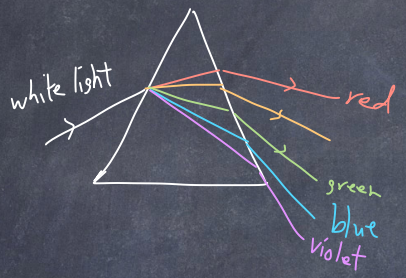
PHY117 HS2024

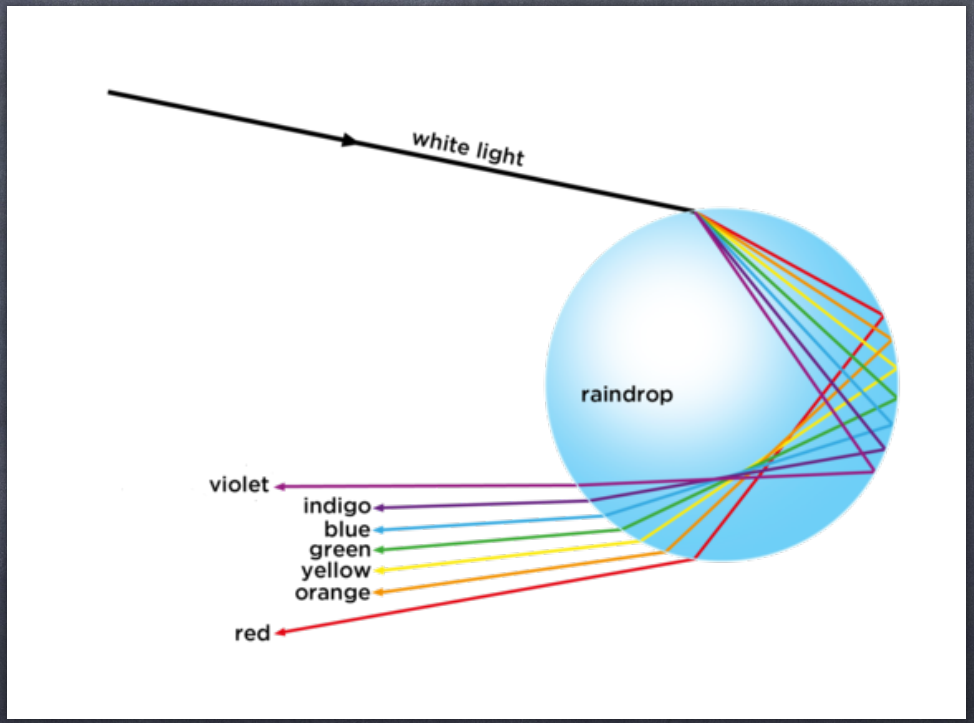
"I have set my rainbow in the clouds"
we add: "and it shall be at 42° with respect to you and the sun due to refraction and geometry..."

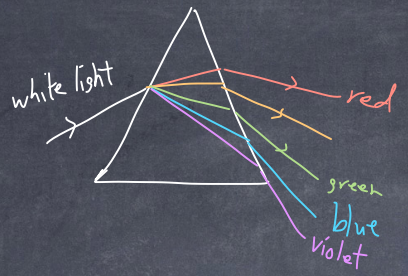
Also today: Creating light from darkness

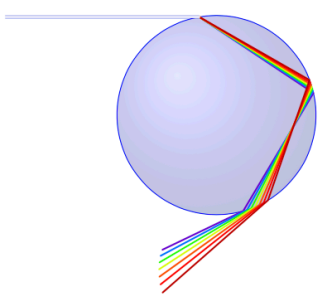
Week 13, Lecture 2
Dec. 11th, 2024
Prof. Ben Kilminster

Light through a rain drop

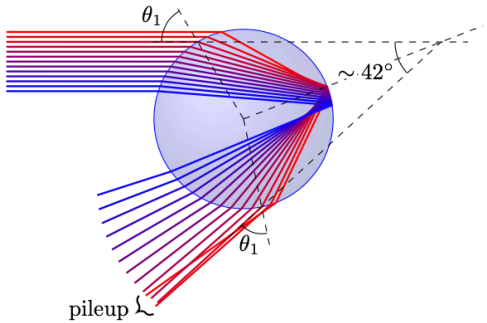






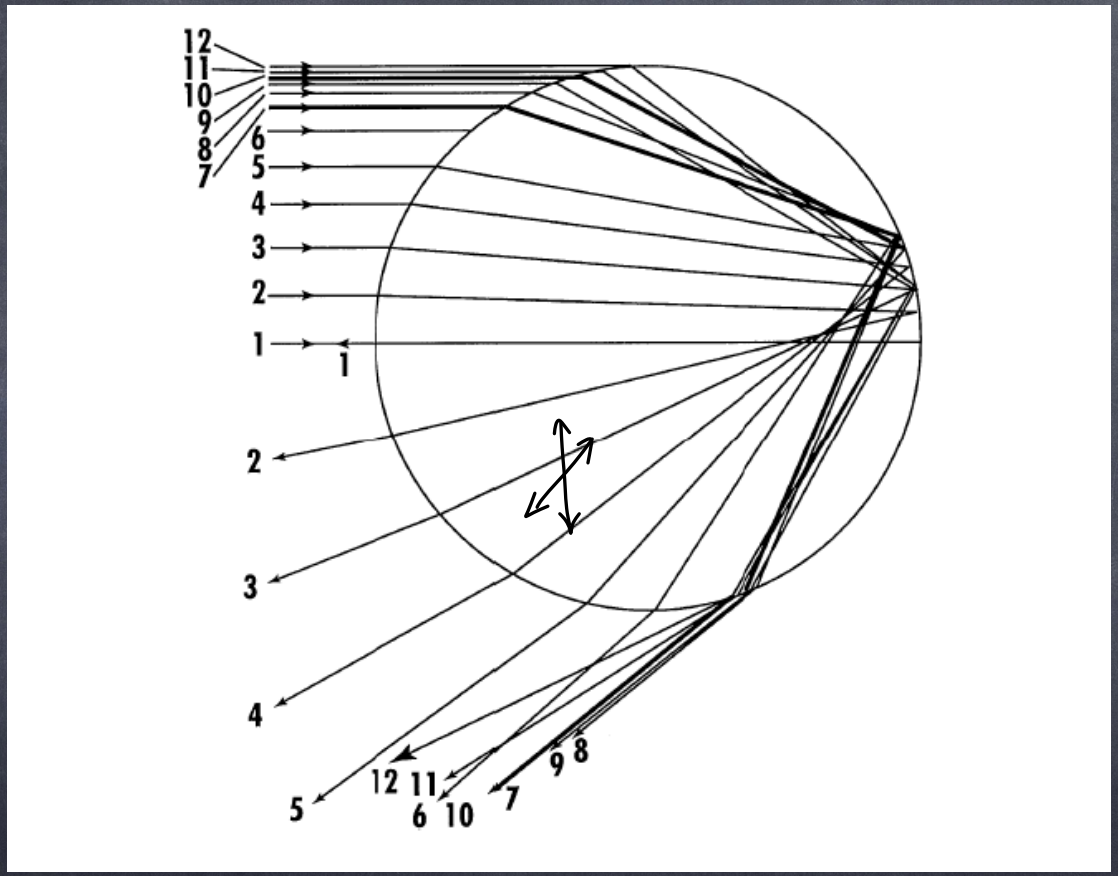


(a) A white light beam is spread in a rainbow due to dispersion (not to scale).



(b) At an effective reflection angle of about 42°, light is more concentrated (color unrelated to wavelength).

Figure 14.6: Explaining rainbows with dispersion and internal reflection in water droplets.


12
11
10
9
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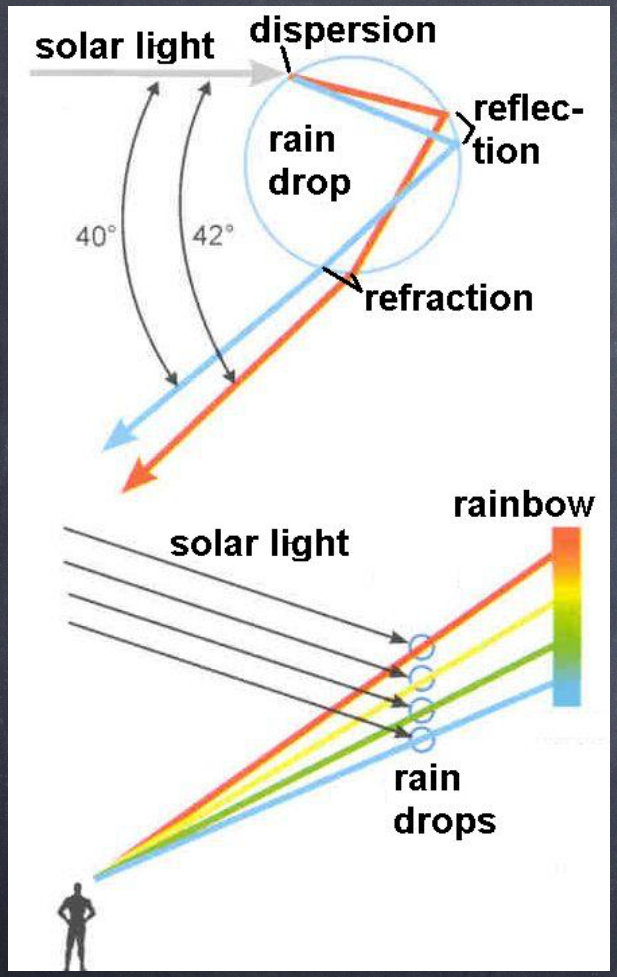
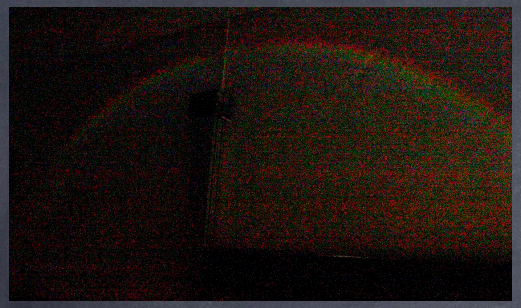
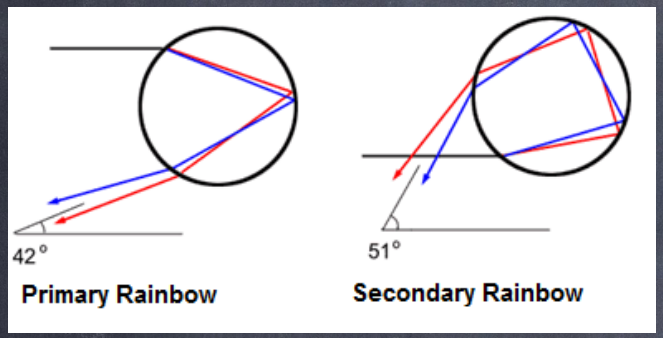
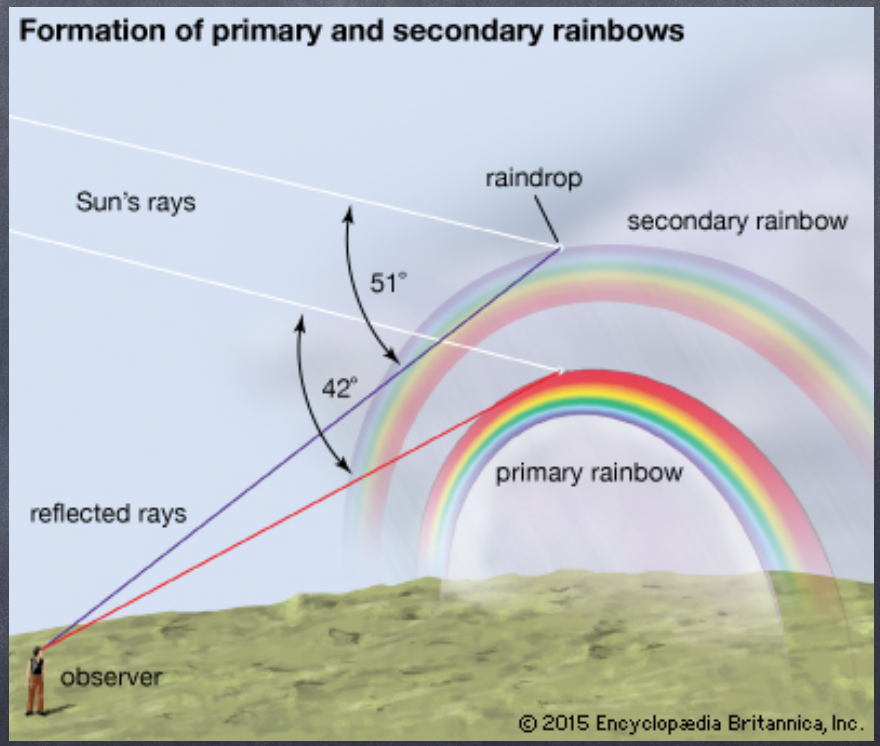

solar light
dispersion
reflec-
tion
rain
drop
40°
42°
refraction
rainbow
solar light
rain
drops




42°
Primary Rainbow
51°
Secondary Rainbow


Formation of primary and secondary rainbows
Sun's rays
raindrop
secondary rainbow
51°
42°
primary rainbow
reflected rays
observer
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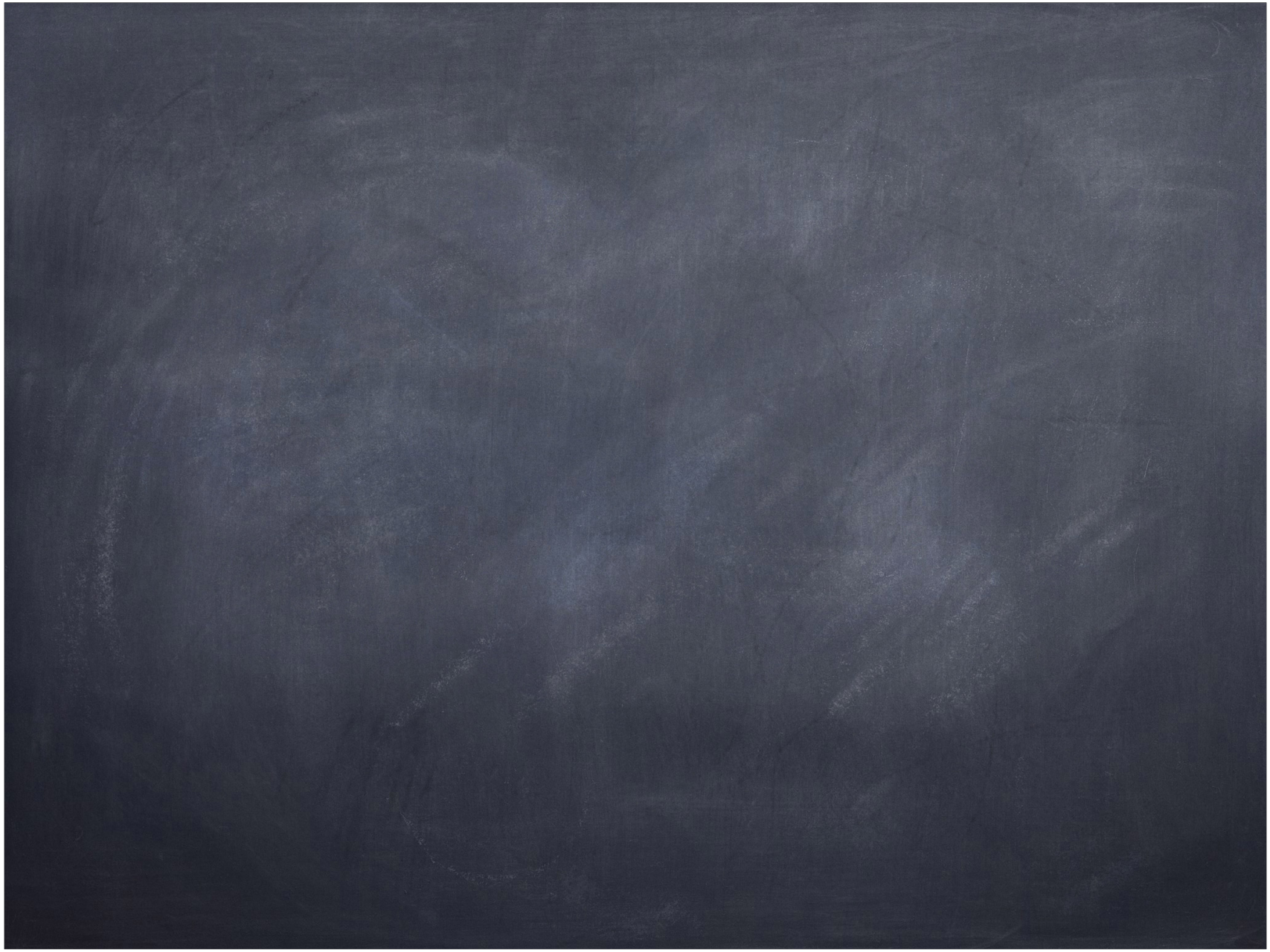
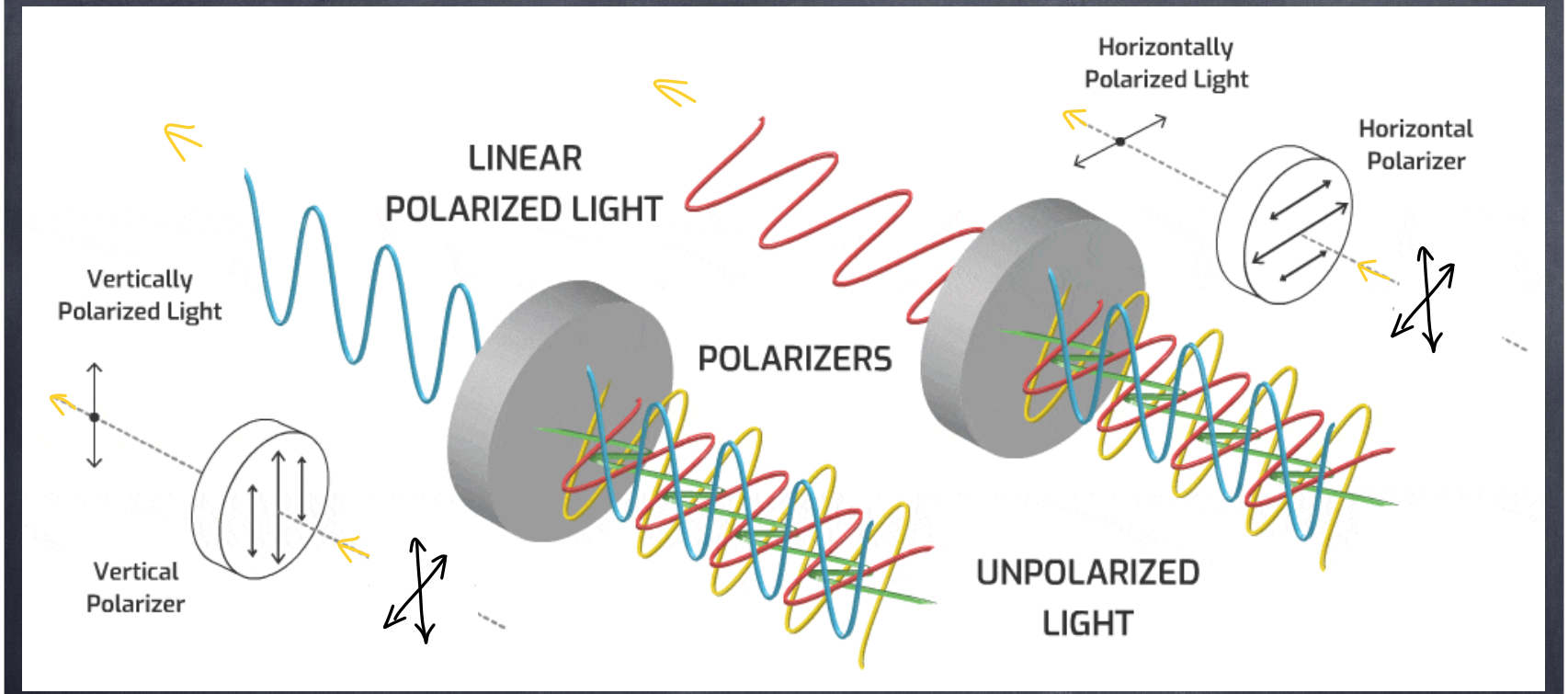
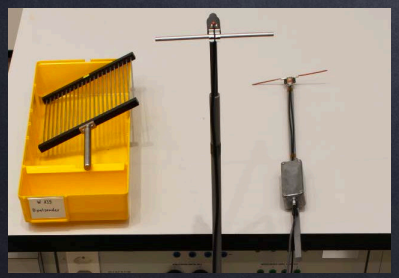
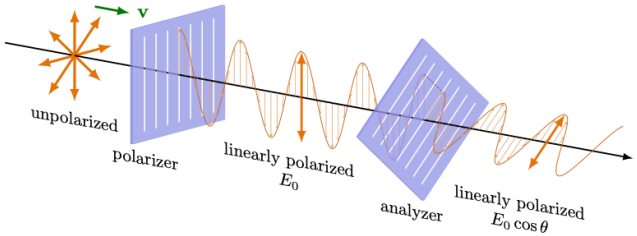


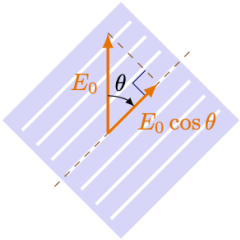

Horizontally
Polarized Light
Horizontal
Polarizer
LINEAR
POLARIZED LIGHT
Vertically
Polarized Light
POLARIZERS
Vertical
Polarizer
UNPOLARIZED
LIGHT

Example of microwaves:

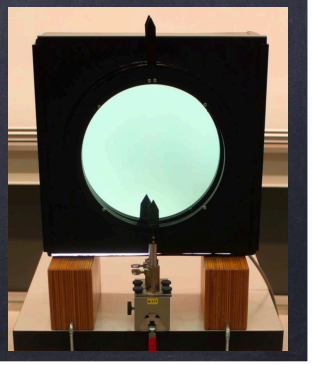


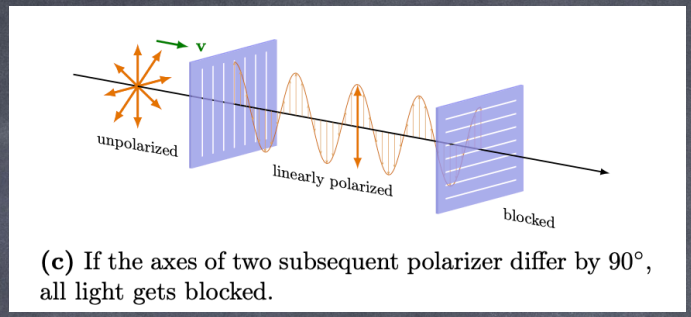


(a) Initially unpolarized light beam gets linearly polarized. The transmitted electric field is reduced to $E_0 \cos\theta$.

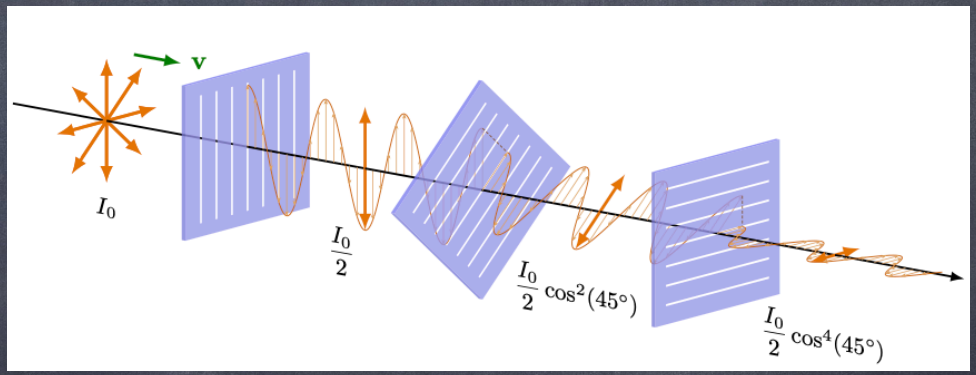


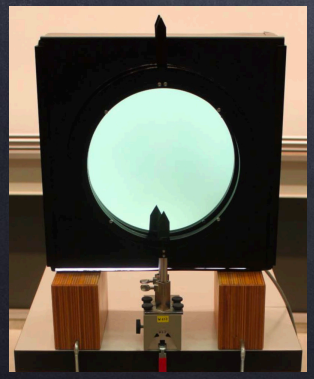
(b) Polarizer only lets through the component parallel to its polarizing axis.



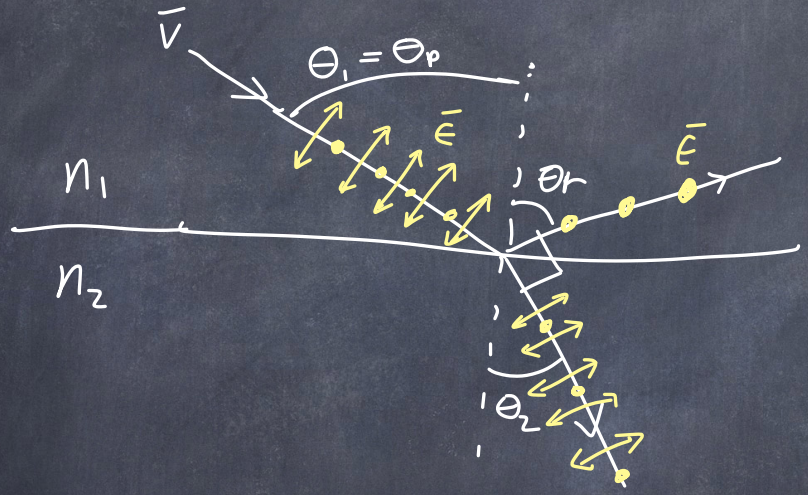


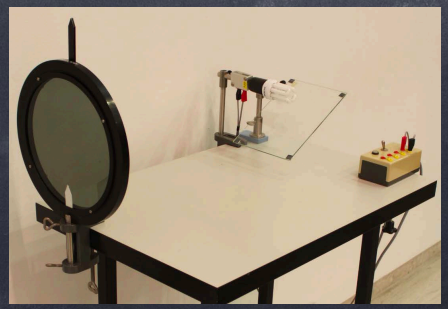
(c) If the axes of two subsequent polarizer differ by 90°, all light gets blocked.



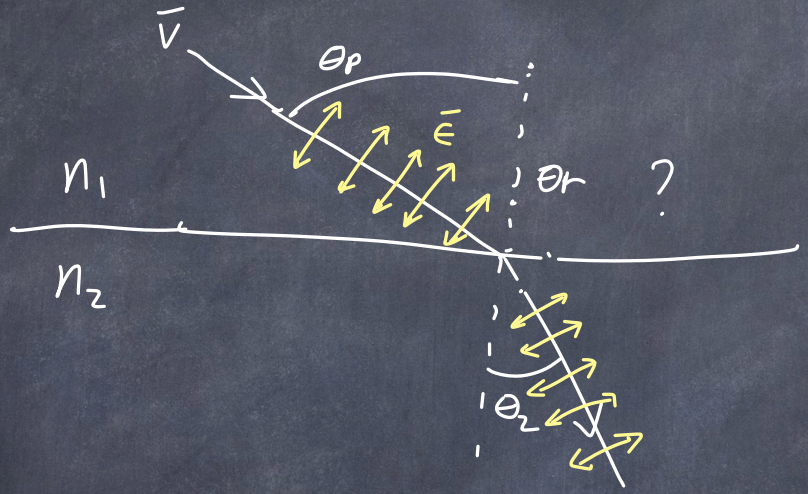


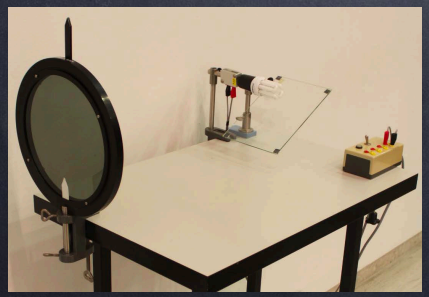
Polarization by reflection:



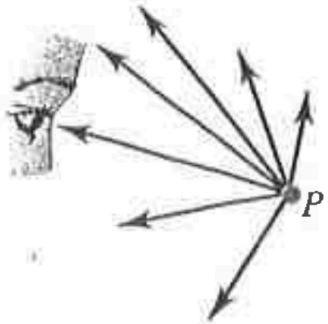


what if our initial light is polarized in a direction ⊥ to surface + direction of motion?

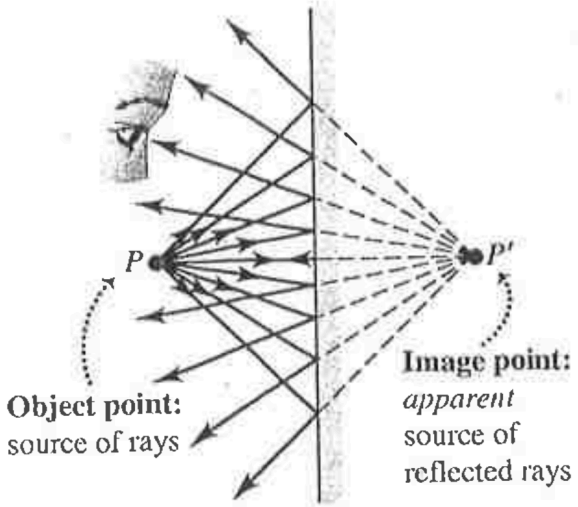




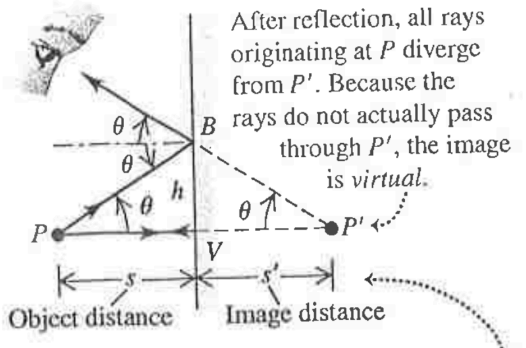
34.1 Light rays radiate from a point object P in all directions. For an observer to see this object directly, there must be no obstruction between the object and the observer's eyes.



34.2 Light rays from the object at point P are reflected from a plane mirror. The reflected rays entering the eye look as though they had come from image point P'.



34.4 Construction for determining the location of the image formed by a plane mirror. The image point P' is as far behind the mirror as the object point P is in front of it.

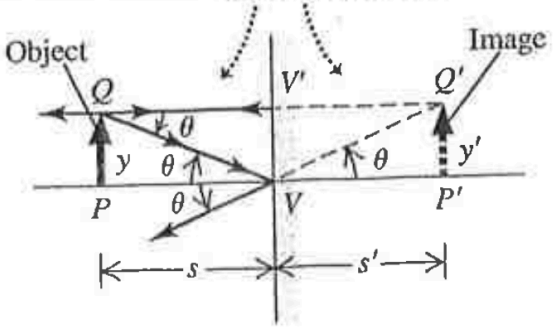


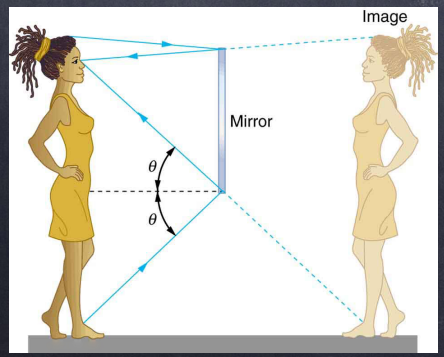
After reflection, all rays originating at P diverge from P'. Because the rays do not actually pass through P', the image is *virtual*.

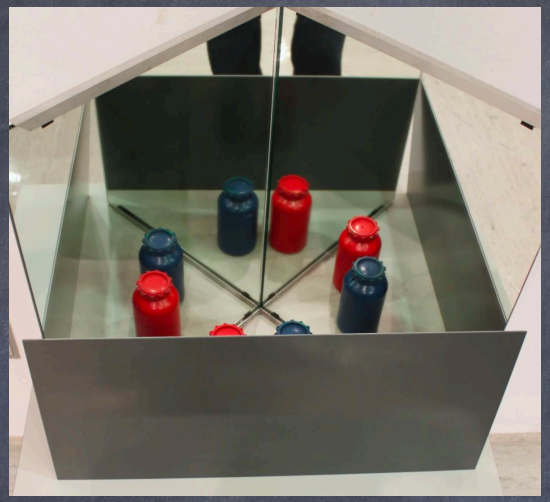
Triangles PVB and $P'VB$ are congruent, so $|s| = |s'|$.

34.6 Construction for determining the height of an image formed by reflection at a plane reflecting surface.

For a plane mirror, PQV and $P'Q'V$ are congruent, so $y = y'$ and the object and image are the same size (the lateral magnification is 1).

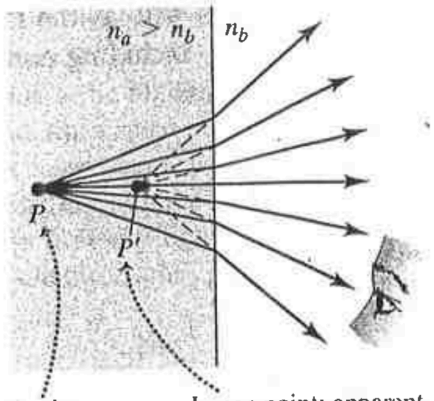






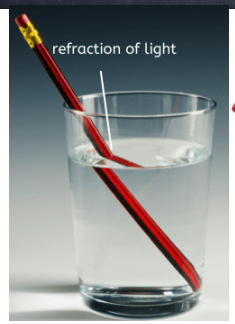
34.3 Light rays from the object at point P are refracted at the plane interface. The refracted rays entering the eye look as though they had come from image point P'.

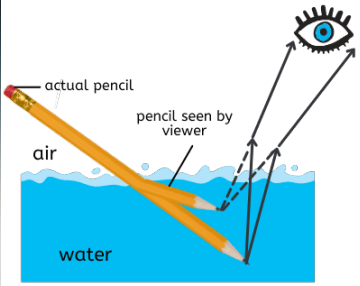
When $n_a > n_b$, P' is closer to the surface than P; for $n_a < n_b$, the reverse is true.



Object point: source of rays

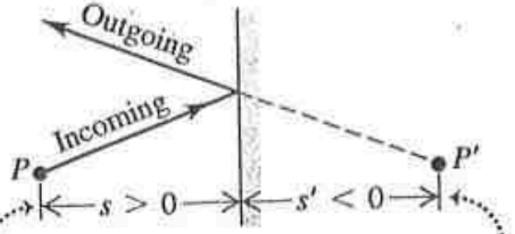
Image point: apparent source of refracted rays





34.5 For both of these situations, the object distance s is positive (rule 1) and the image distance s' is negative (rule 2).

(a) Plane mirror

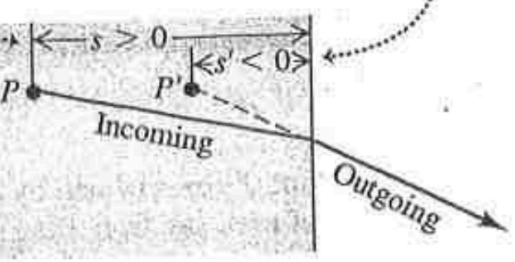


In both of these specific cases:

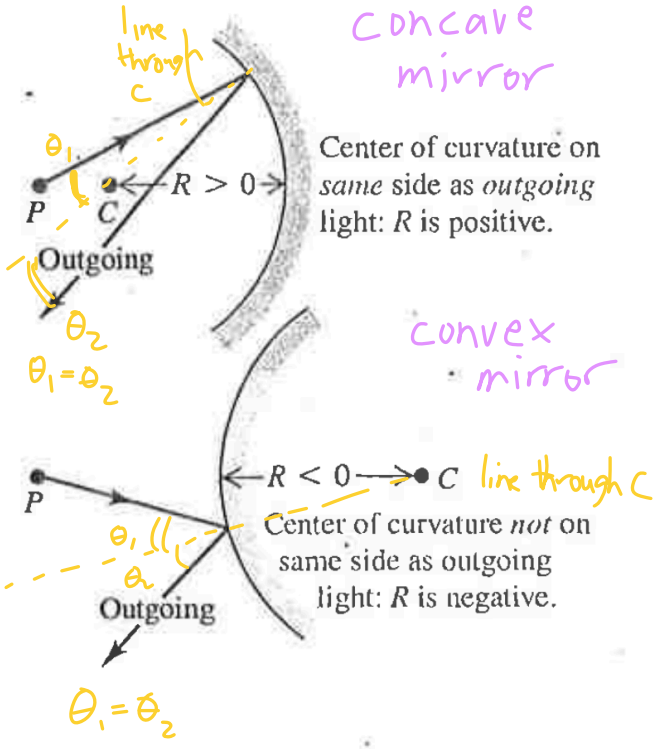
Object distance s is *positive* because the *object is on the same side as the incoming light.*

Image distance s' is *negative* because the *image is NOT on the same side as the outgoing light.*

(b) Plane refracting interface



34.11 The sign rule for the radius of a spherical mirror.

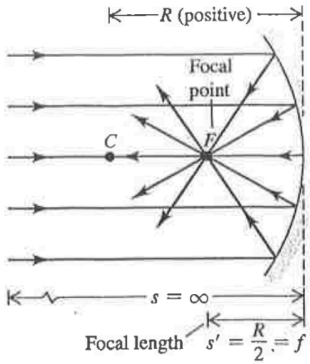


light rays through spherical mirrors

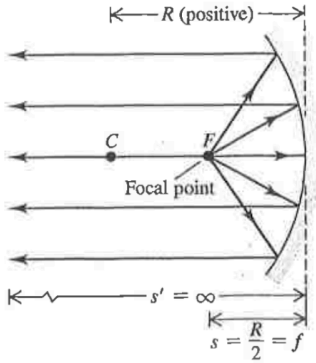
concave mirror

34.13 The focal point and focal length of a concave mirror.

(a) All parallel rays incident on a spherical mirror reflect through the focal point.

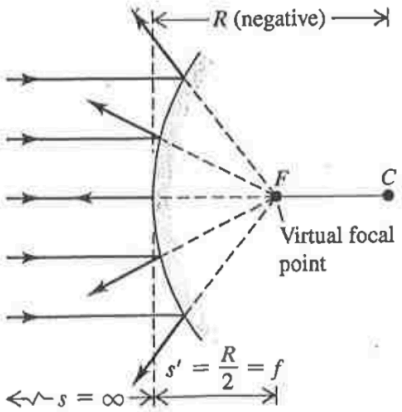


(b) Rays diverging from the focal point reflect to form parallel outgoing rays.

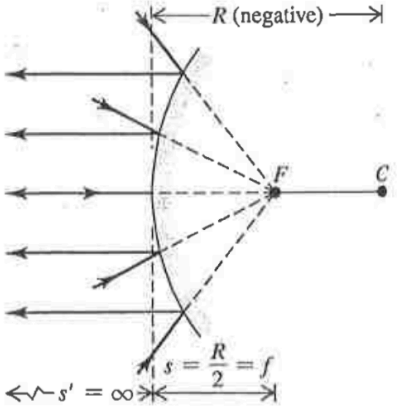


convex mirror

(a) Paraxial rays incident on a convex spherical mirror diverge from a virtual focal point.

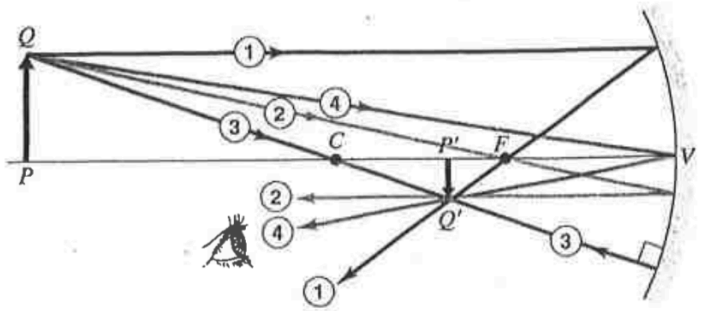


(b) Rays aimed at the virtual focal point are parallel to the axis after reflection.



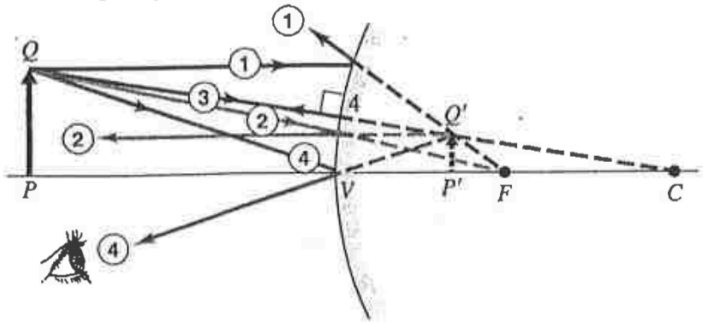
34.19 The graphical method of locating an image formed by a spherical mirror. The colors of the rays are for identification only; they do not refer to specific colors of light.

(a) Principal rays for concave mirror

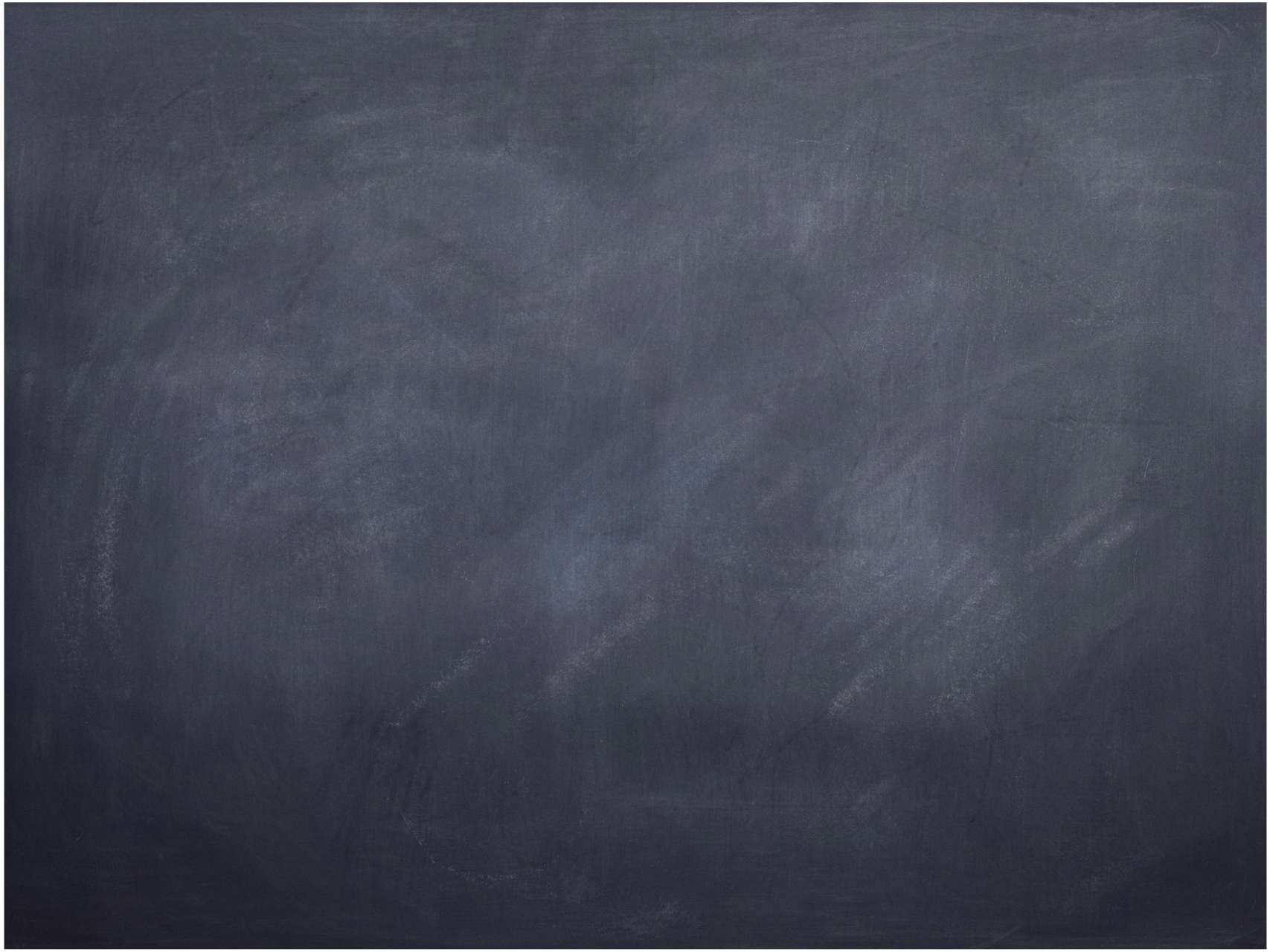


(1) Ray parallel to axis reflects through focal point.
(2) Ray through focal point reflects parallel to axis.
(3) Ray through center of curvature intersects the surface normally and reflects along its original path.
(4) Ray to vertex reflects symmetrically around optic axis.

(b) Principal rays for convex mirror



(1) Reflected parallel ray appears to come from focal point.
(2) Ray toward focal point reflects parallel to axis.
(3) As with concave mirror: Ray radial to center of curvature intersects the surface normally and reflects along its original path.
(4) As with concave mirror: Ray to vertex reflects symmetrically around optic axis.

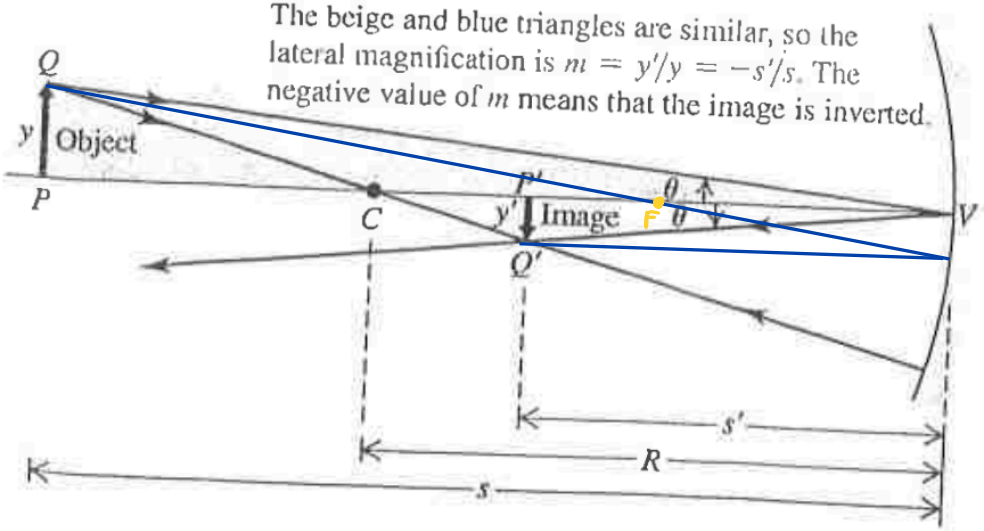


s	+ if the object is in front of the mirror (real object)
	− if the object is behind the mirror (virtual object)*
s'	+ if the image is in front of the mirror (real image)
	− if the image is behind the mirror (virtual image)
r,f	+ if the center of curvature is in front of the mirror (concave mirror)
	− if the center of curvature is behind the mirror (convex mirror)

Example where object has $s > R$: Finding image

34.14 Construction for determining the position, orientation, and height of an image formed by a concave spherical mirror.

The beige and blue triangles are similar, so the lateral magnification is $m = y'/y = -s'/s$. The negative value of m means that the image is inverted.

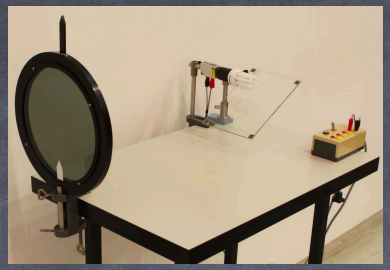


Example: An object 2cm tall is 3cm from a concave mirror with radius of curvature of 10 cm.

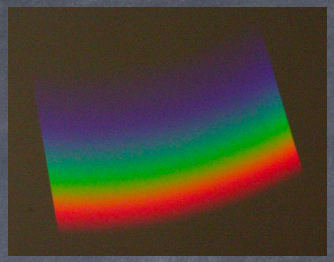
Where is the image? What is the image height?

Is it inverted? Is it real or virtual?

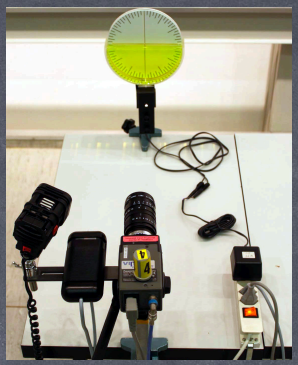
W51



W138

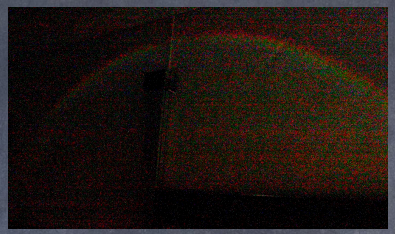


W100

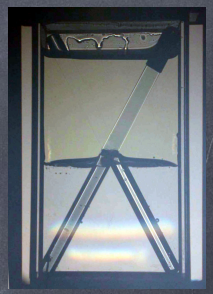


W73

W77



W95



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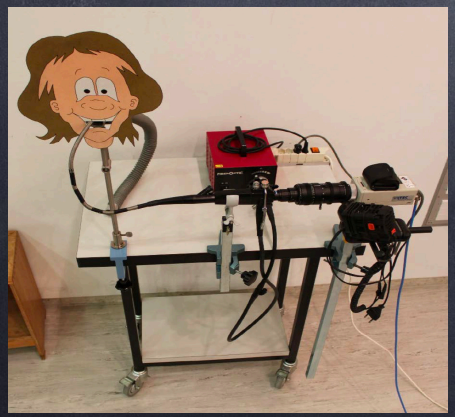
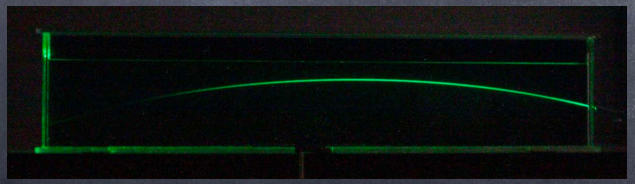
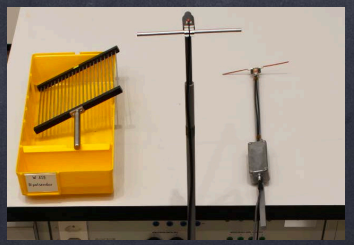


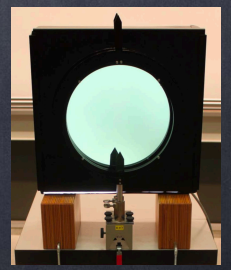
W78



W94



W139



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