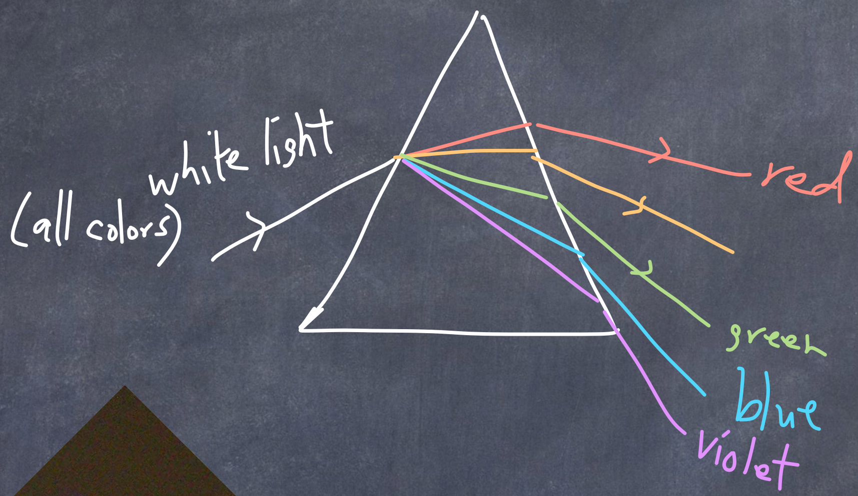
"I have set my rainbow in the clouds"
we add: "and it shall be at 42° with respect to you and the sun due to refraction and geometry..."

Also today: Creating light from darkness

PHY117 HS2023

Week 13, Lecture 1
Dec. 12th, 2023
Prof. Ben Kilminster

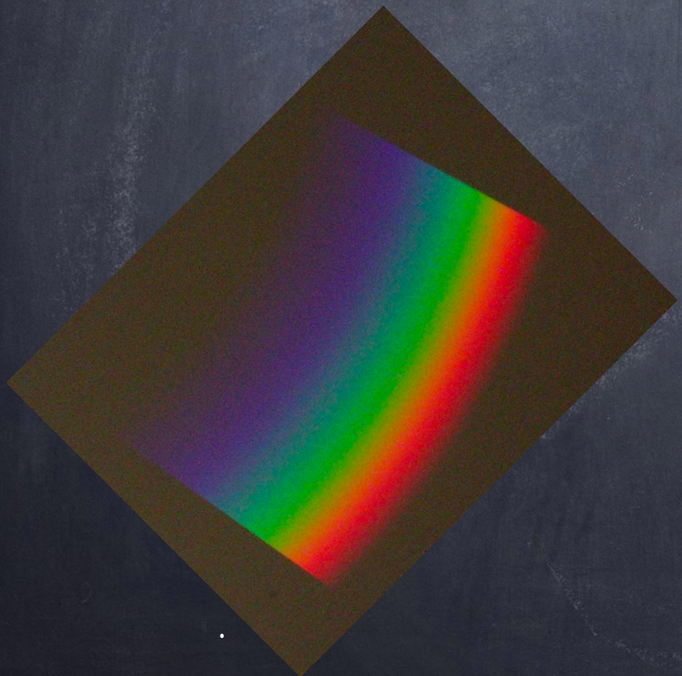
In addition) The index of refraction, "n," depends slightly on the wavelength of the light



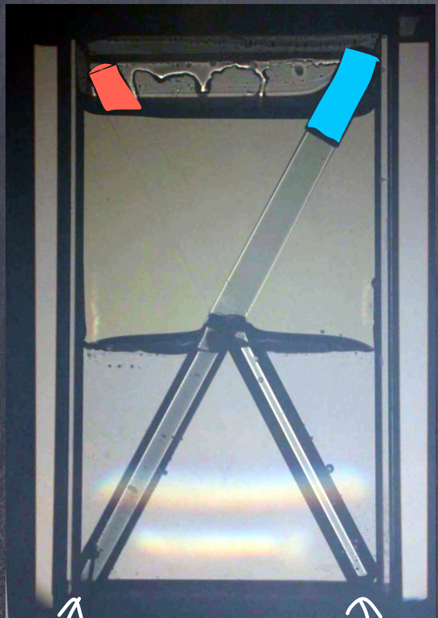
(exaggerated)

short wavelength is bent more

blue bent more than red



$n_1 = n_2$ for one of the glasses

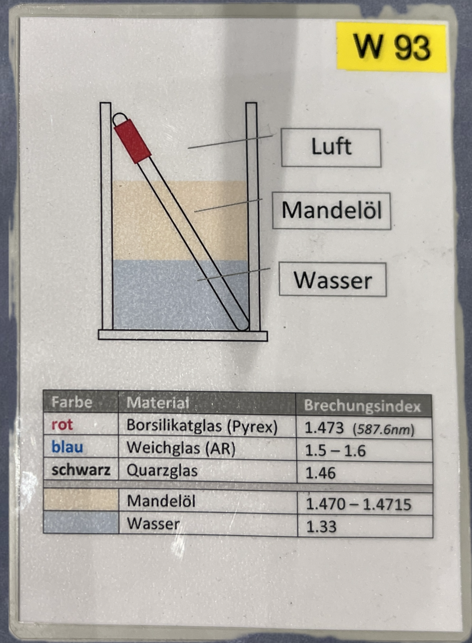


oil

water

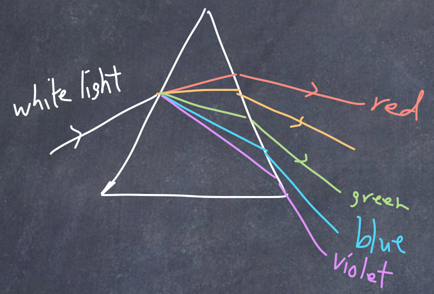
glass one

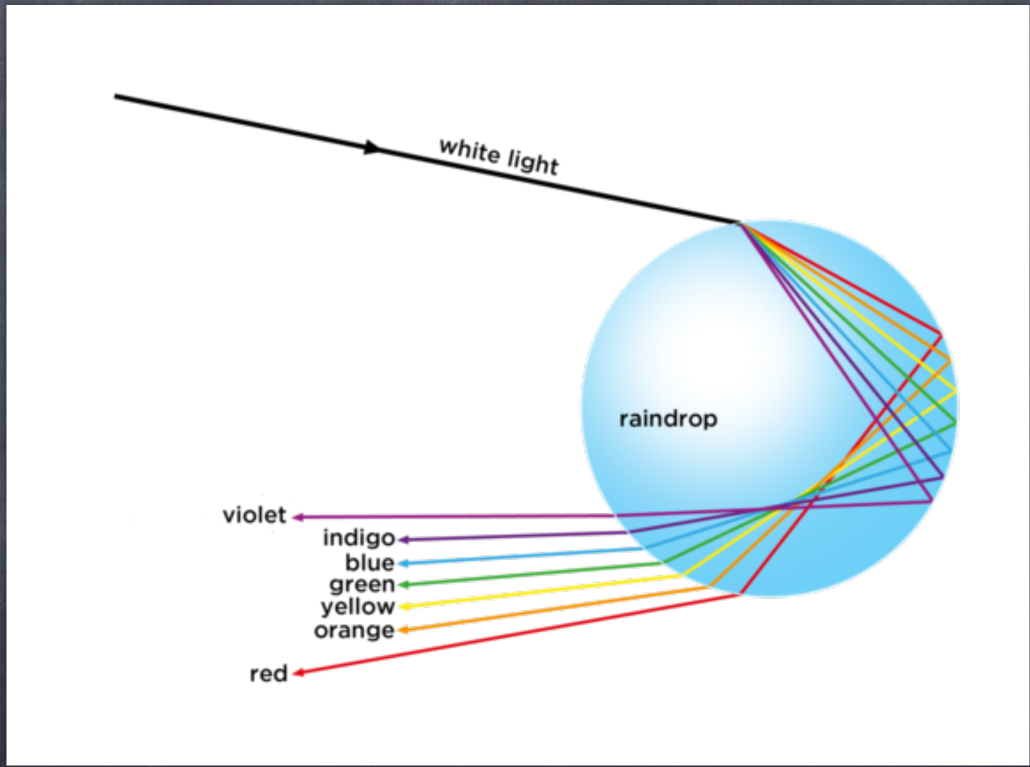
glass two



Farbe	Material	Brechungsindex
rot	Borsilikatglas (Pyrex)	1.473 (587.6nm)
blau	Weichglas (AR)	1.5 – 1.6
schwarz	Quarzglas	1.46
	Mandelöl	1.470 – 1.4715
	Wasser	1.33

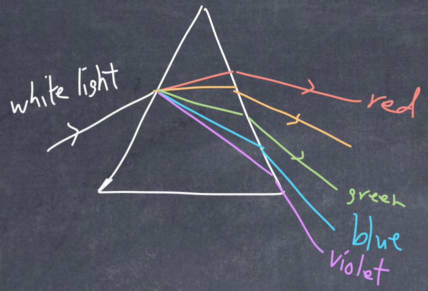
Light through a rain drop





Light is refracted at different angles depending on λ

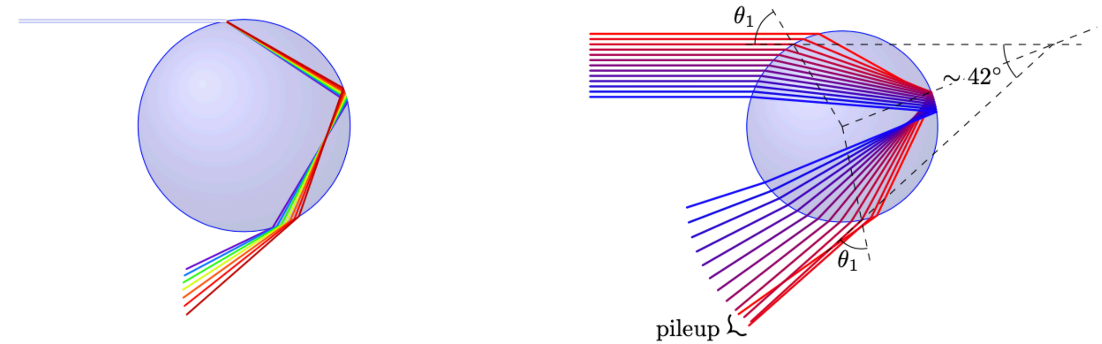
Pyramid:



water droplet sphere:

Different wavelengths:

Same wavelength
Different paths

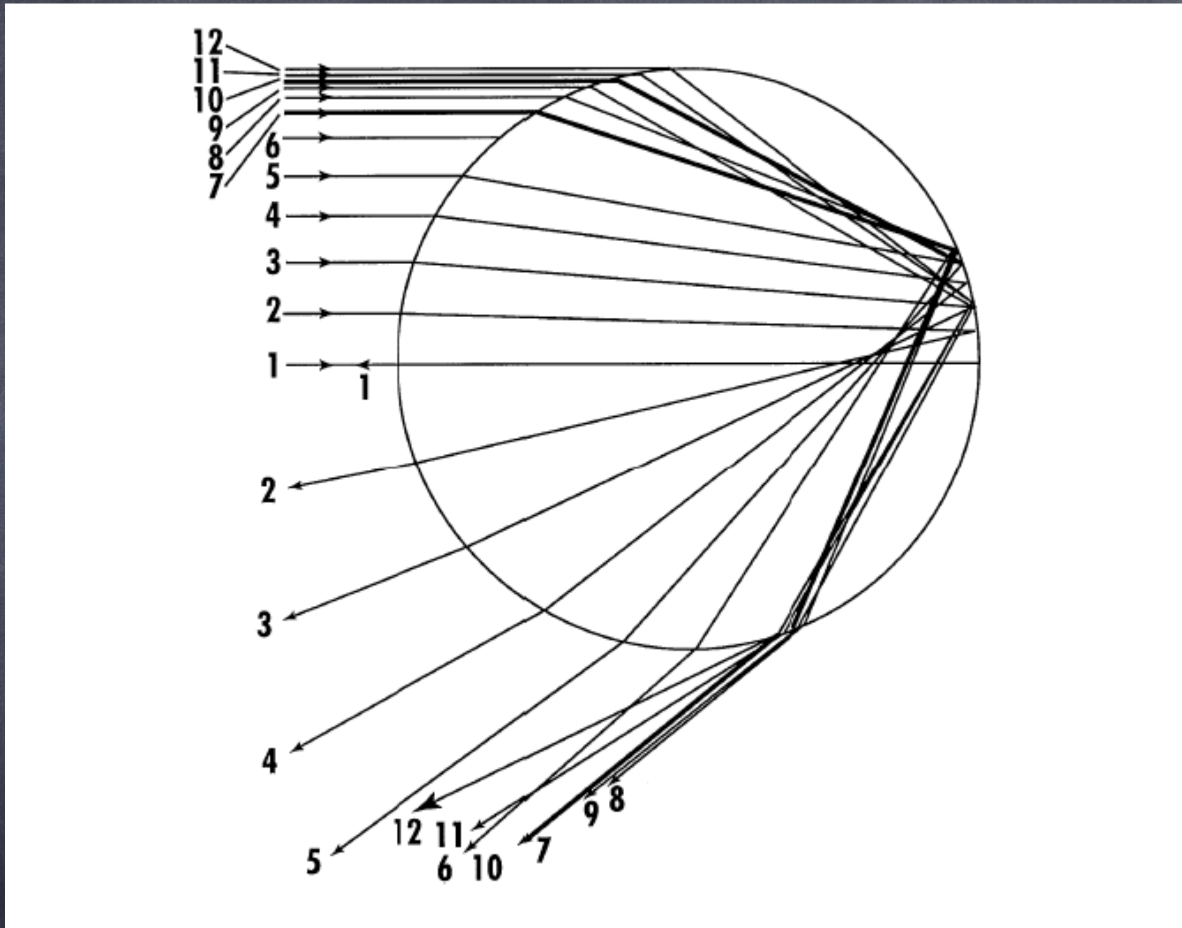


(a) A white light beam is spread in a rainbow due to dispersion (not to scale).

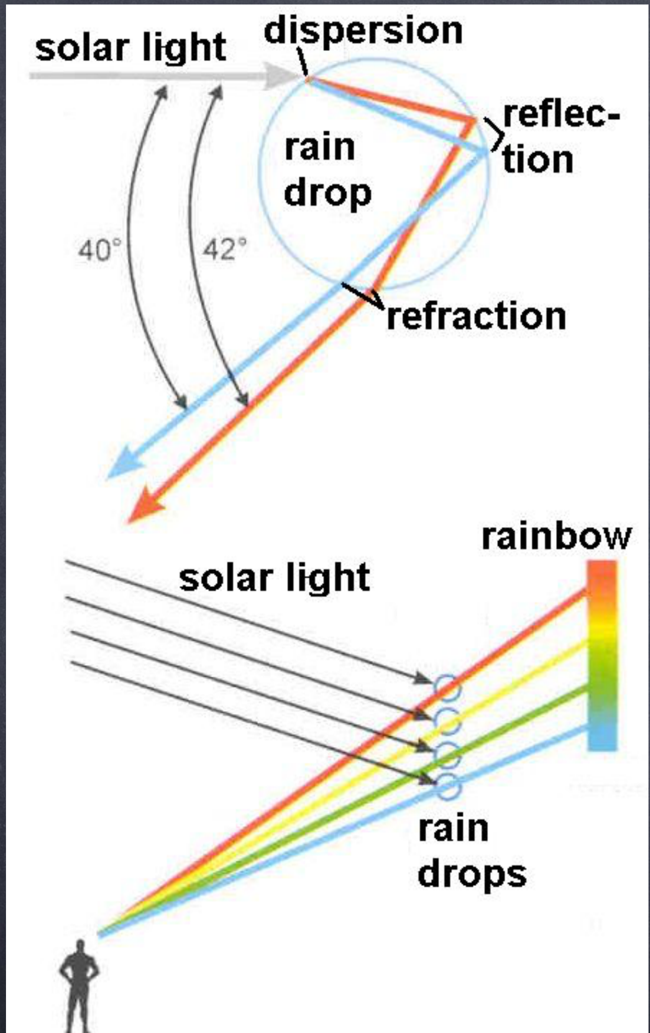
(b) At an effective reflection angle of about 42°, light is more concentrated (color unrelated to wavelength).

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

parallel
light
of same
wavelength
entering



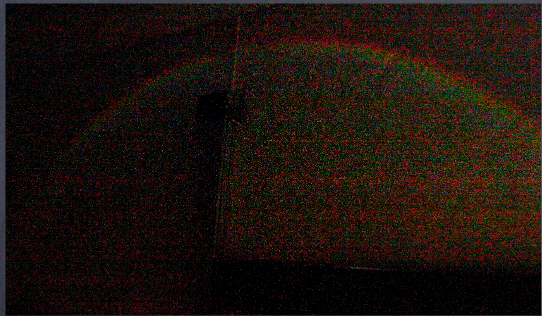
pileup of light
at a certain angle.



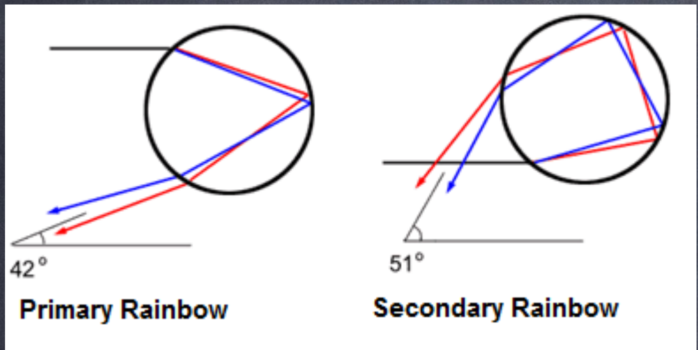
Blue light has an angle which piles up at 40°

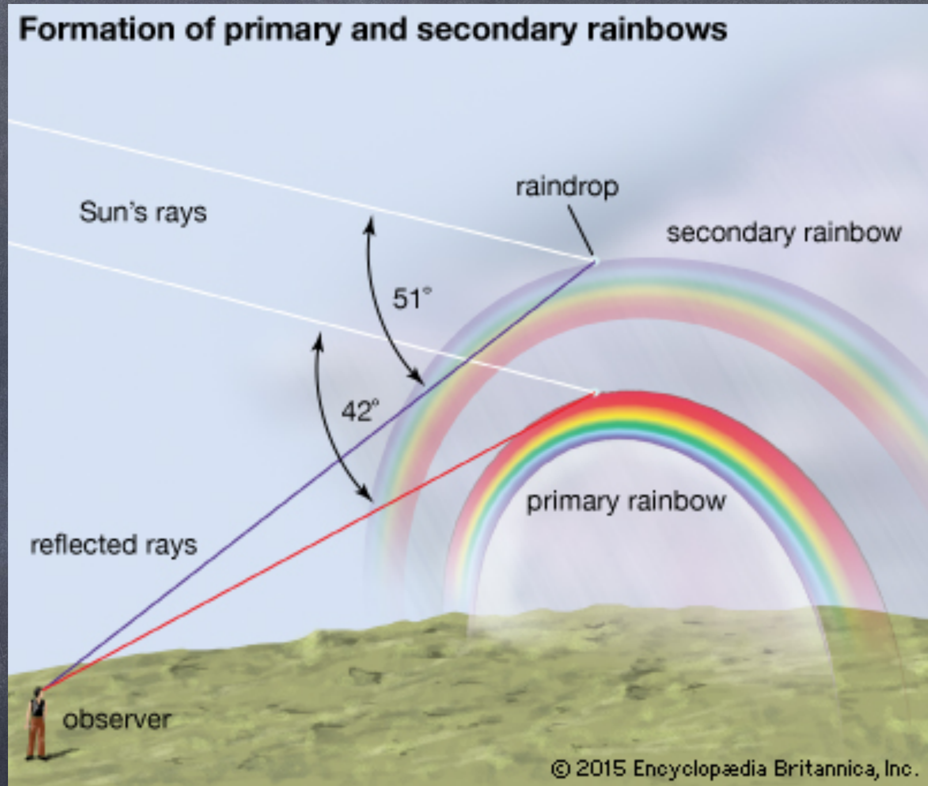
and red light has an angle of 42°

This is how a rainbow works



Sometimes, you even see a second, "inverted" rainbow.





~42°

Look out for the second one!

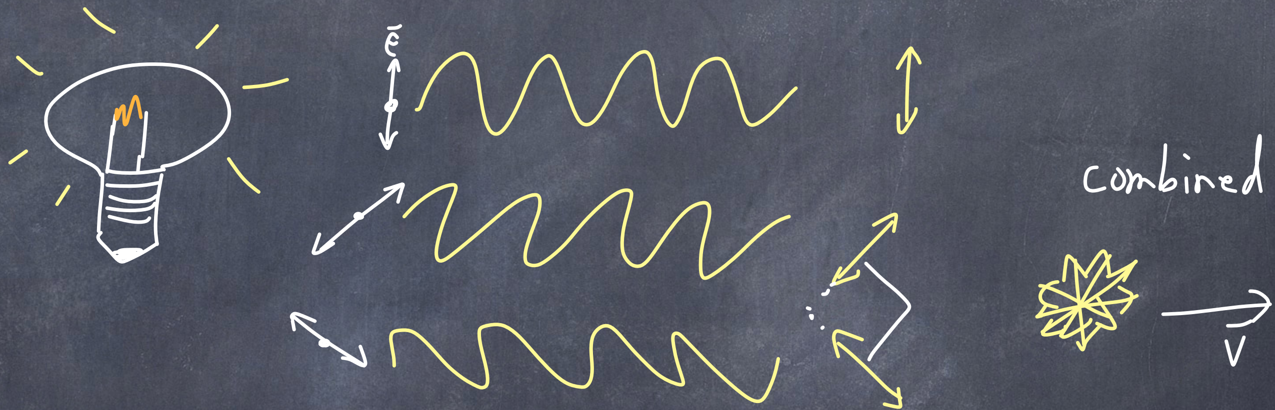
Polarization - in any transverse wave

linear polarization

$\bar{E}$ ∥ to just one axis

unpolarized

many sources oscillating in random directions (all $\bar{E}$ ⊥ to $\bar{v}$)



circular polarization - $\bar{E}$ rotates with time (* not in this class)

EM waves can be produced unpolarized in a substance since all atoms may act independently (random from heating)

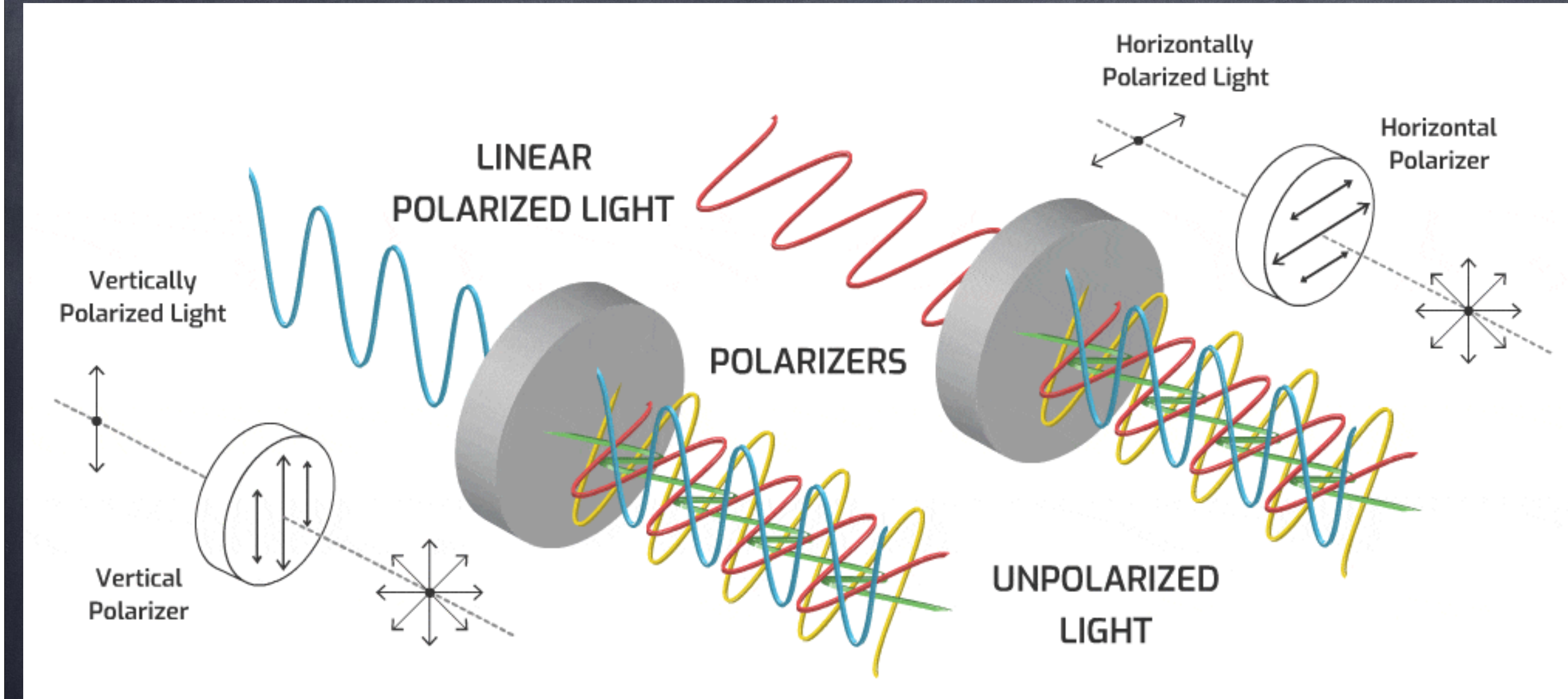
or polarized if coherent electric field

Polarized light can be produced from unpolarized light by:

1) absorption *
2) scattering
3) reflection *
4) birefringence

* In this class

absorption



polarizers can produce + detect polarized light

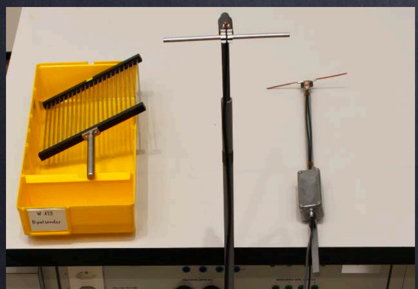
polarization by absorption:

When E-field is absorbed in one direction, then only the E-field ⊥ to the absorption is transmitted.

polarizing film or natural crystals

↑ long chains of hydrocarbons aligned, conducting at optical wavelengths.

Example of microwaves

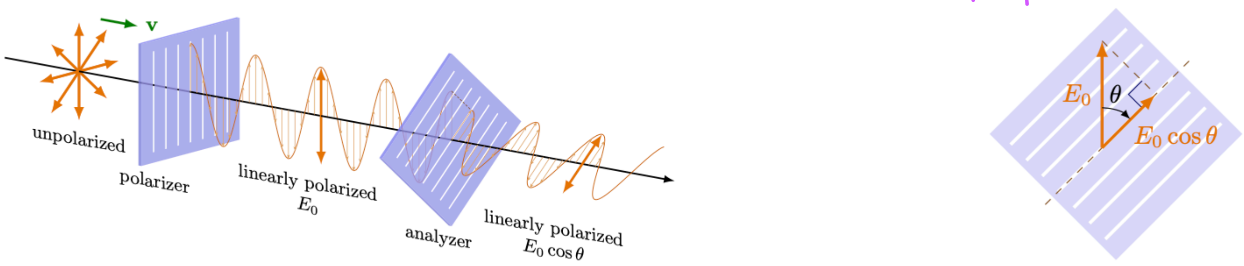


transmission axis is ⊥ to conductors

no light passes through

conductor parallel to $\vec{E}$ absorbs polarized light

$E_{transmitted} = E_0 \cos\theta$



(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.

Two polarizing absorbers: polarizer, analyzer

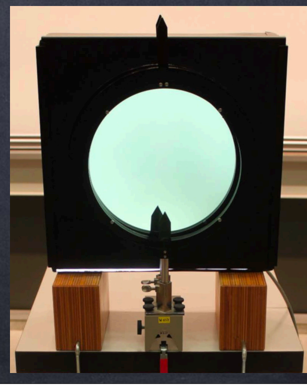
The intensity of light goes like $|E|^2$: $I \propto E^2$

(electric field $= E$)

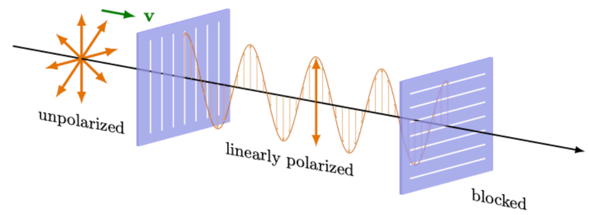
$$I = I_0 \cos^2\theta$$

Malus' Law

case: $\theta = 90^\circ \rightarrow I = 0$

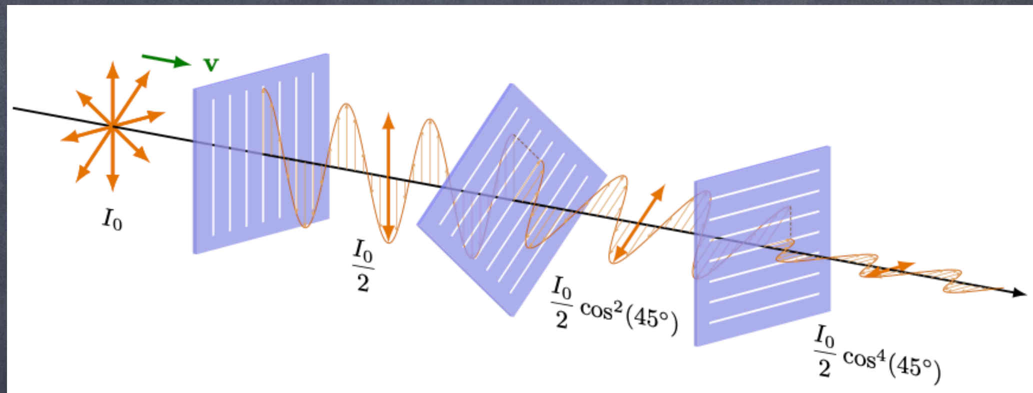


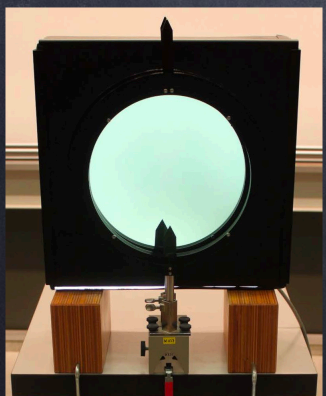
No light passes



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

Light passes





initial

intermediate

Final

Example: $\theta = 10°$

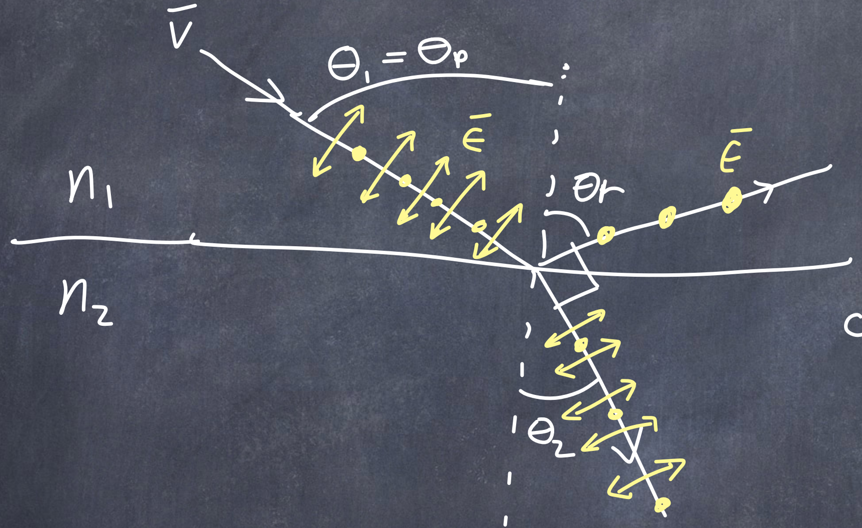
$I_1 = I_0 \cos^2 10°$

$\theta = 80°$

$I_2 = I_0 (\cos^2 10°)(\cos^2 80°)$

Polarization by reflection:

There is a partial polarization on the reflecting light reflected between two transparent media, such as air + glass, or air + water, ...



Incoming light as $\bar{E}$-field with 2 components, perpendicular to velocity

check: $\theta_r = \theta_1$

$\theta_r + 90° + \theta_2 = 180°$

If the angle of incidence $\theta_1 = \theta_p$ (polarization angle), which is defined such that there is a 90° angle between the reflected and refracted light, then the reflected light will be 100% polarized perpendicular to the plane of incidence.

The refracted light is slightly polarized.

Condition of polarization by reflection:

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

$\updownarrow$

θ_p

The condition is that $\theta_2 = 90^\circ - \theta_1$

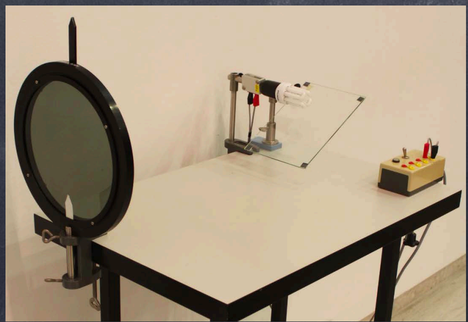
$$n_1 \sin\theta_p = n_2 \sin(90^\circ - \theta_p)$$

$$n_1 \sin\theta_p = n_2 \cos\theta_p$$

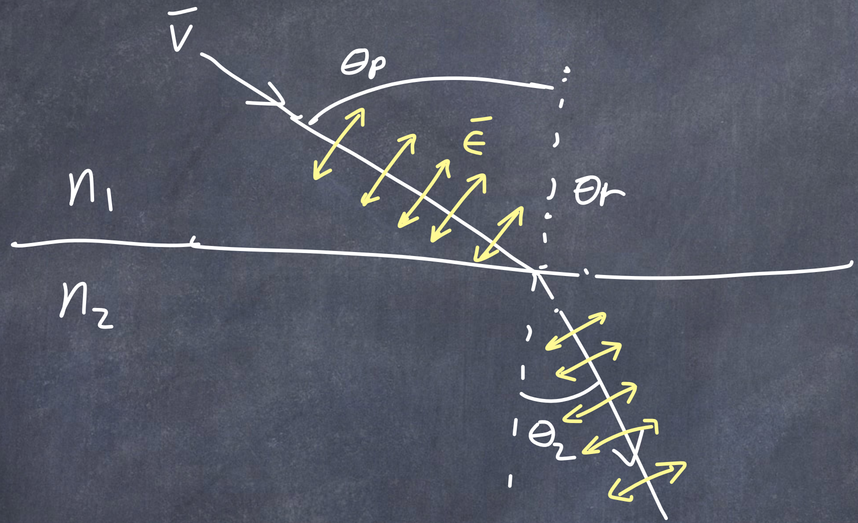
$$\tan\theta_p = \frac{n_2}{n_1}$$

Brewster's Law for the angle of complete polarizaton of reflected light

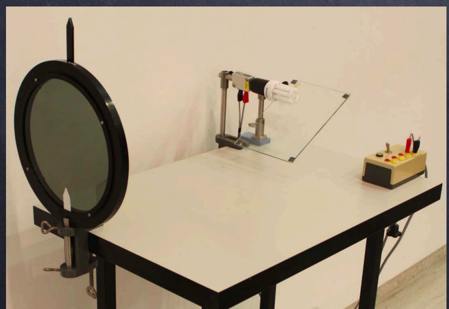
polarizer used as analyzer



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



then at $\theta_1 = \theta_p$, no reflection occurs



To calculate the B-field and E-field using Ampere's law and Gauss' law, one must define a closed surface.

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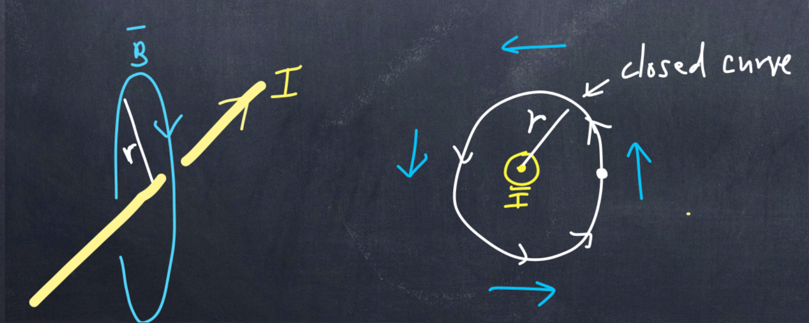
Ampere's Law

$$\oint_{\text{closed curve}} \bar{B} \cdot d\bar{l} = \mu_0 I_c$$

I_c : current passing through the closed curve.



The sum of the voltages into a junction are the same as the sum leaving the junction.

1

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18

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iv) The sum of currents into a junction must equal the sum of currents out of the junction.

Current decreases when it moves through a resistor.

17

26

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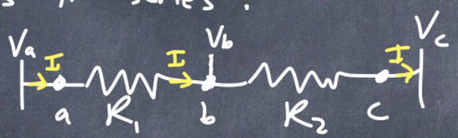
Resistors in series:



Note: opposite rules as for capacitors

Equivalent resistance

$$R_{eq} = R_1 + R_2 + \ldots$$

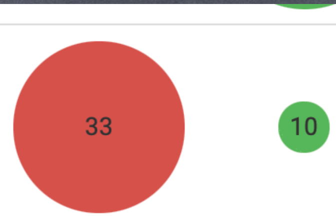
$$V_b = V_a - IR_1$$

$$V_c = V_a - IR_1 - IR_2$$

$$I_a = I_b = I_c = I$$

Potential decreases, current stays same.

A complete loop around any circuit will be equal to the battery voltage.



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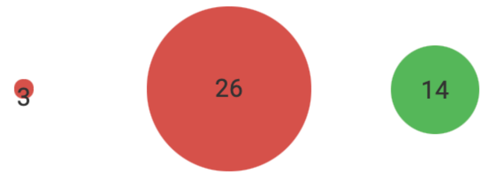
ii) Any complete loop around a circuit has a total potential change of zero.
(Potential difference between 2 points is always the same, no matter which path)

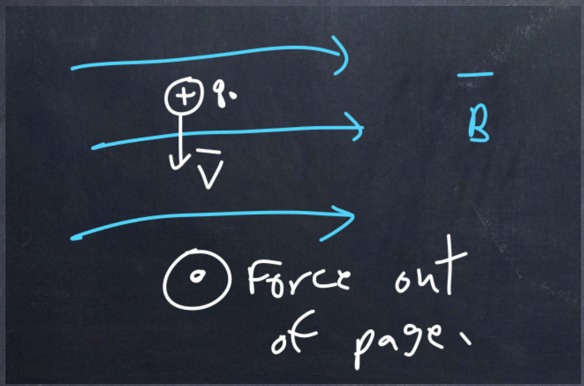
Loop: $+\mathcal{E} - IR = 0$

$IR = \mathcal{E}$

$I = \frac{\mathcal{E}}{R} = \frac{10V}{100\Omega} = 0.1\,A$

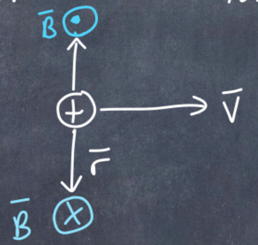
Since a moving charged particle produces a magnetic field, the charged particle will feel a force from its own movement.

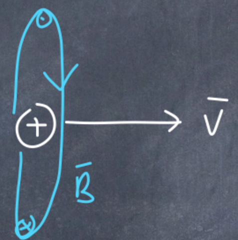




Now: A moving charge ⊕→ $\bar{v}$ generates its own magnetic field.

The direction of $\bar{B}$ is $\bar{v} \times \bar{r}$





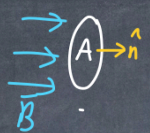
The magnetic field loops around the direction of motion.

The magnetic flux through 10 loops of optical fiber is 10 times more than through 1 loop.

3 17 23

Magnetic flux:

For a loop ⊥ to $\bar{B}$-field

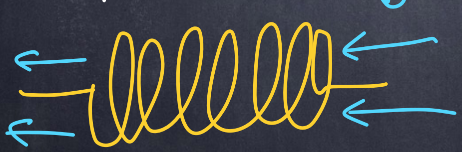


we can quantify the $\bar{B}$-field by

$$\phi_m = BA$$

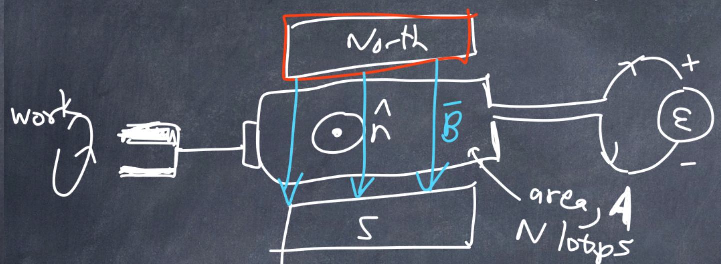
A : area

where ϕ_m is known as the magnetic flux



area, A of one loop

$\phi_m = NBA$



magnetic flux through loop : $\phi_m = NBA\cos\theta$

$\phi_m = NBA$

↑ # of loops

A 4-sided loop of current, in which all 4 sides are perpendicular to a magnetic field, feels zero net force, but a non-zero net torque.

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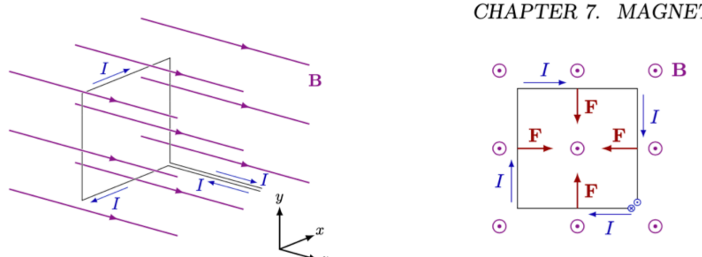
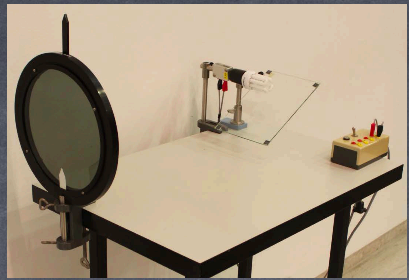


(a) 3D. (b) 2D in xy plane.

Figure 7.9: Rectangular current loop in an external, uniform magnetic field $\mathbf{B} = B\hat{\mathbf{z}}$.

No net force, no net torque


W51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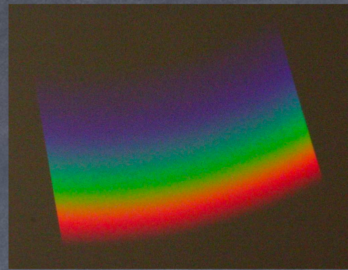
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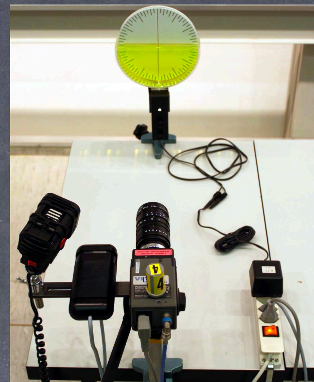
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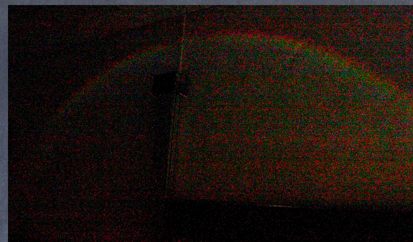
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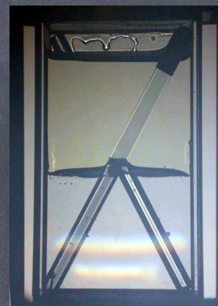
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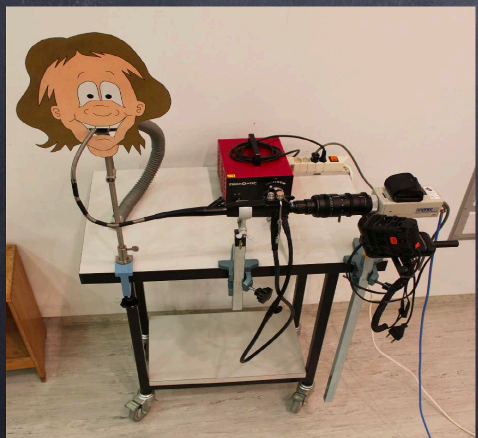
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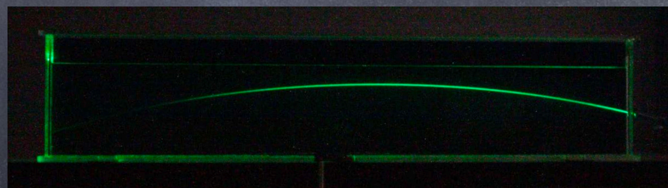
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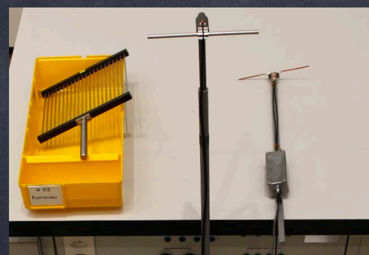
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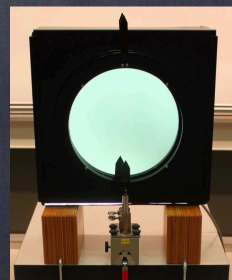
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