of reflection

A Point source radiates many light rays



Angle of incidence = Angle of reflection

Note arrow direction!

Reflection by rough surfaces

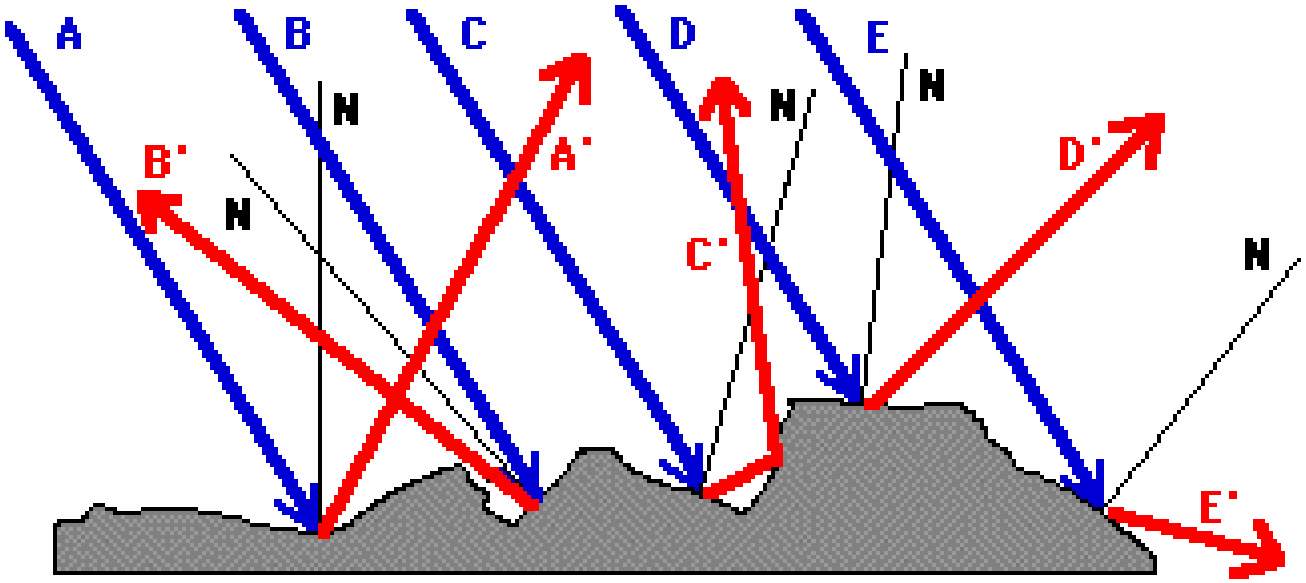
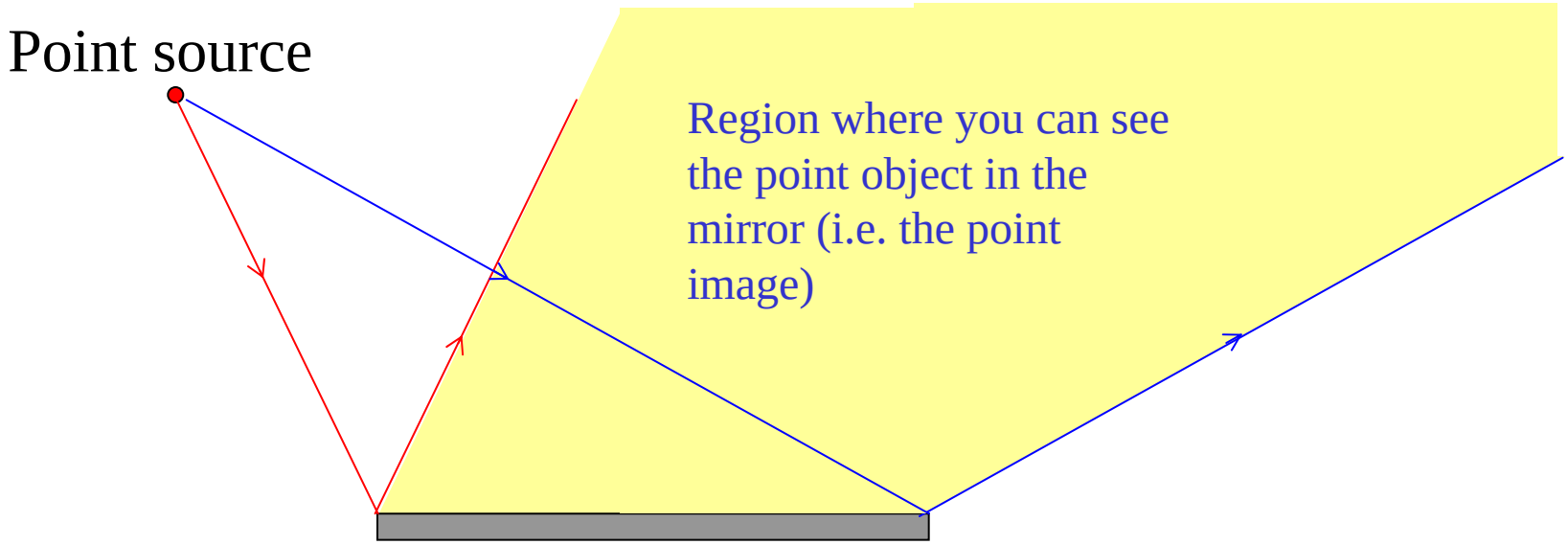


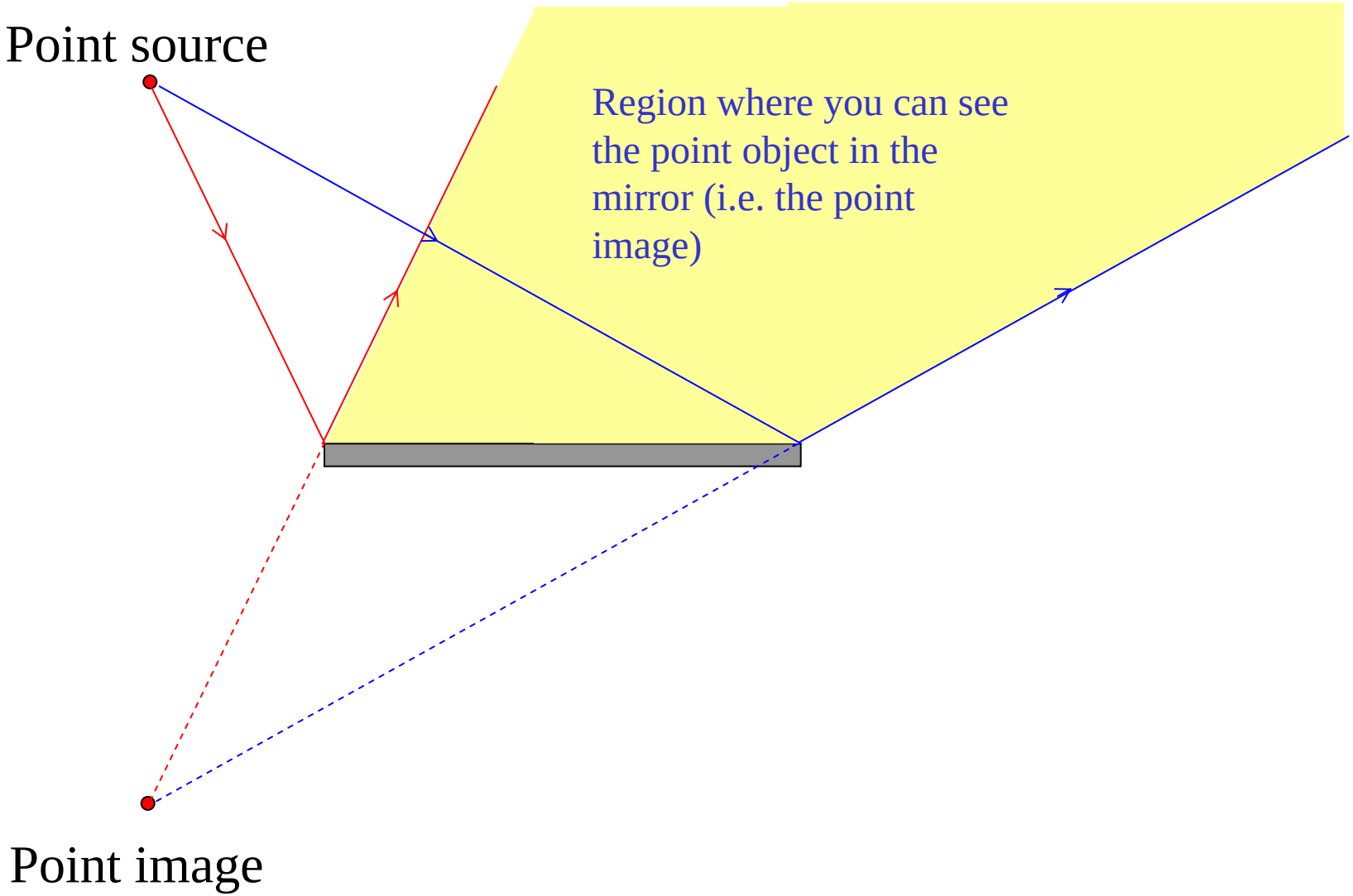
Image in a mirror

Image seems to be located *behind* the mirror!

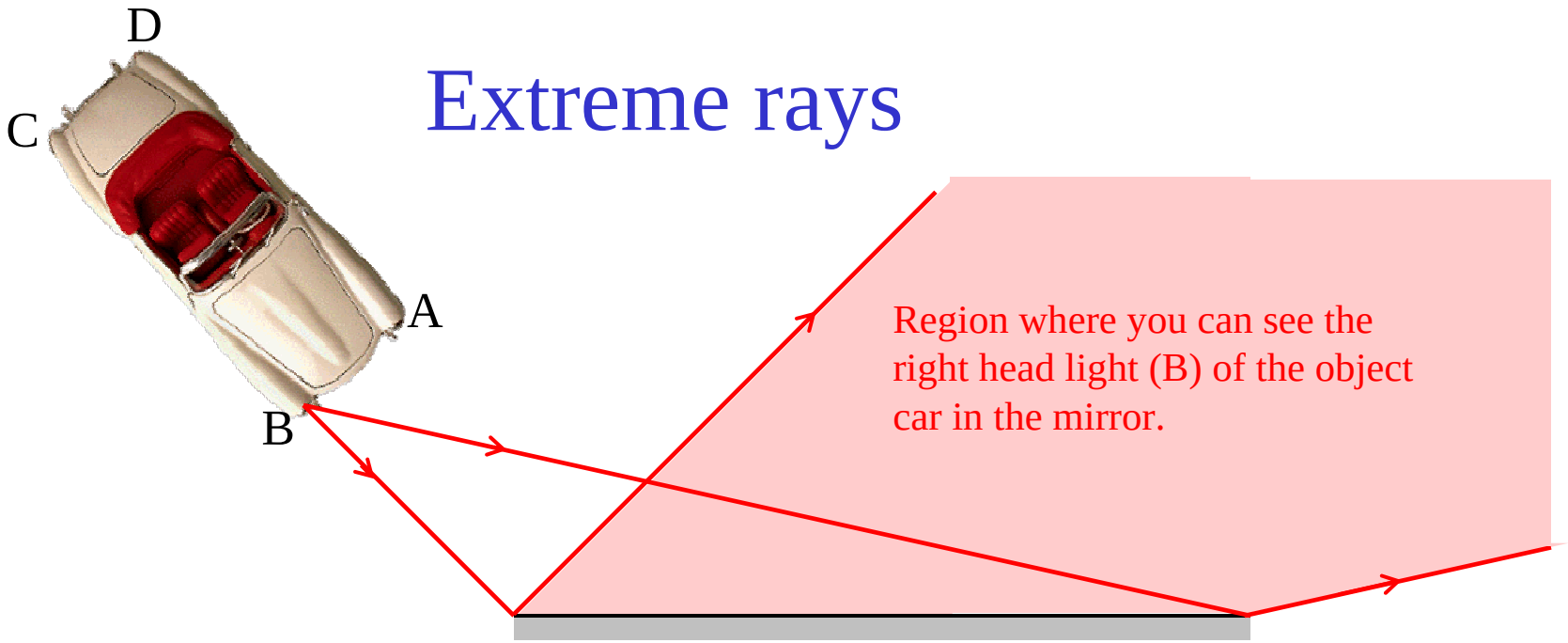
Use of Extreme Rays



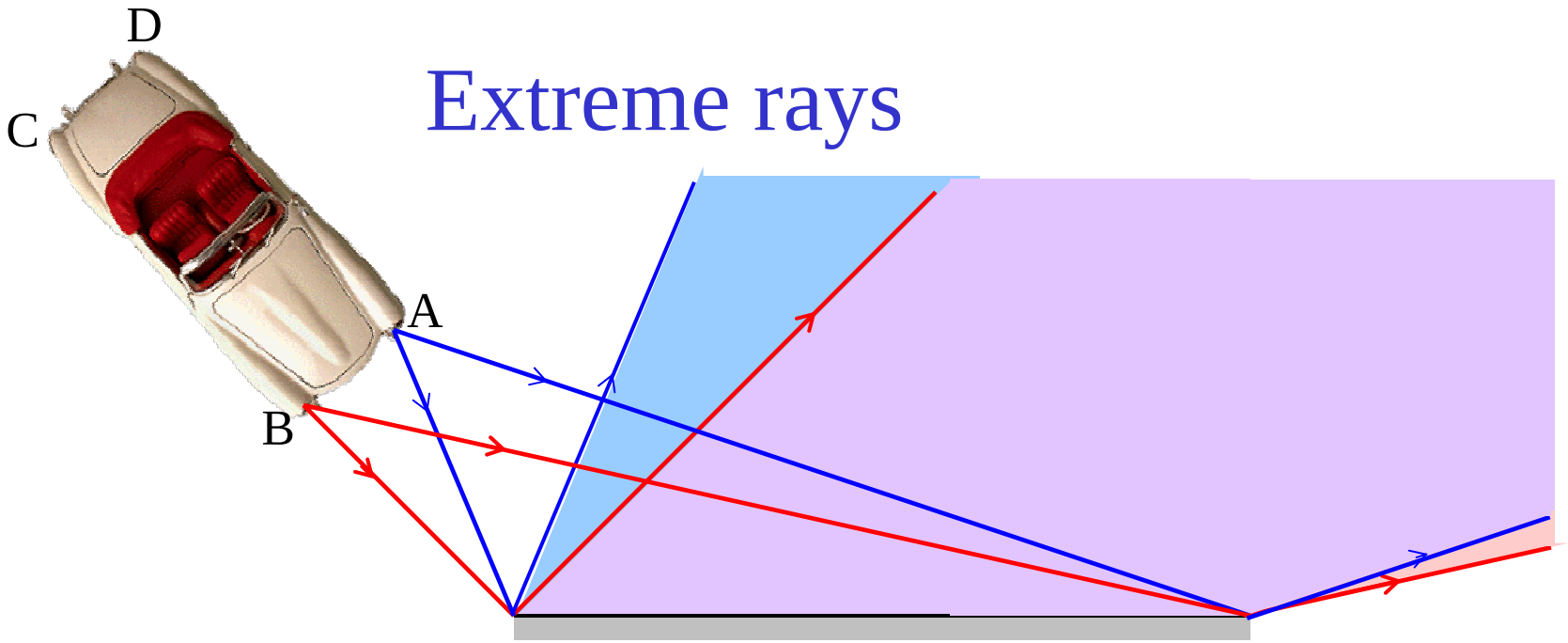
Use of Extreme Rays



Extreme rays



Extreme rays

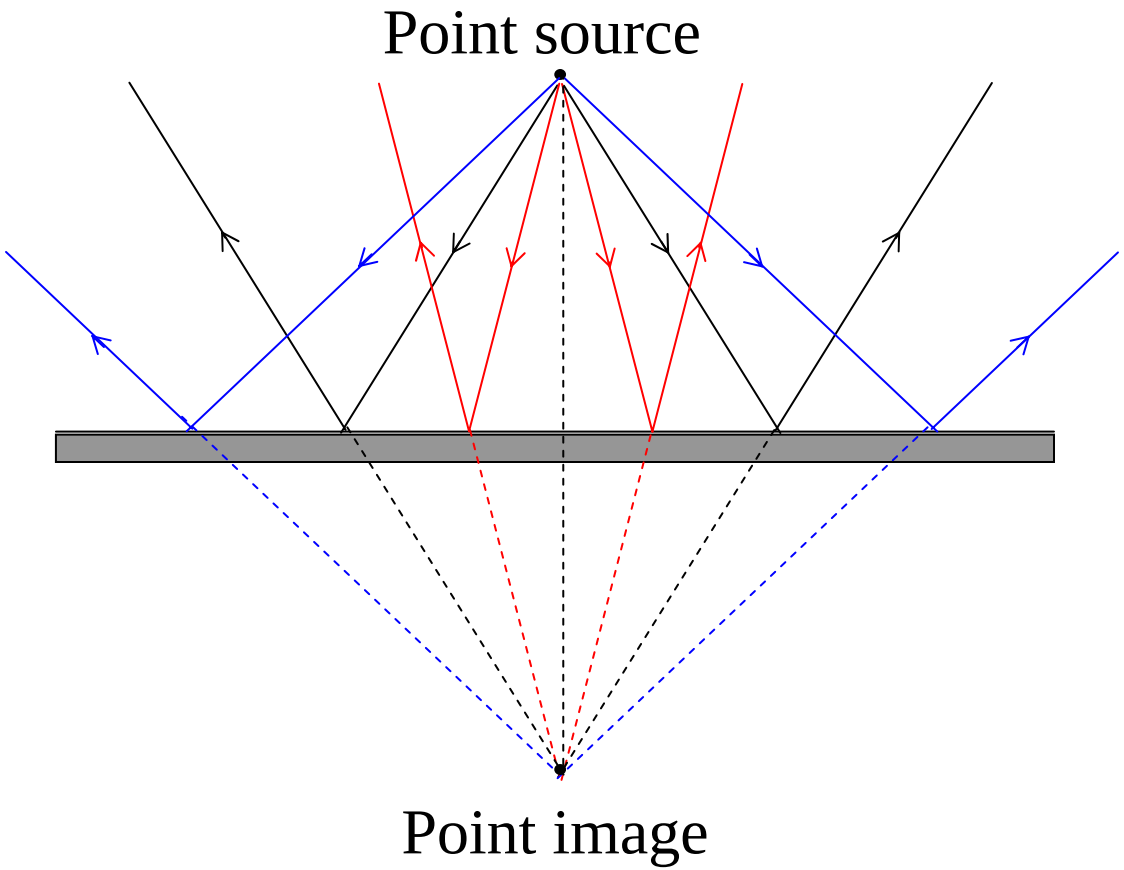


Region where you can see only the right head light (B) of the object car in the mirror.

Region where you can see only the left head light (A) of the object car in the mirror.

Region where you can see both head lights (A and B) of the object car in the mirror.

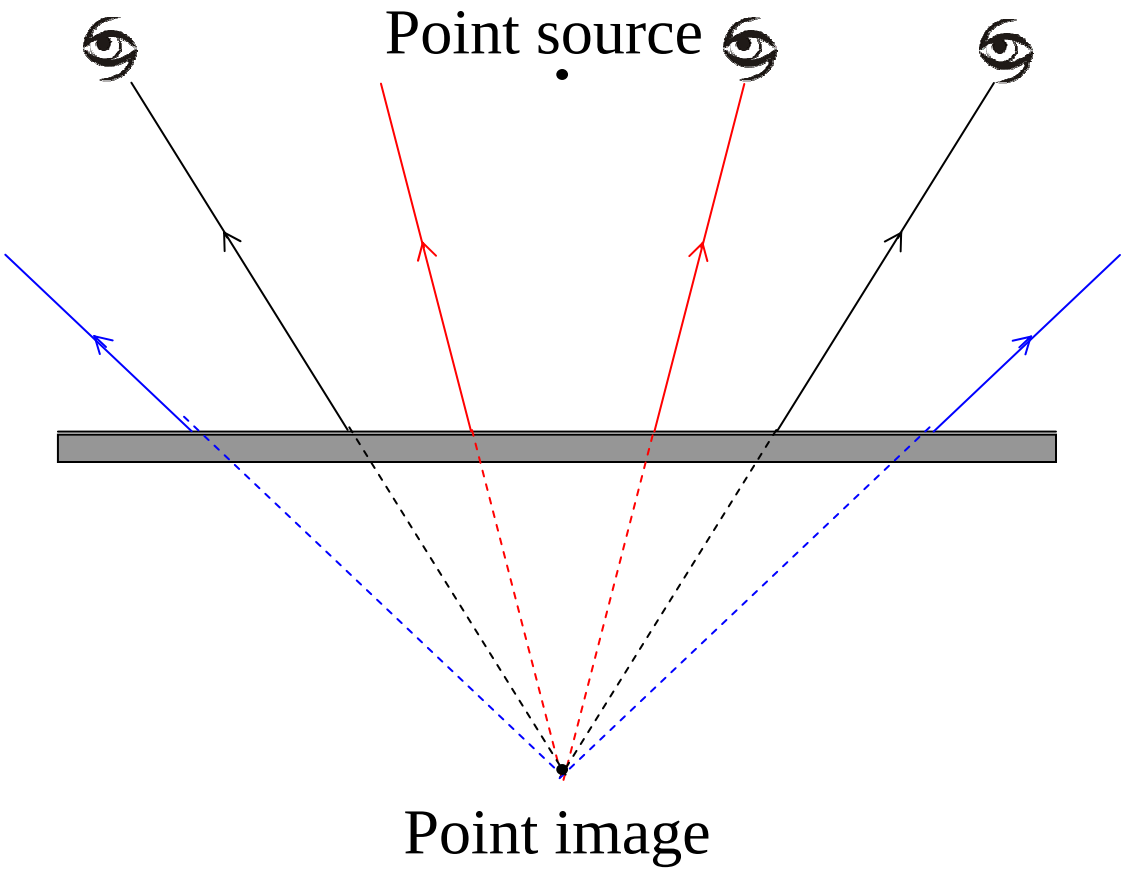
Theoretical Argument: Formation of image



Angle of incidence = Angle of reflection

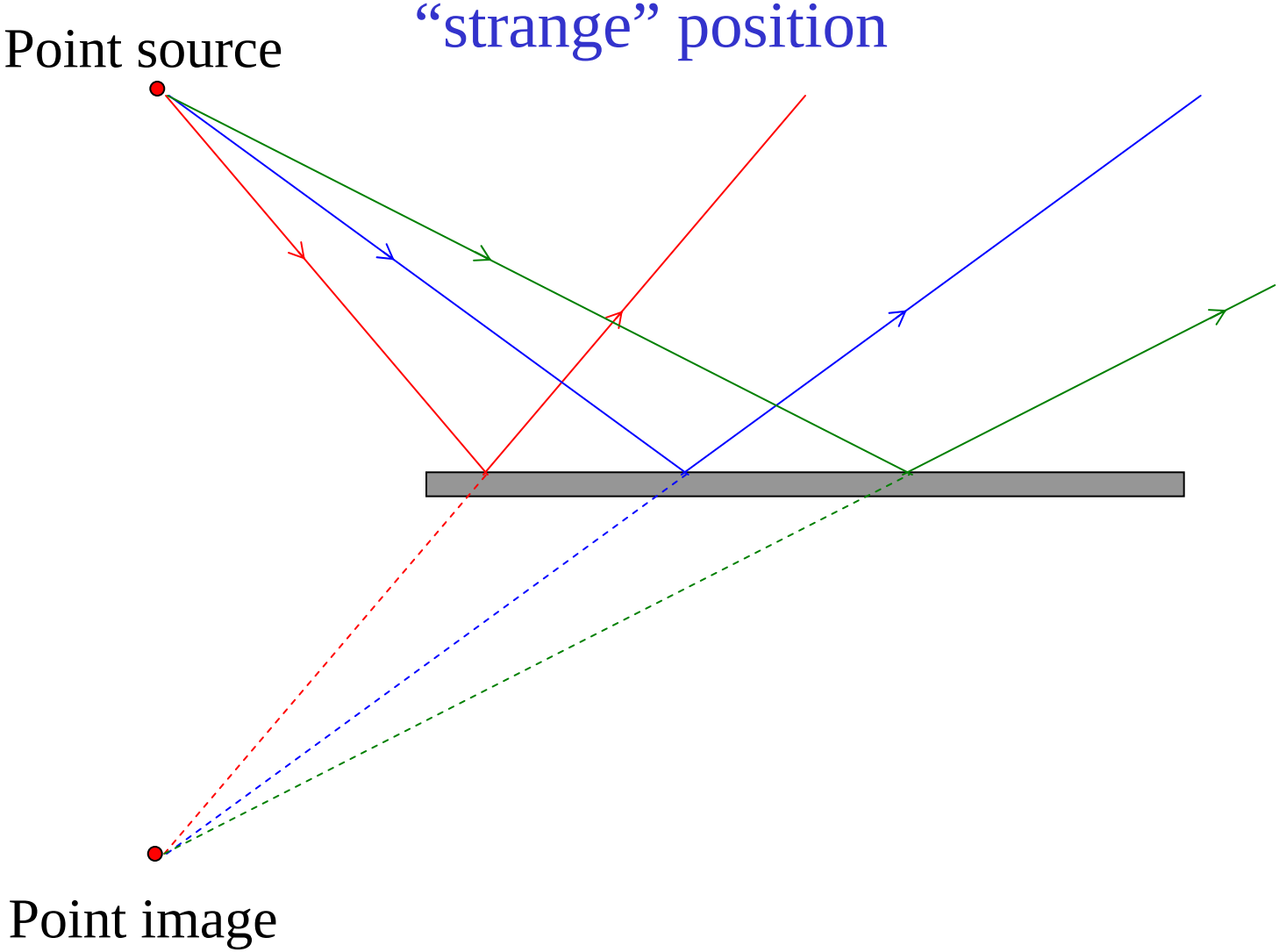
Note arrow directions!

Formation of image

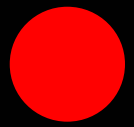


The image is a point *behind* the mirror your eye telling you where the reflected rays come from.

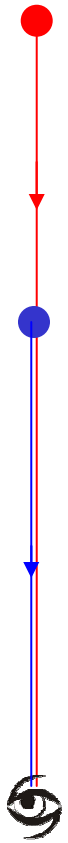
This is true even when the point object is at a “strange” position



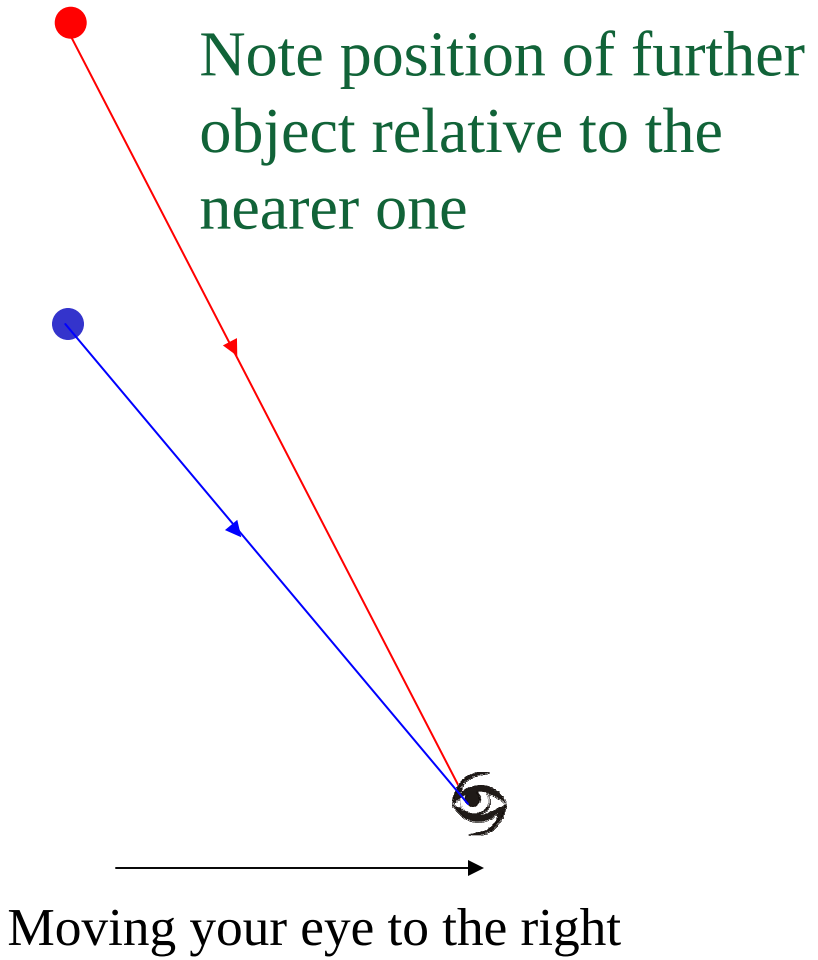
Which Object is closer?



Parallax method

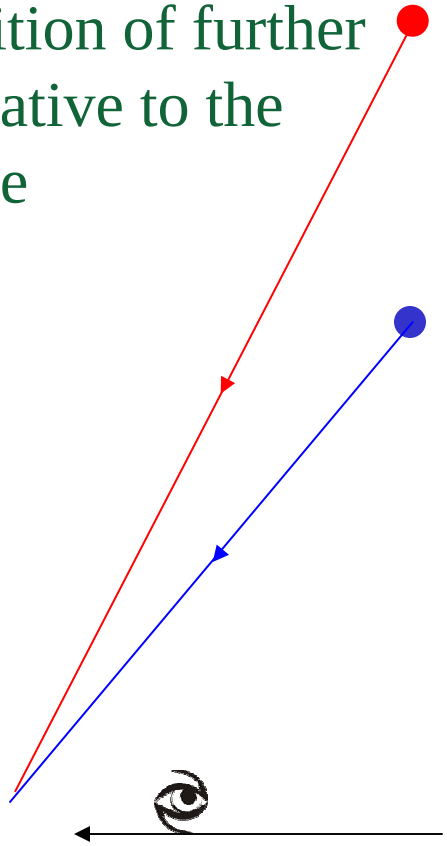


Parallax method



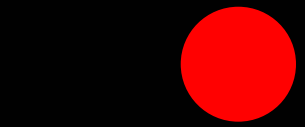
Parallax method

Note position of further object relative to the nearer one



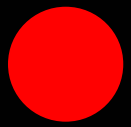
Moving your eye to the left

Which Object is closer?



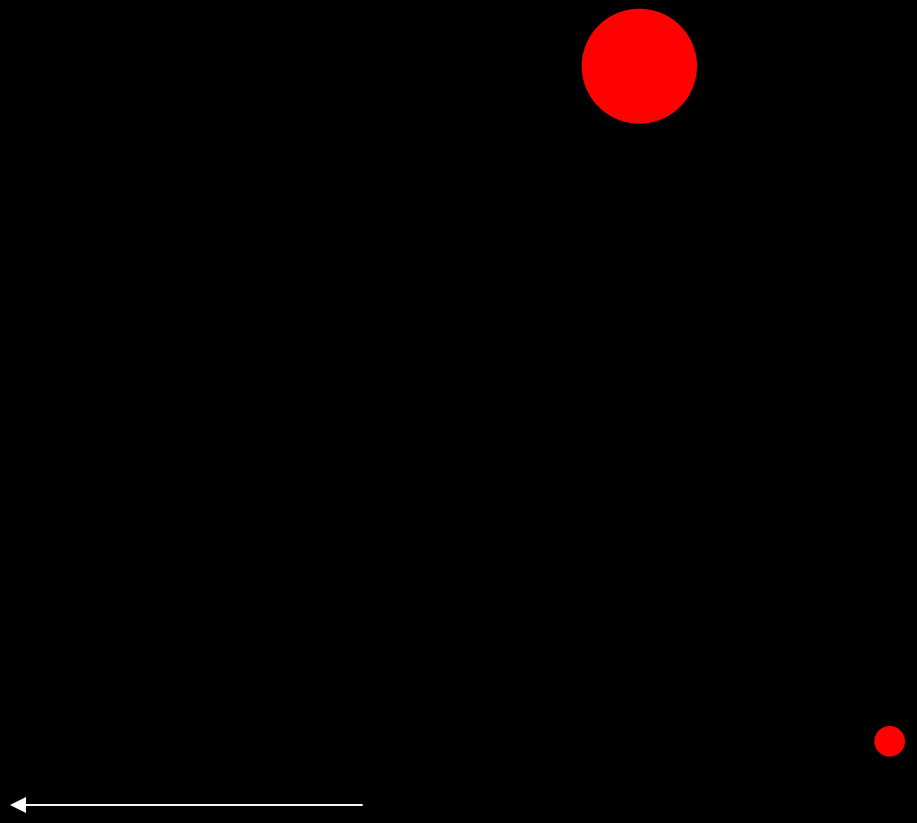
Moving my eye towards right

Which Object is closer?



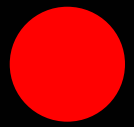
Moving my eye back to original position

Which Object is closer?



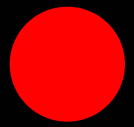
Moving my eye towards left

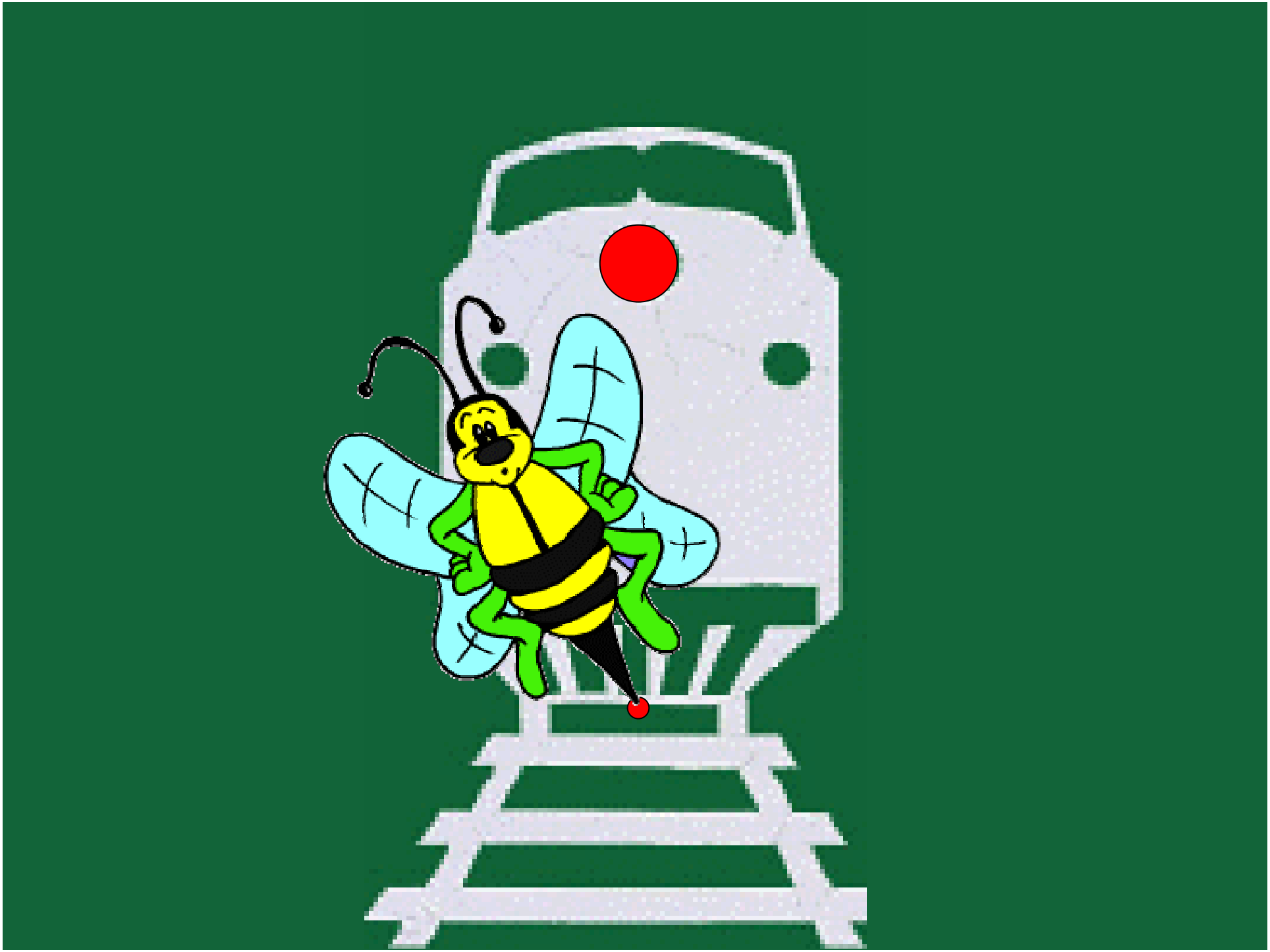
Which Object is closer?

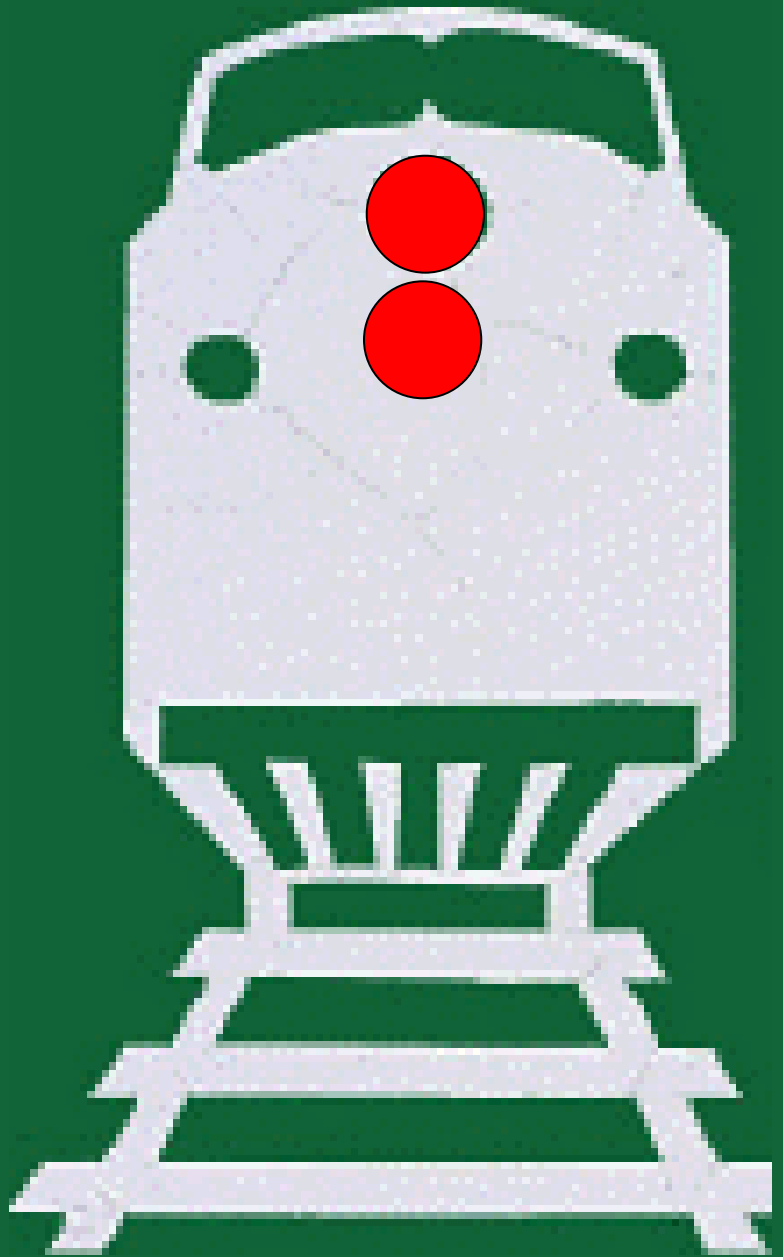


Moving my eye back to original position

Which Object is closer?

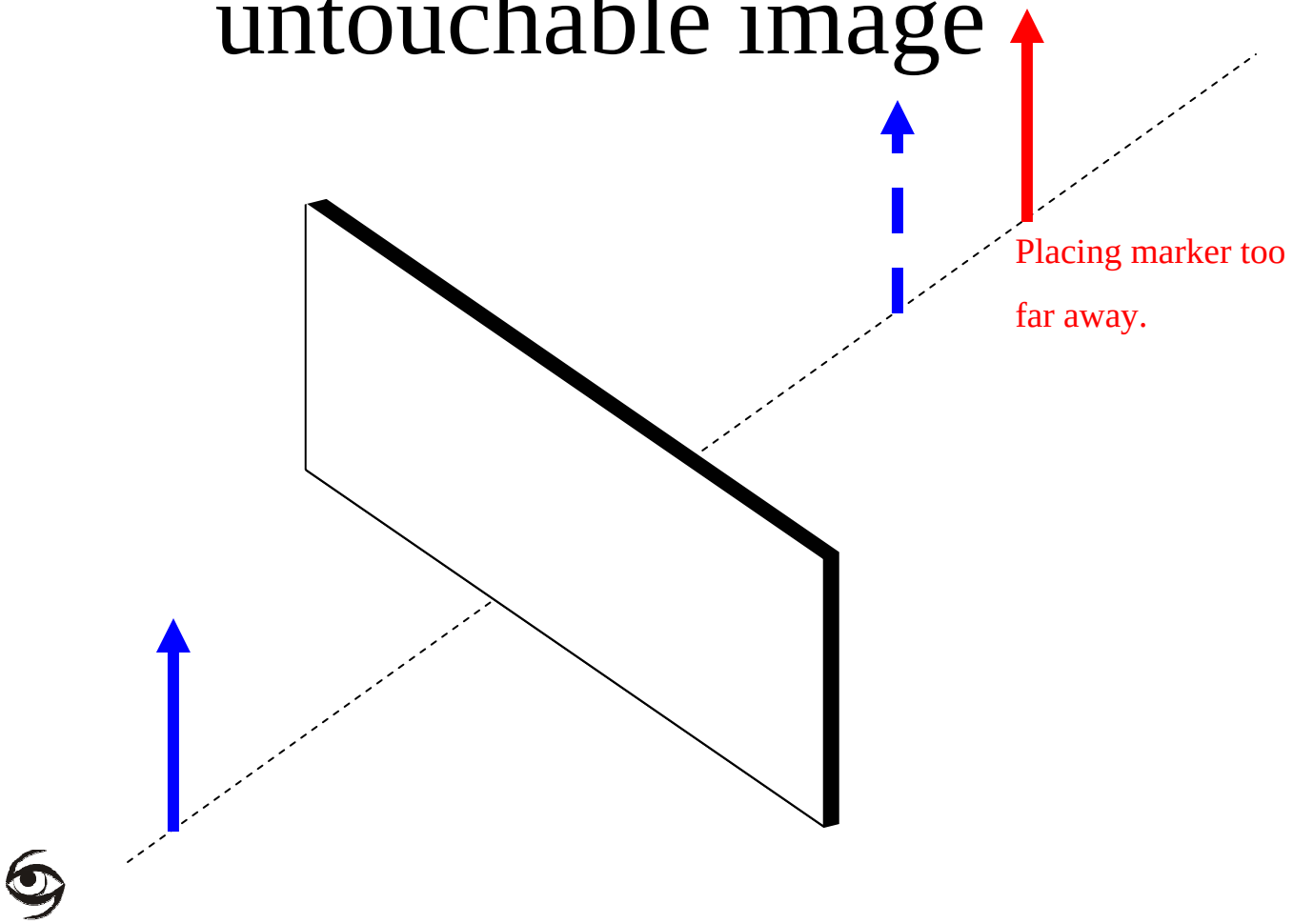




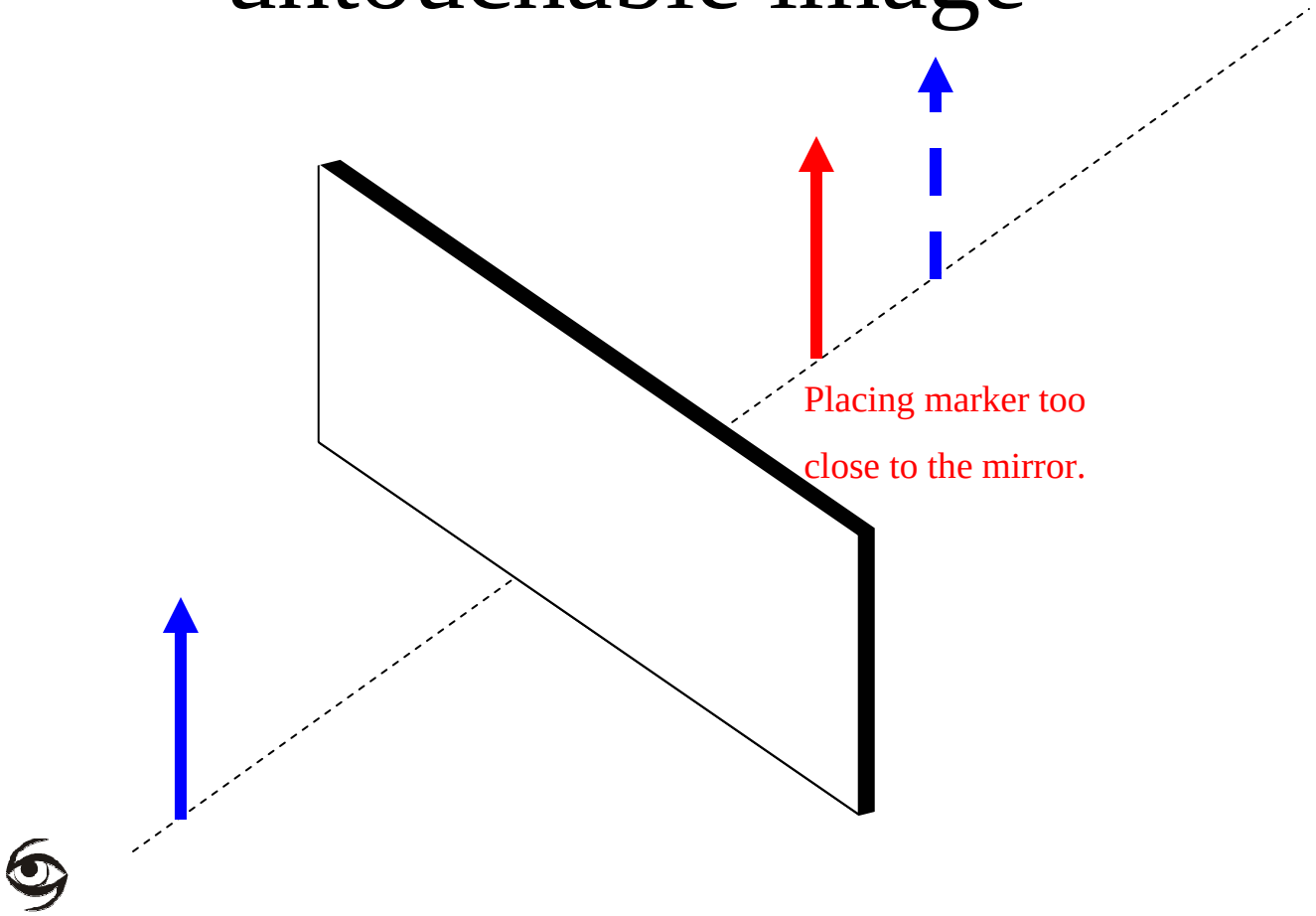


It two objects always stay together, no matter which way and how far you move your eye, then these two objects must be at the same place!

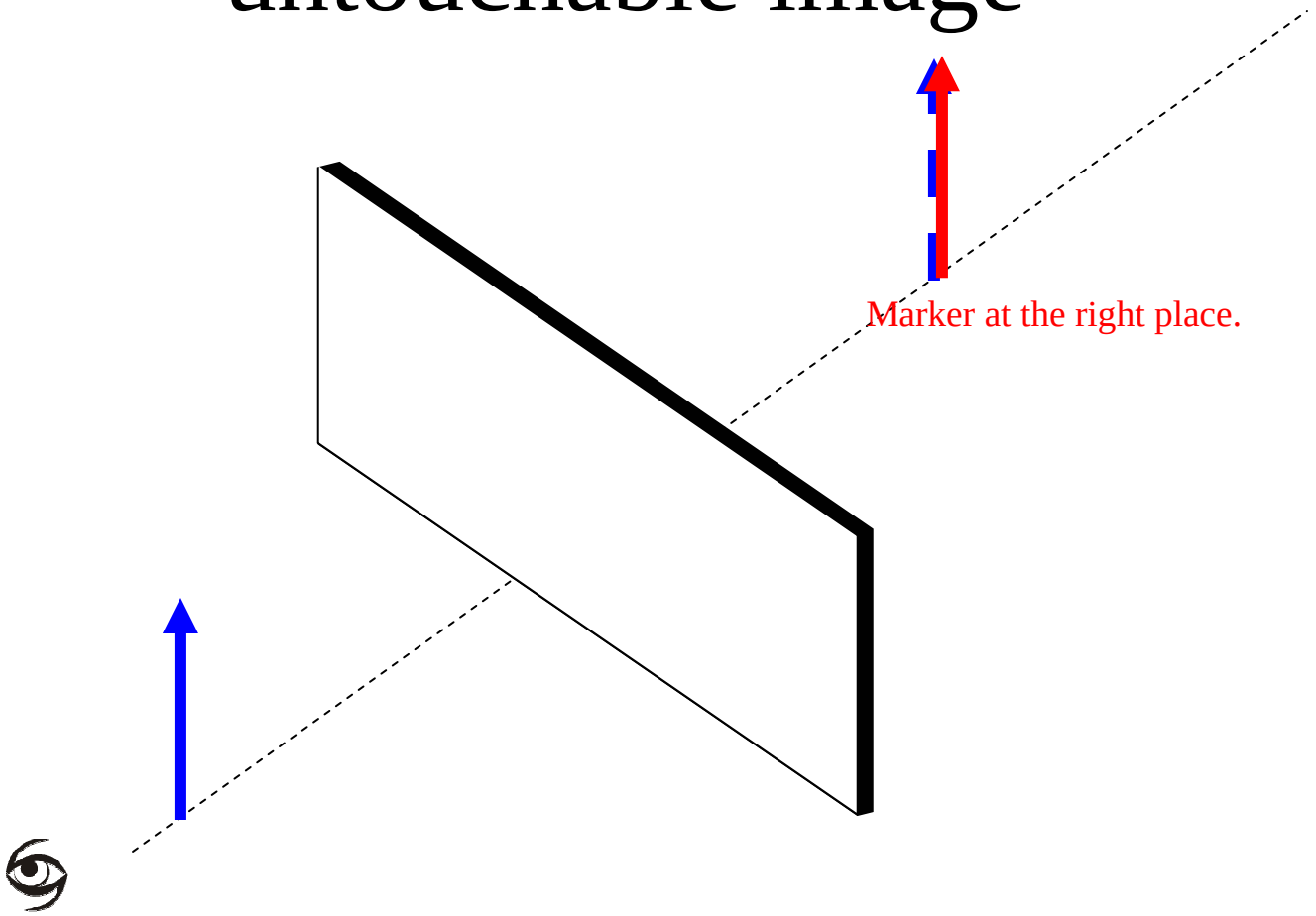
Using parallax to locate the untouchable image



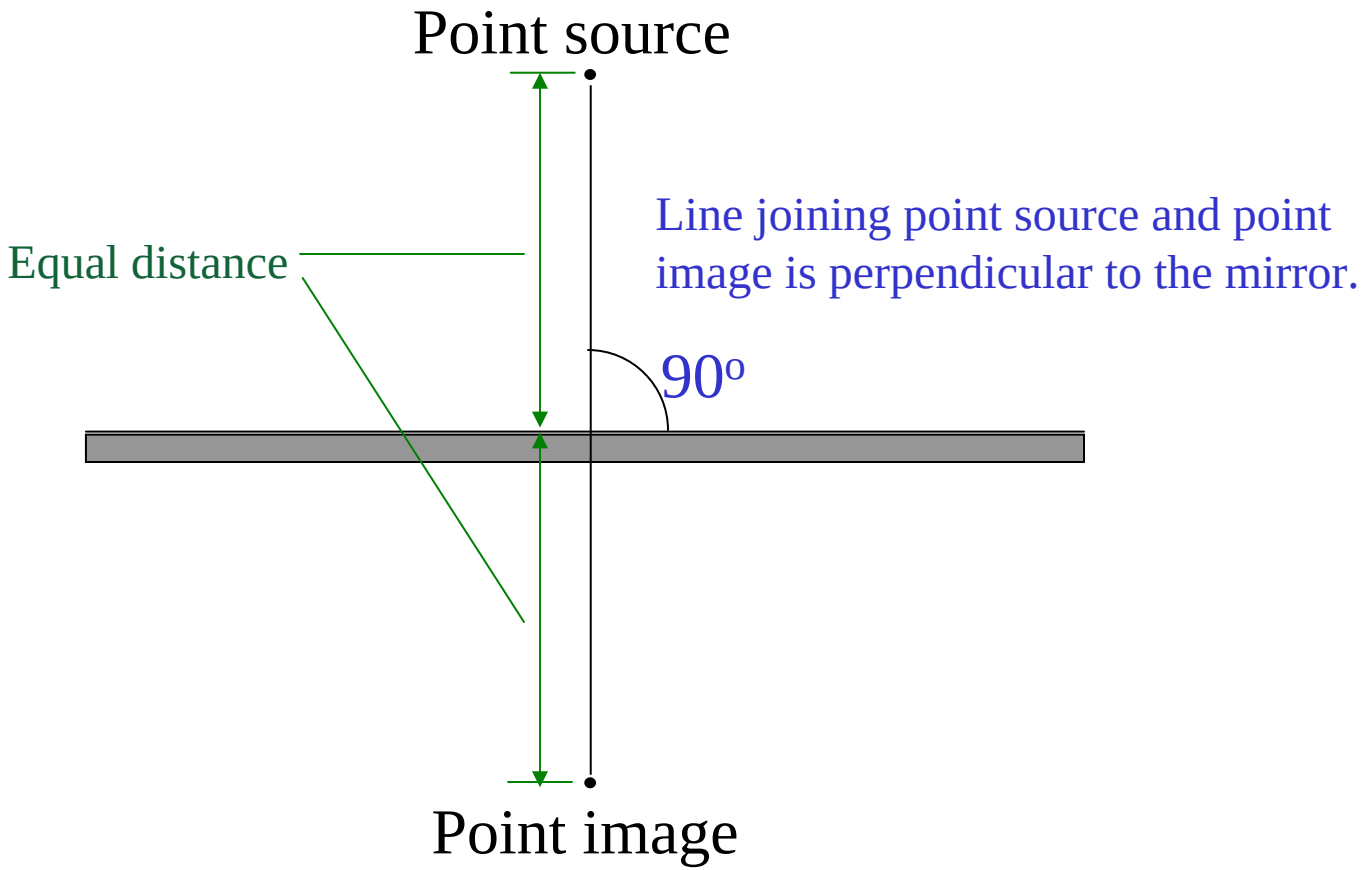
Using parallax to locate the untouchable image



Using parallax to locate the untouchable image

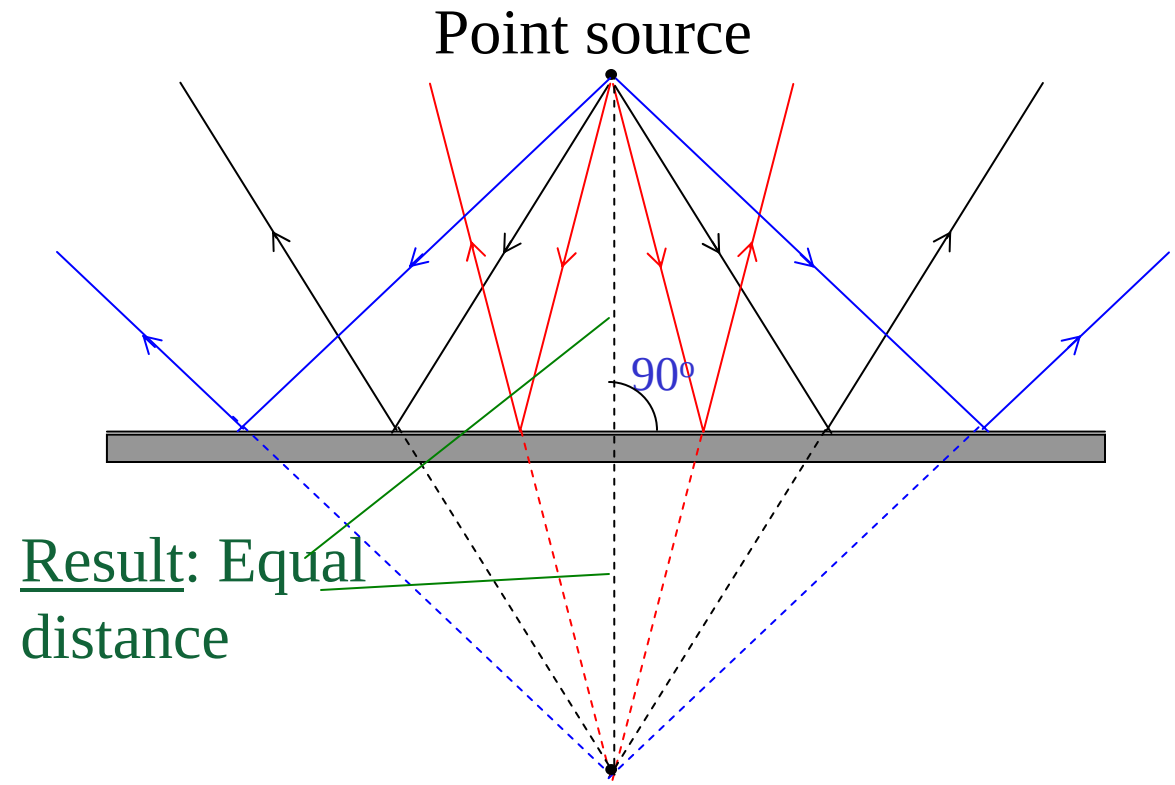


Location of image (another method)



A real object is always in front of the mirror, and its image is always *behind* the mirror.

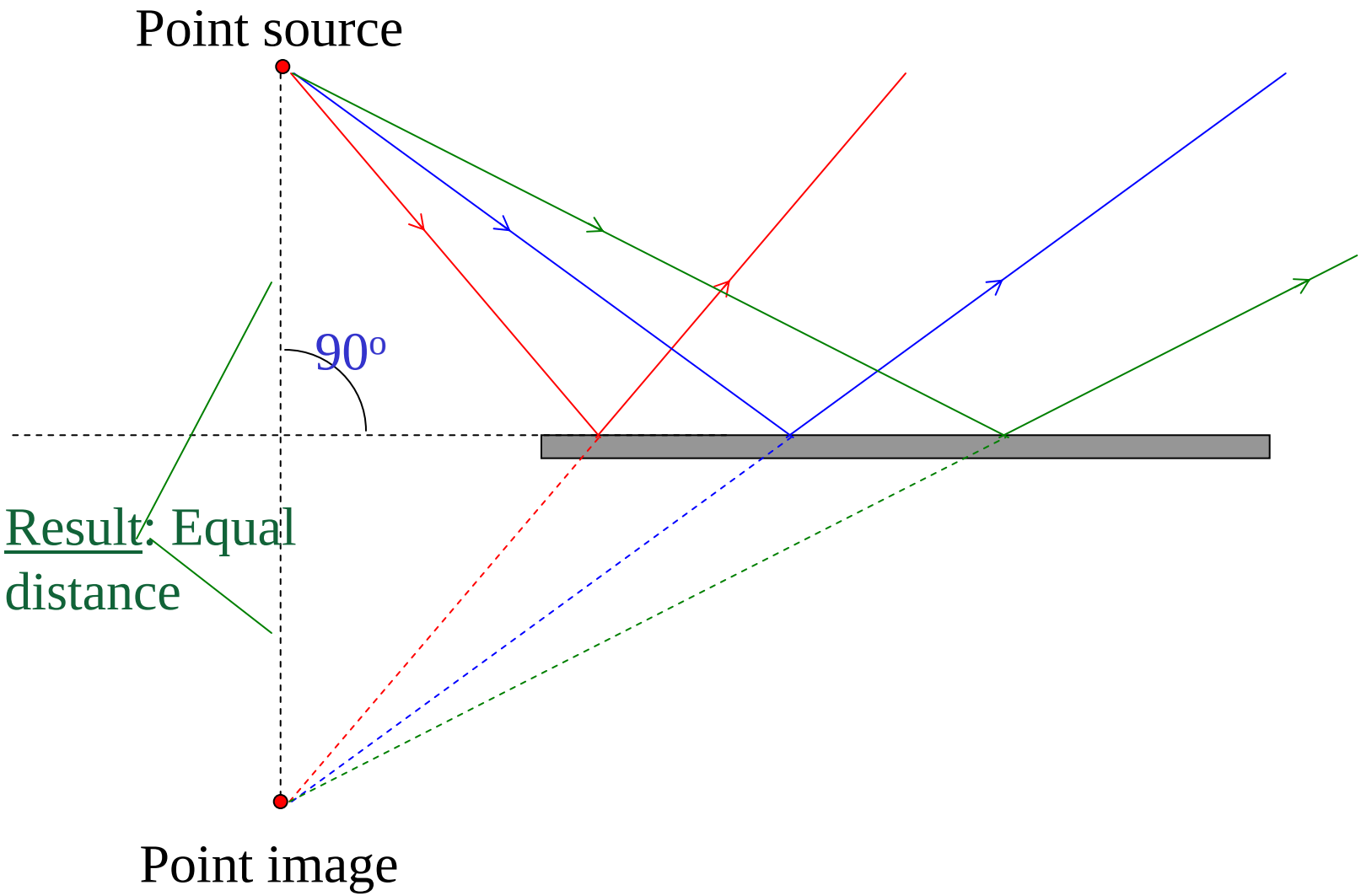
Theoretical Argument: Formation of Image by Ray Tracing

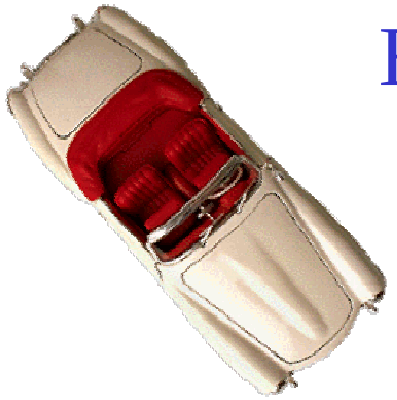


Angle of incidence = Angle of reflection

Note arrow directions!

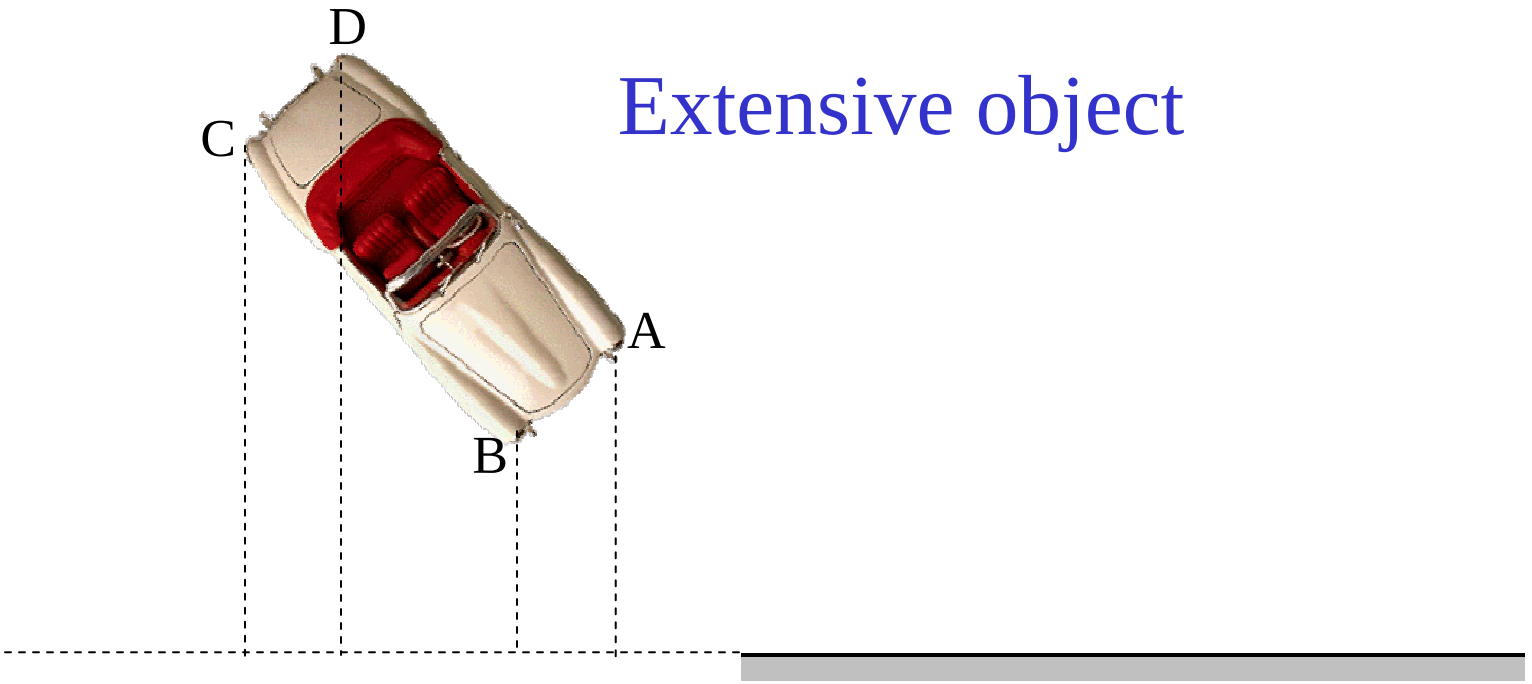
This is true even when the point object is not "directly" in front of the mirror:





Extensive object

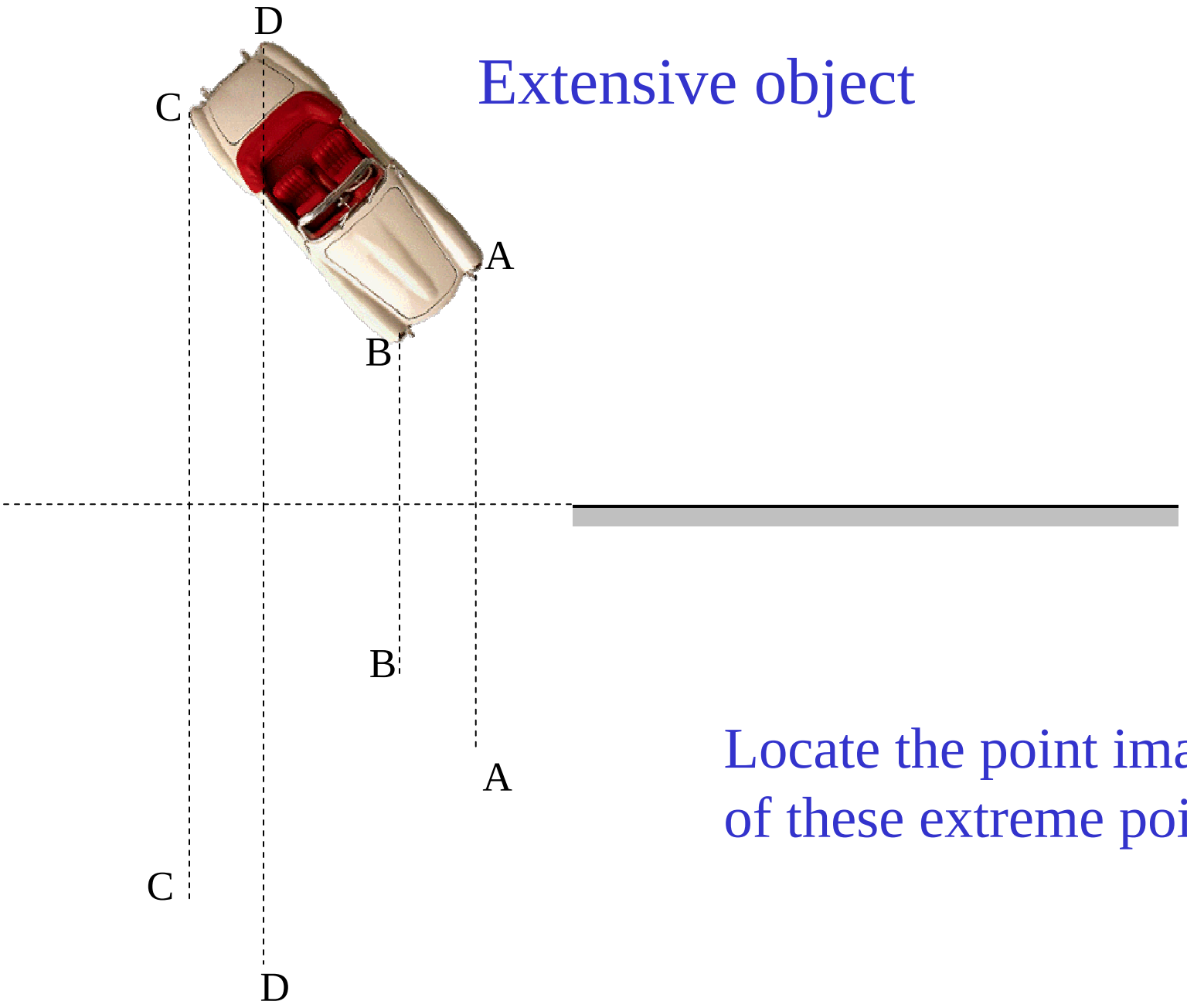
Where is the image and
how does it look like?



Extensive object

Choose some “extreme points” outlining the object.

Extensive object



Locate the point image
of these extreme points.

Extensive object

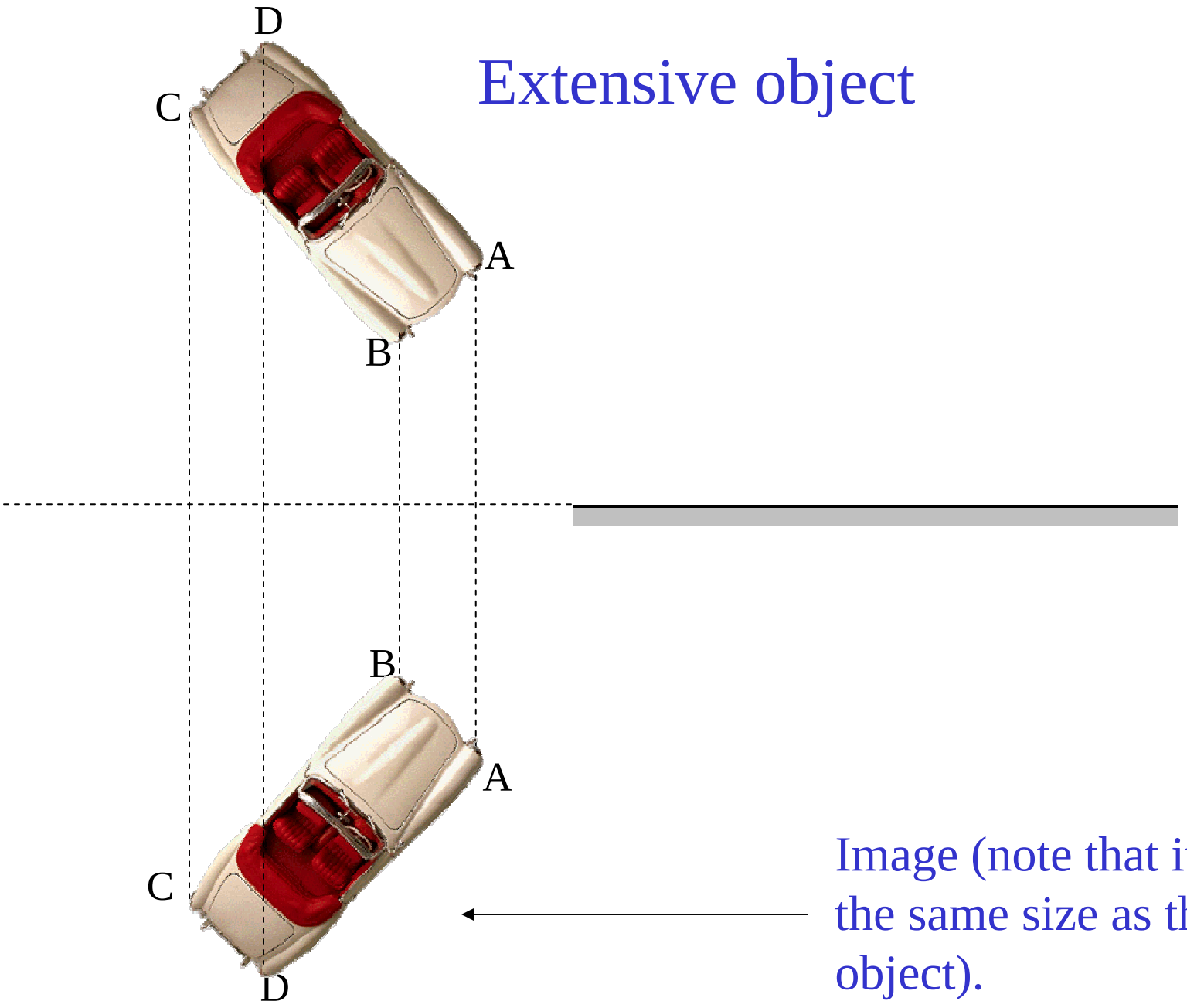
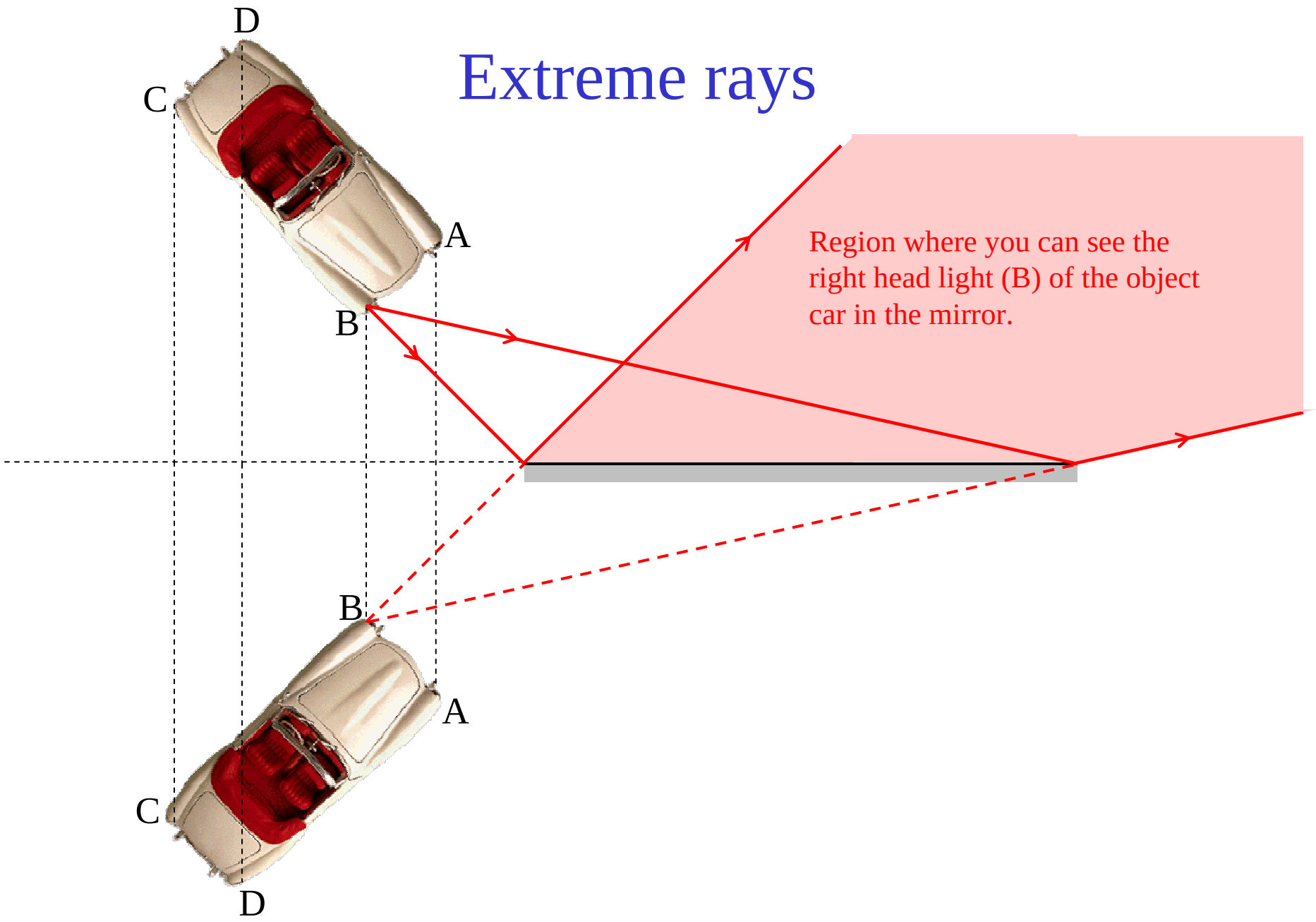
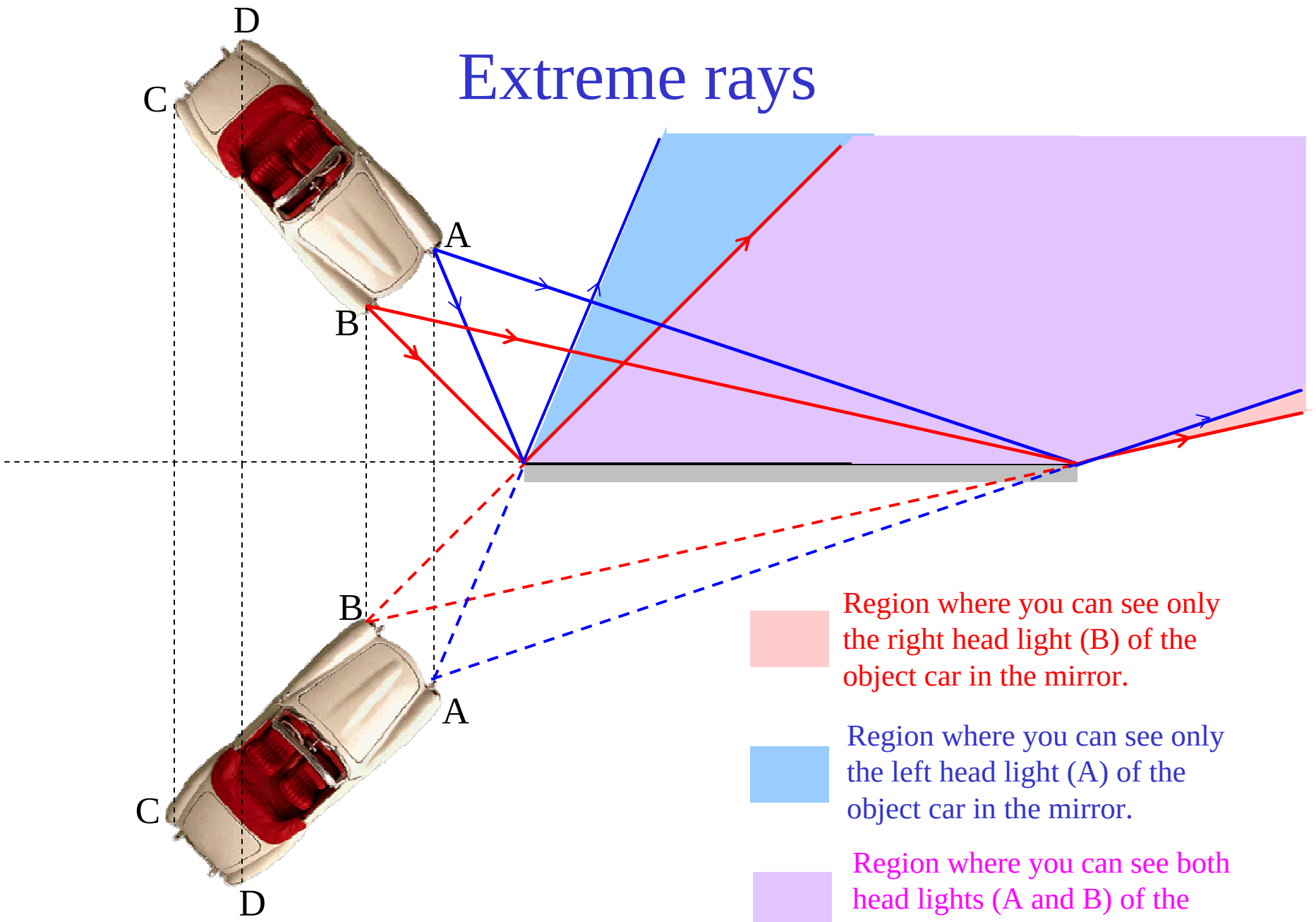


Image (note that it has the same size as the object).

Extreme rays



Extreme rays



Region where you can see only the right head light (B) of the object car in the mirror.

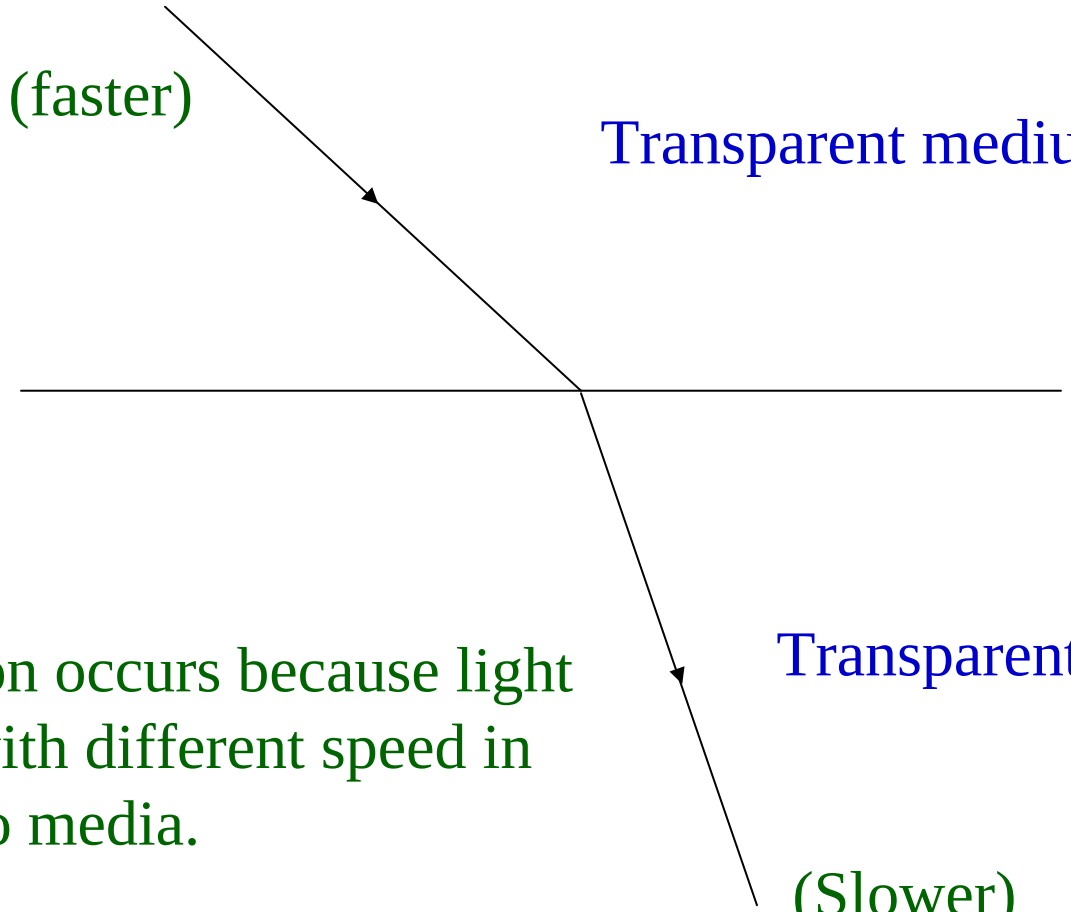
Region where you can see only the left head light (A) of the object car in the mirror.

Region where you can see both head lights (A and B) of the object car in the mirror.

Opaque and Transparent

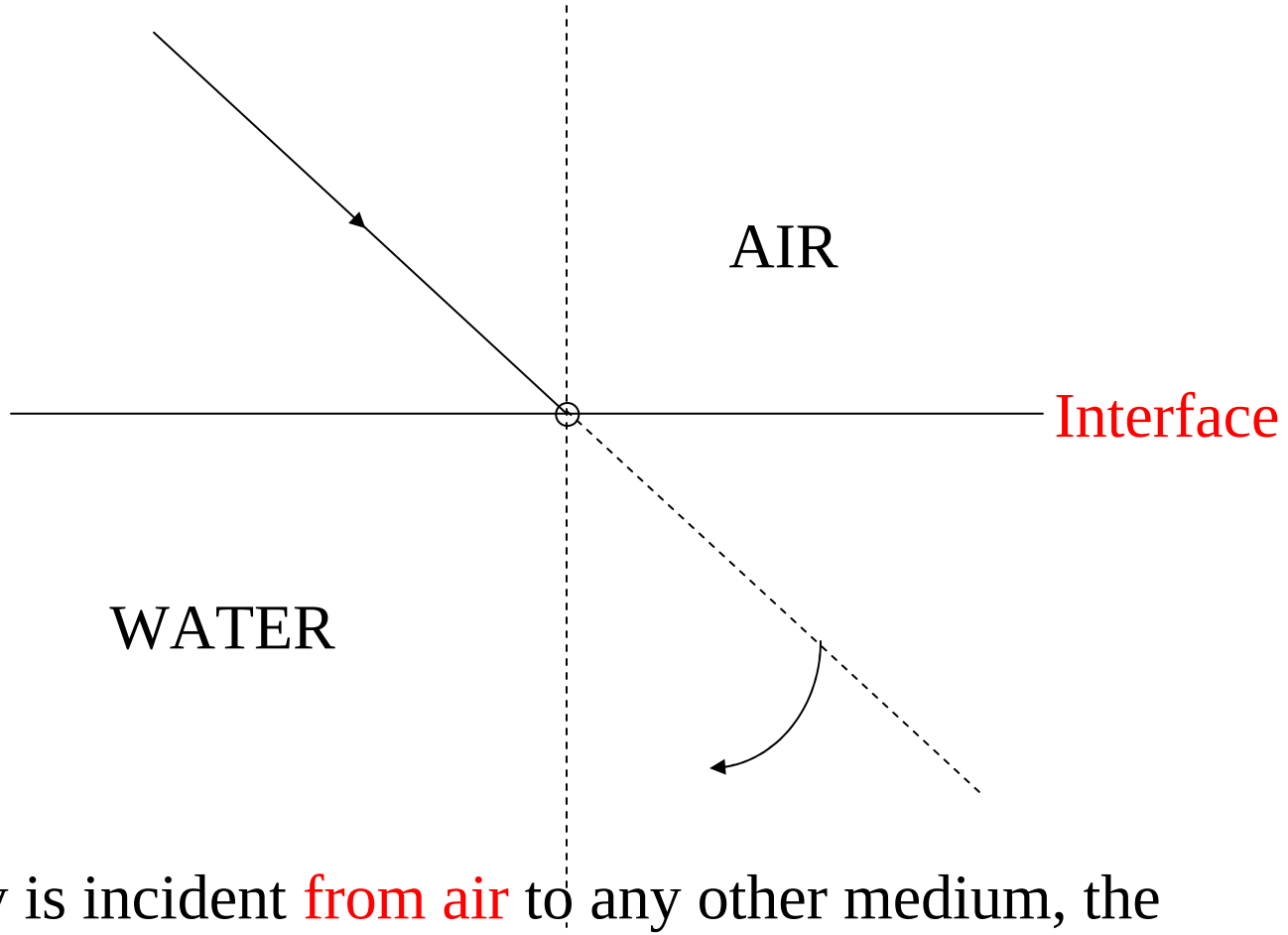
- Light ray is blocked, absorbed, or reflected by opaque object.
- Light ray can transmit from one transparent medium to another transparent medium and refraction will occur at the interface between the two media.

Refraction



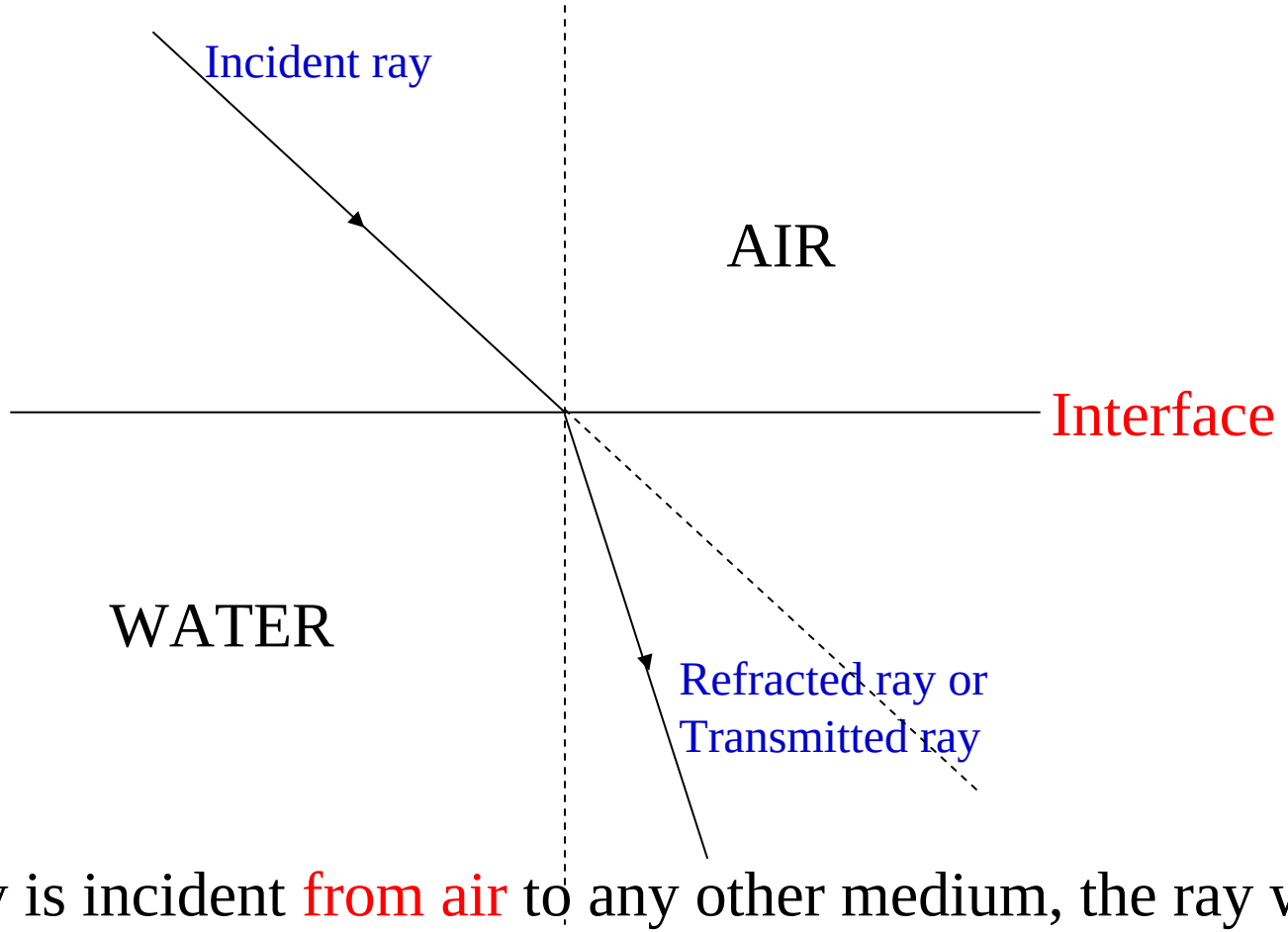
Refraction occurs because light travels with different speed in these two media.

What can you say about the refracted ray?



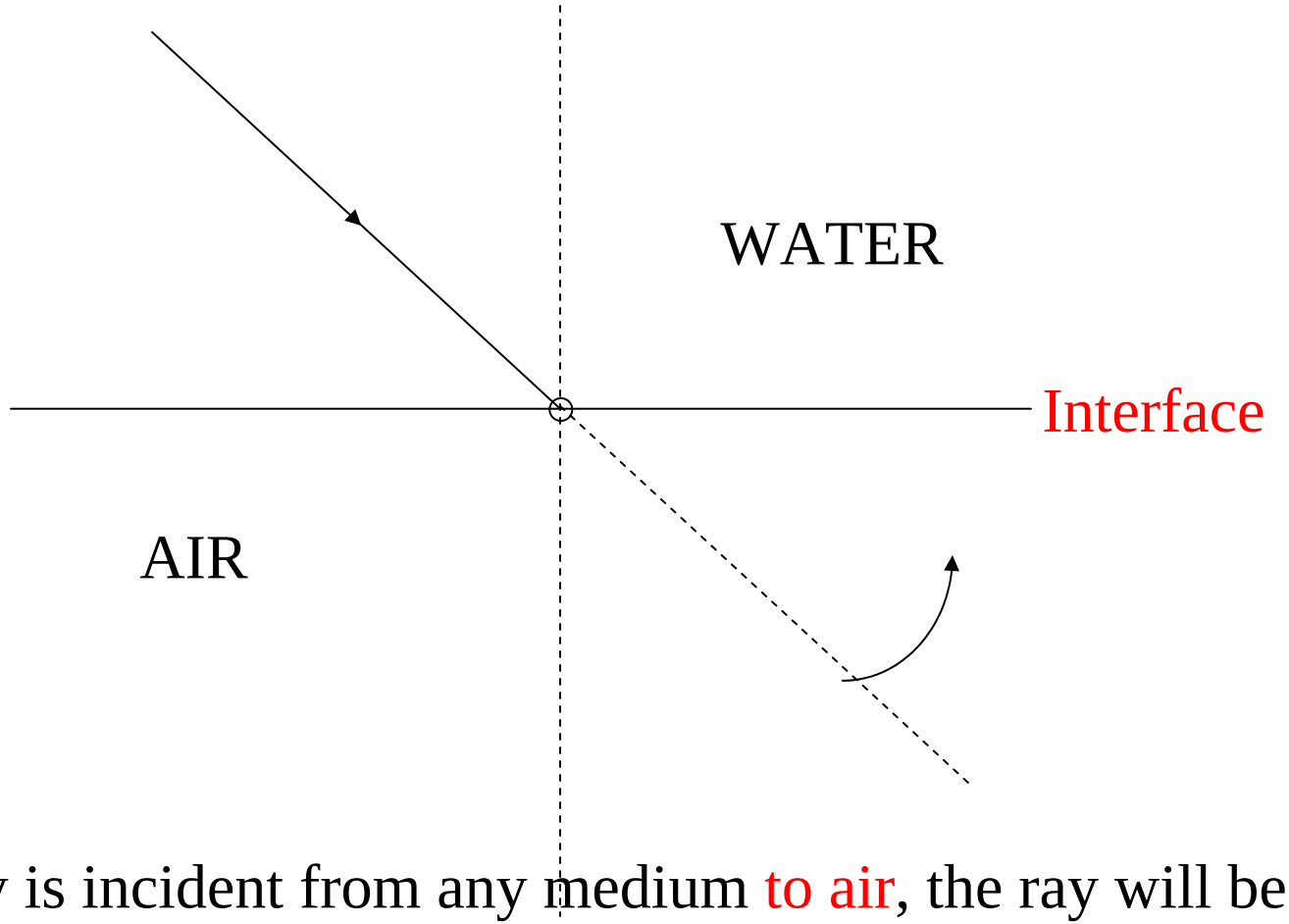
If the ray is incident from air to any other medium, the transmitted ray will be bent away from the surface.

What can you say about the refracted ray?



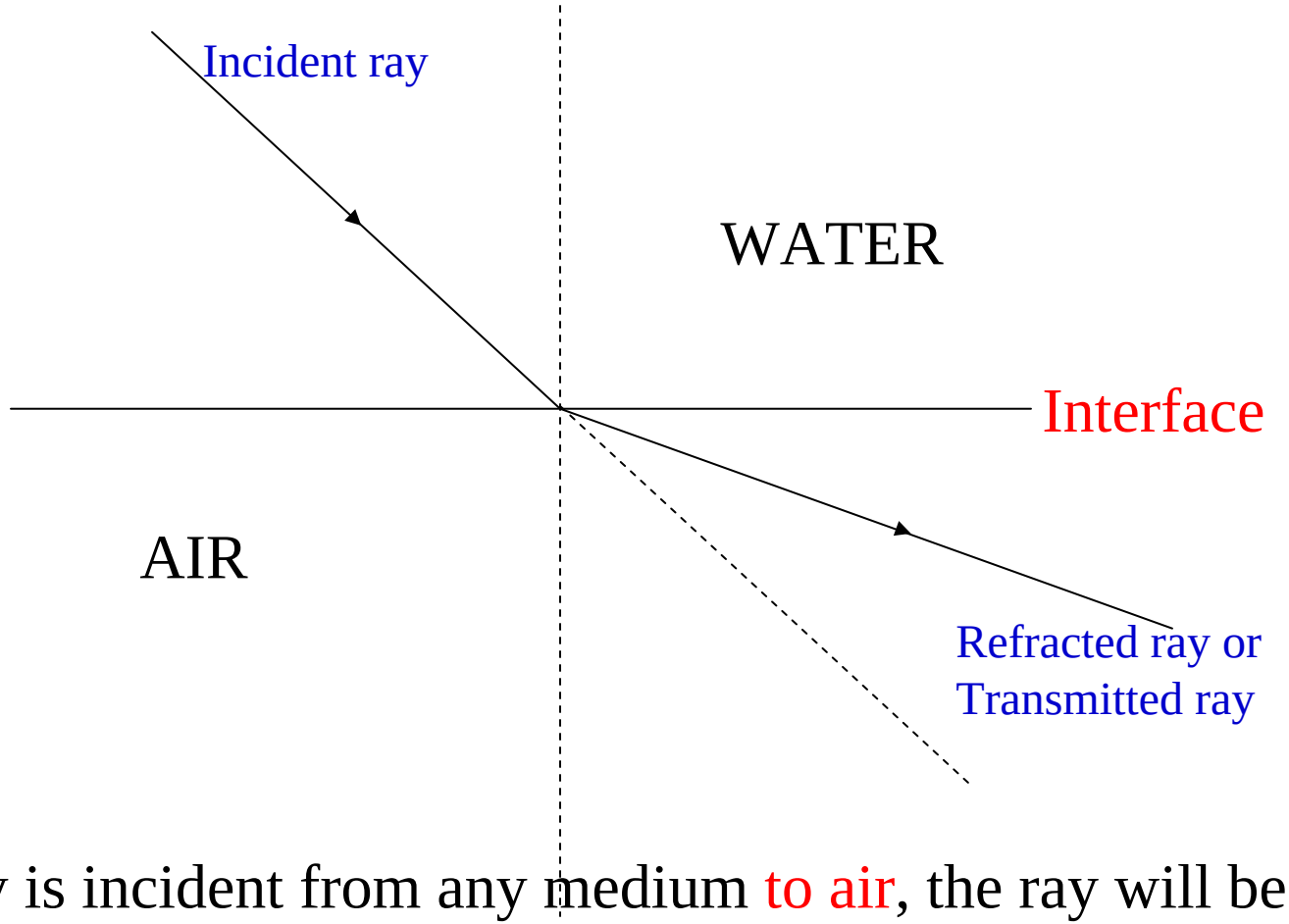
If the ray is incident from air to any other medium, the ray will be bent away from the surface.

What can you say about the refracted ray?



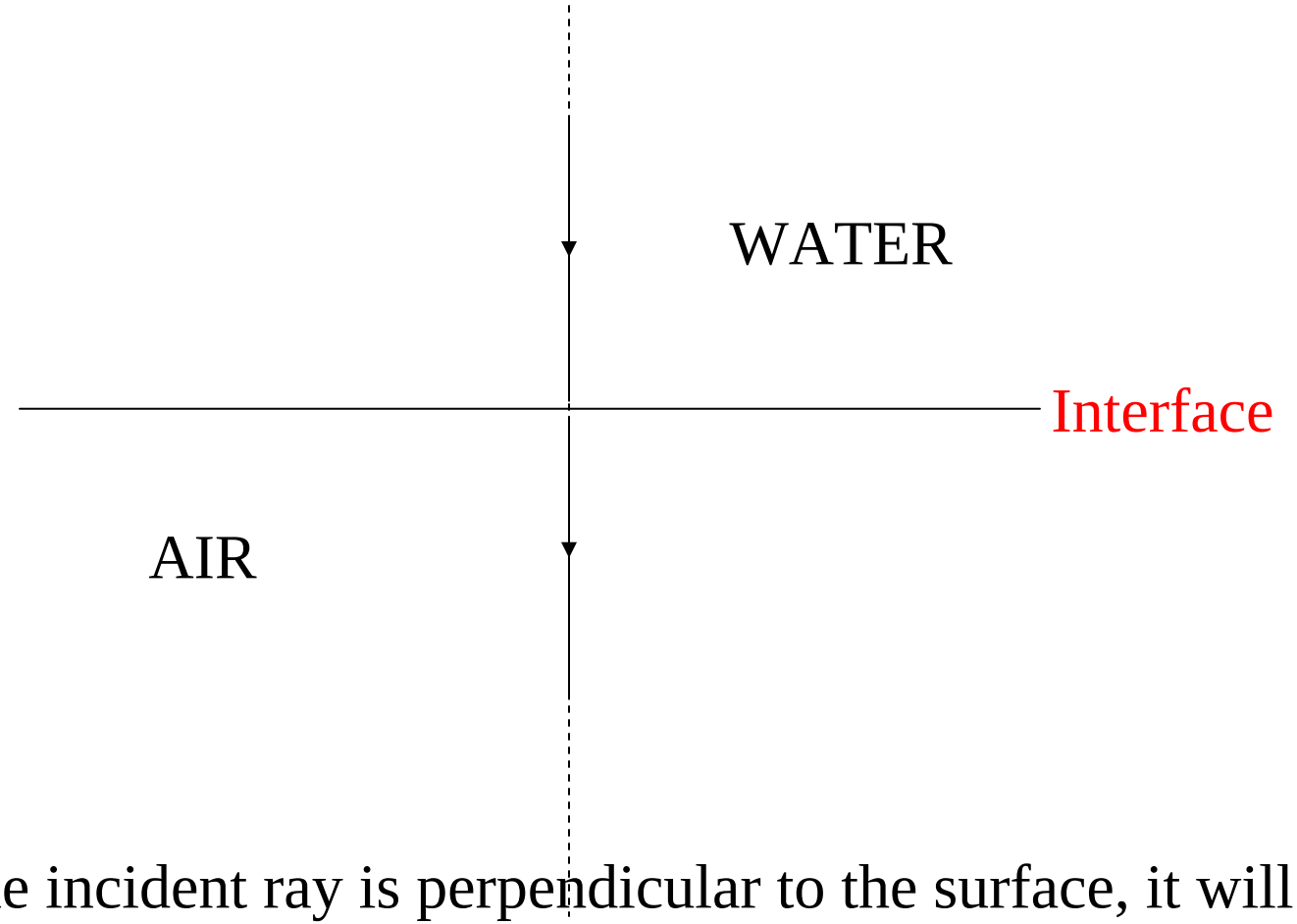
If the ray is incident from any medium to air, the ray will be bent toward the surface.

What can you say about the refracted ray?



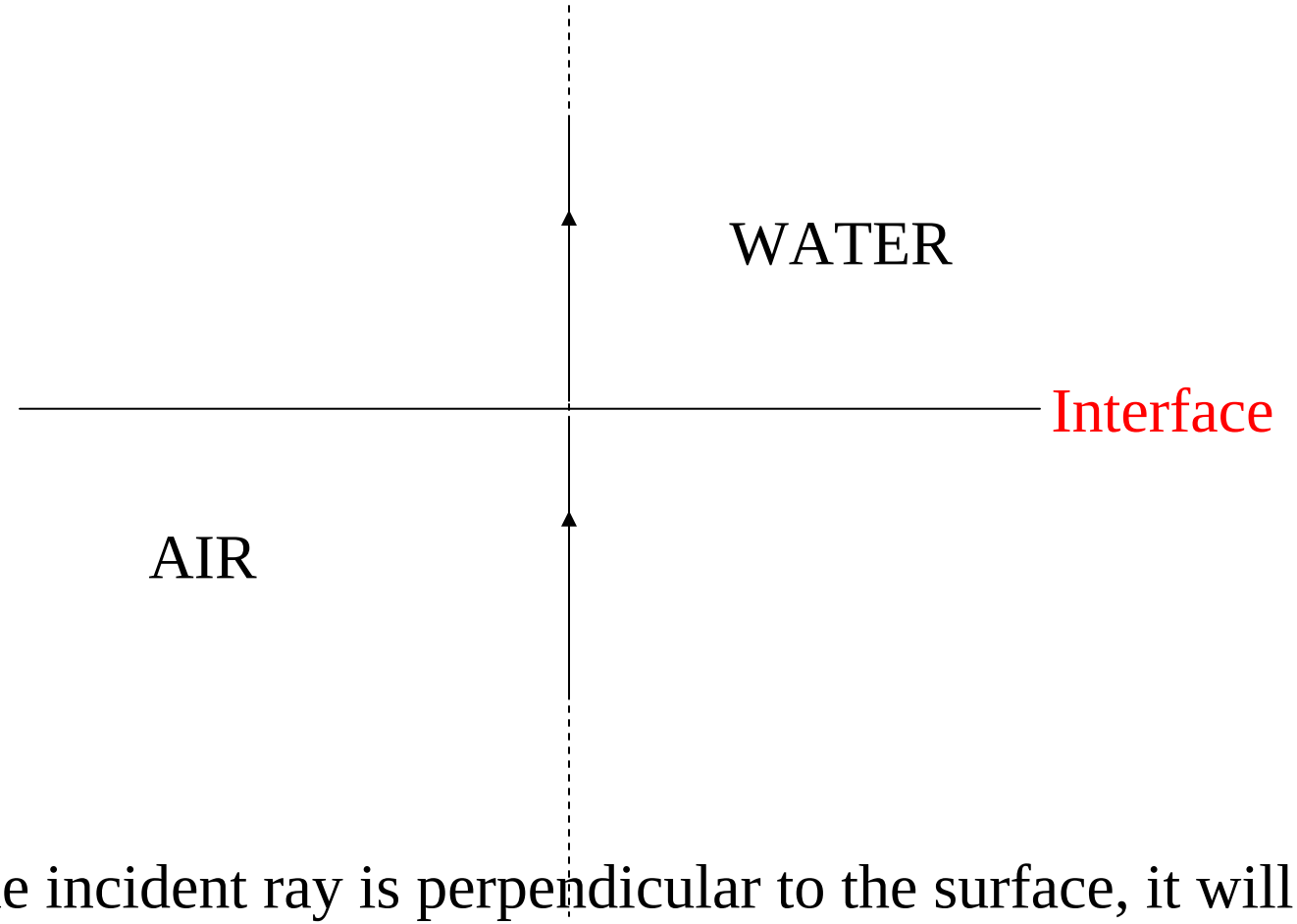
If the ray is incident from any medium to air, the ray will be bent toward the surface.

When the incident ray is perpendicular to the surface:



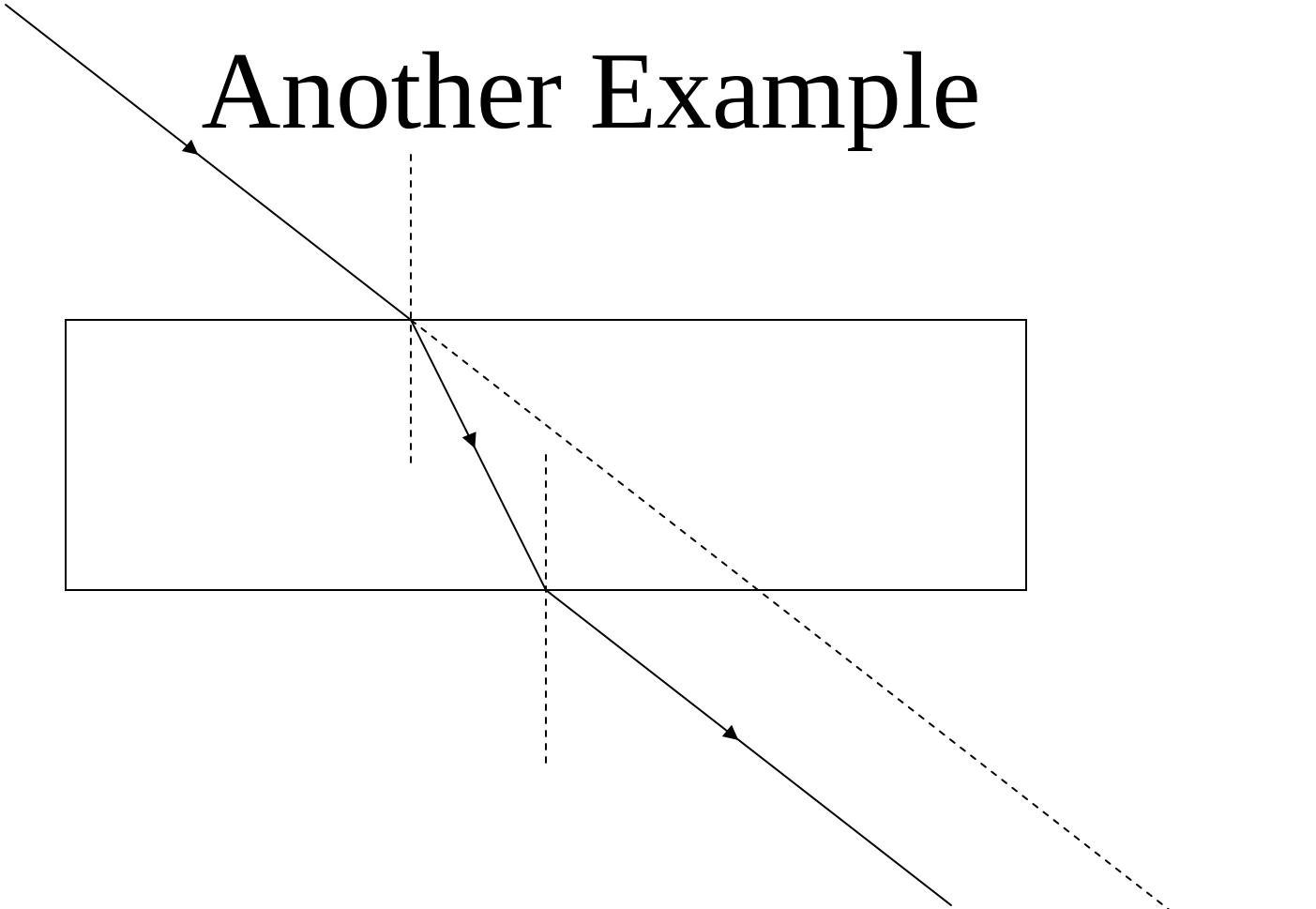
When the incident ray is perpendicular to the surface, it will not bend.

When the incident ray is perpendicular to the surface



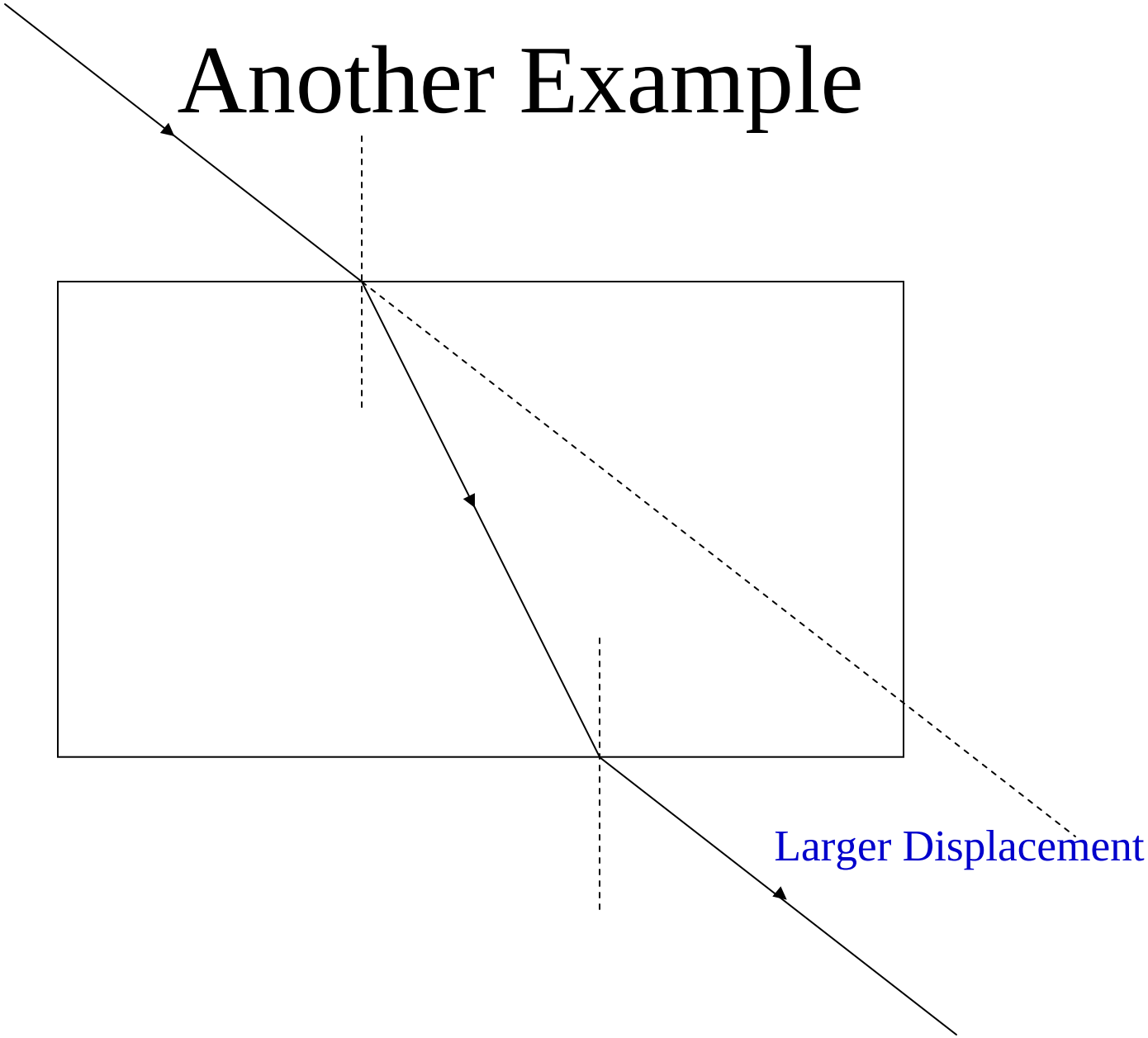
When the incident ray is perpendicular to the surface, it will not bend.

Another Example

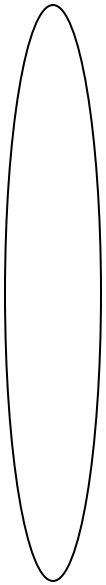


Displacement of rays.

Another Example

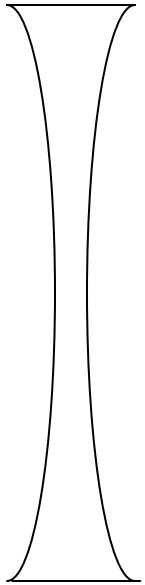


Lenses



Convex lens

e.g. magnifying glass



Concave lens

e.g. glasses worn by nearsighted people

Image of a convex lens

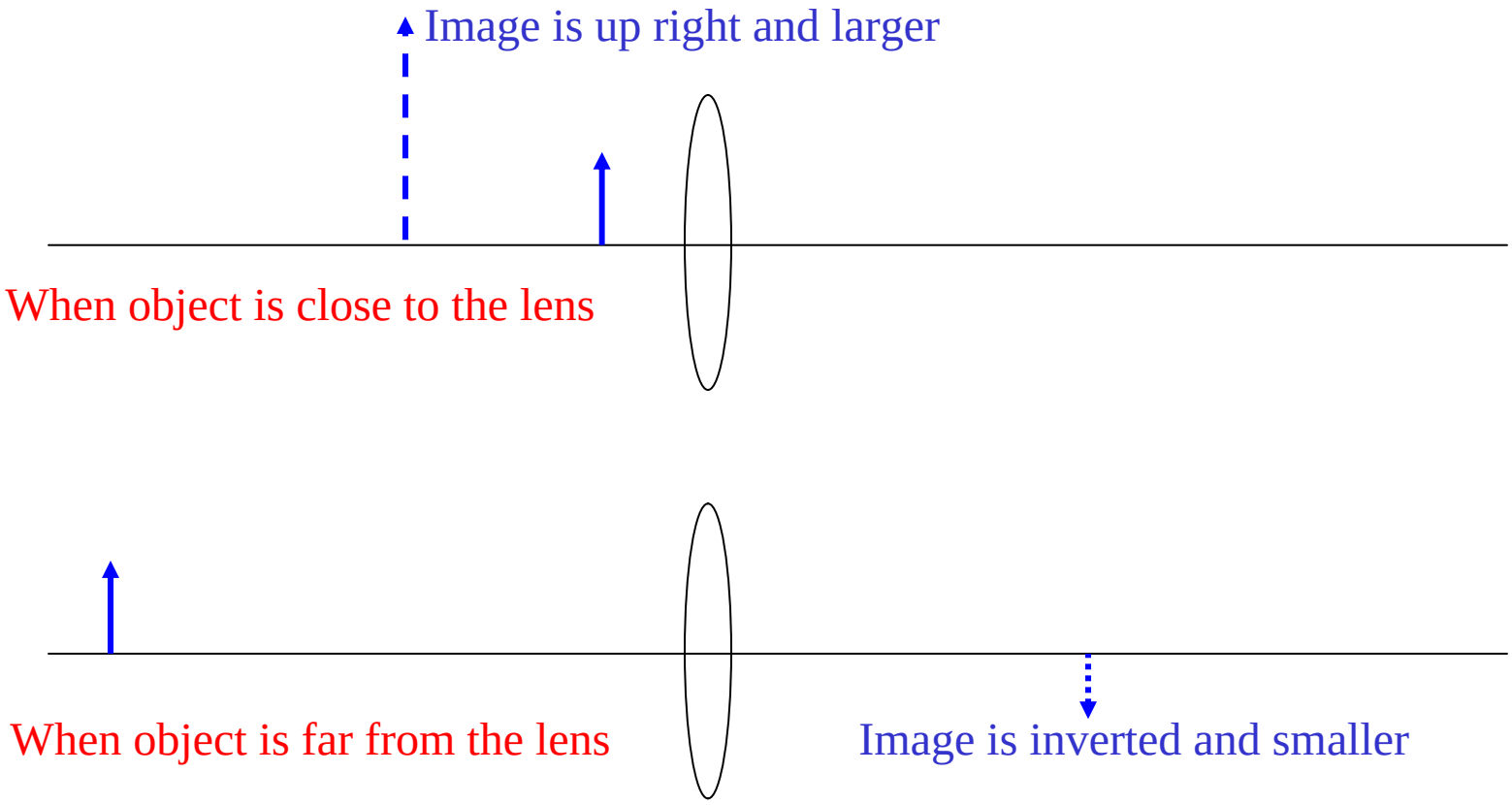
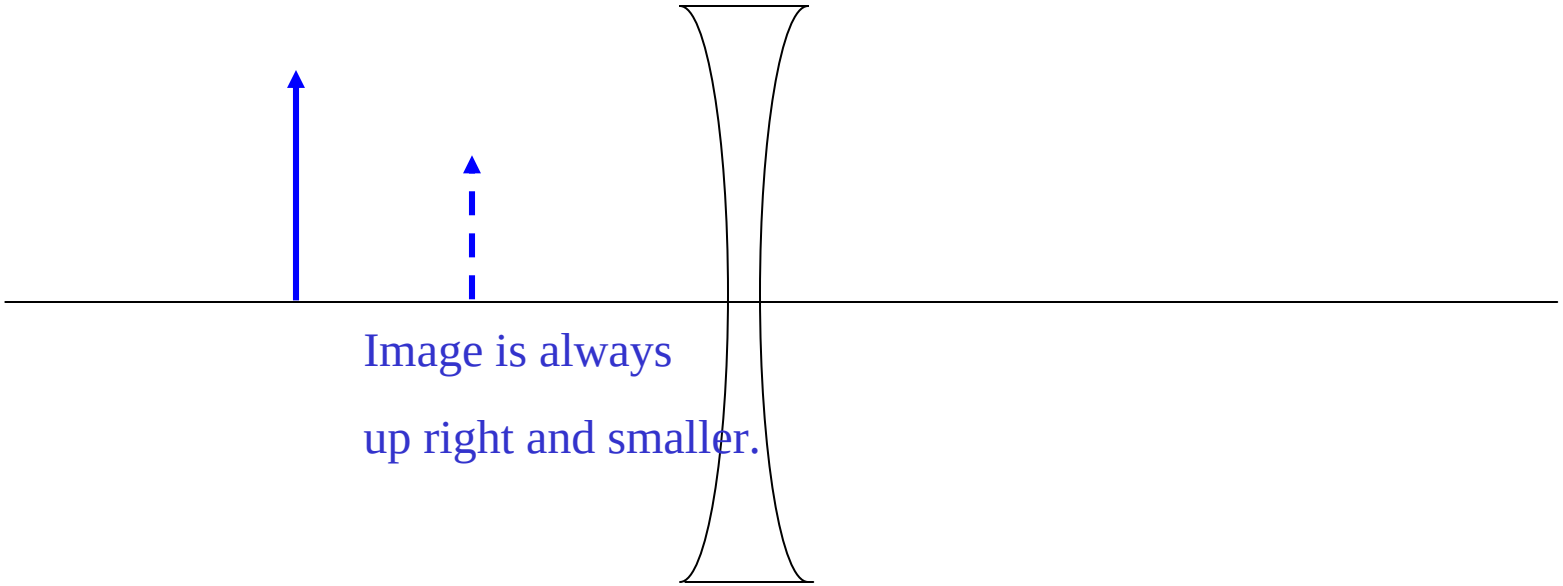
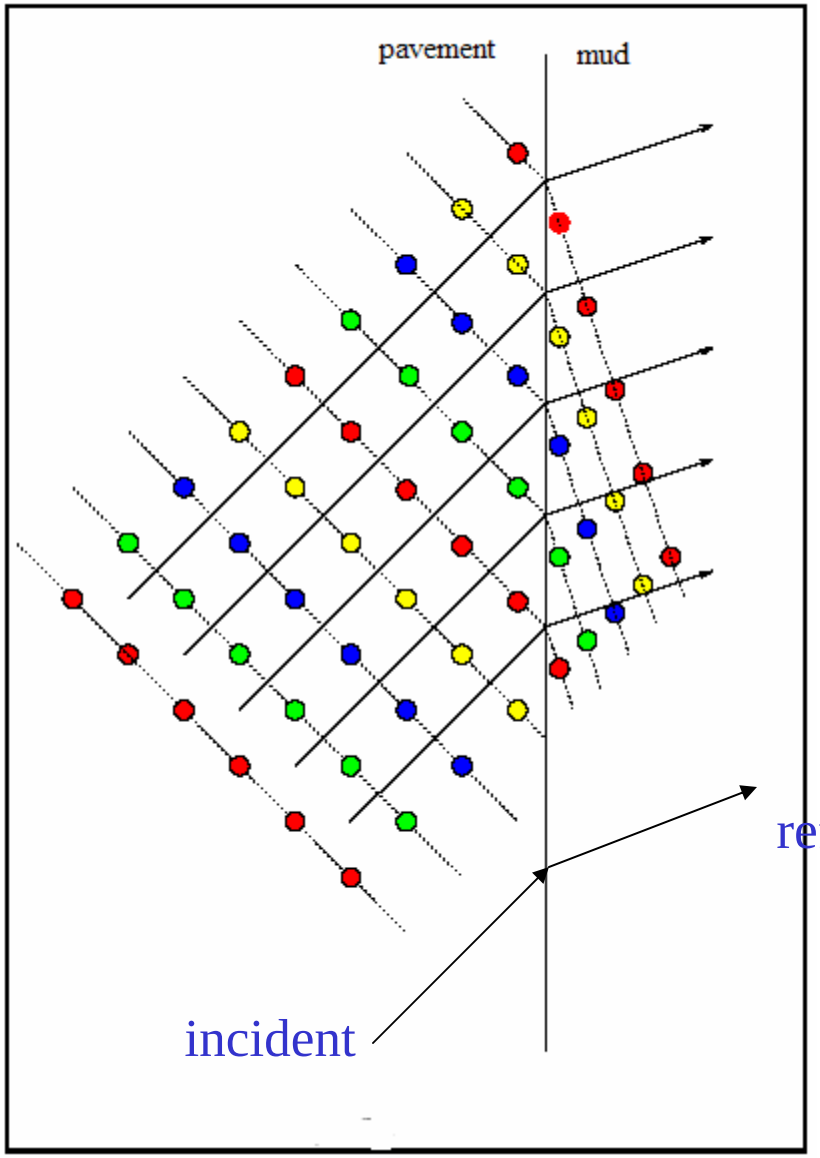


Image of a concave lens



Refraction occurs because light travels with different speed in the two media.

It is analogous to a marching band changing speed (e.g. going from pavement to mud) – when they hit the slower medium (mud), they must change their angle to stay in formation:



Why does light slow down in different materials?

It is because the light is absorbed and reemitted by the atoms in the material – it is as if each atom catches the light, turns around, and throws it to the next atom – each "catch" slows down the passage of the light.

The amount the light slows down therefore depends on the type of atoms and also on their density.

Because the density of air is so low, light is hardly slowed down at all in air – its speed is very close to its speed in ***vacuum:*** 300,000,000 meters/second.

(In water, its speed decreases by ~ 25%.)