PHY117 HS2024

Today:
Geometric optics

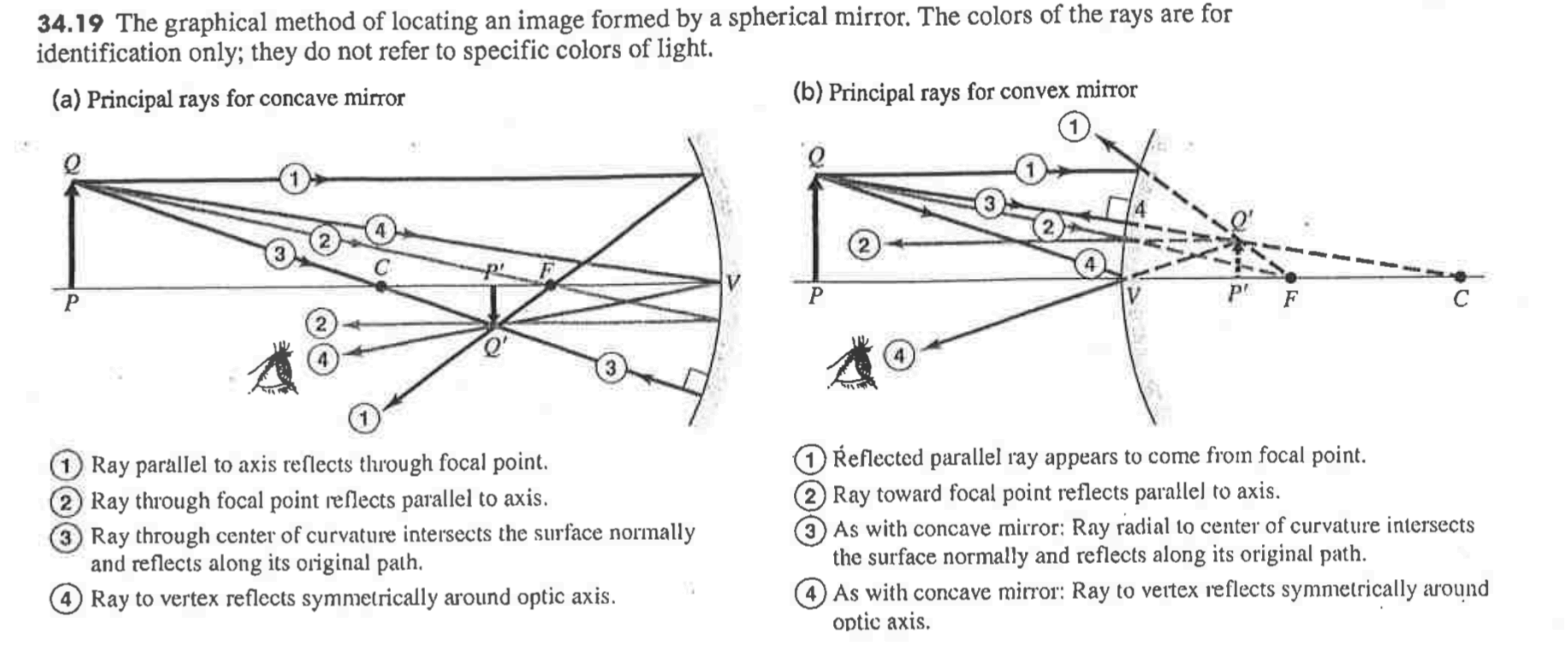
Last day!

Tomorrow: Frau Bründler will present the solutions to the last exercise sheet in Lecture Hall 60

(not here)

Week 10, Lecture 1
Dec. 17th, 2024
Prof. Ben Kilminster

Rules for mirrors



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.

Any 2 rays are enough to find the image, (position, & the height)

but more will check your answer.

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?

---

we know: $R = 10\text{ cm} \Rightarrow f = \frac{1}{2}R = 5\text{cm}$

$s = 3\text{cm}, \; y = 2\text{cm}$

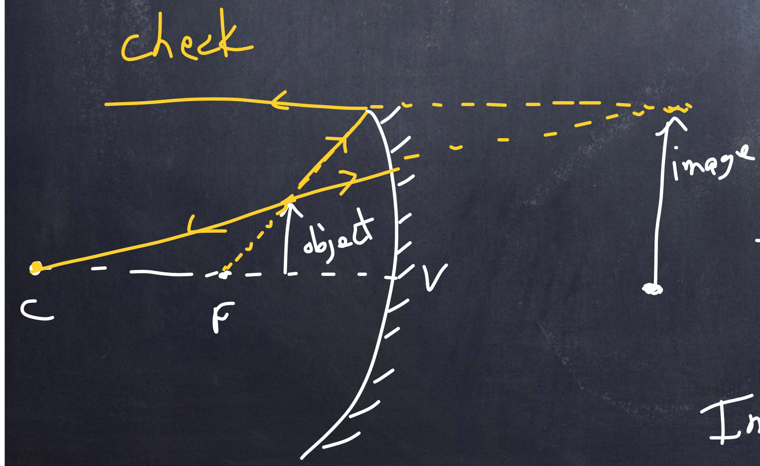
we need: $s' + y'$

solve for s': $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{5\text{cm}} - \frac{1}{3\text{cm}}$

$$\frac{1}{s'} = \frac{3-5}{15\text{cm}} = \frac{-2}{15\text{cm}}$$

$$s' = -7.5\text{ cm}$$

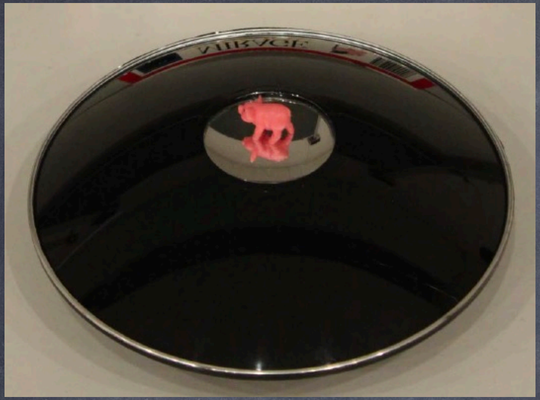
(7.5 cm behind mirror.



$$\frac{y'}{y} = m = \frac{-s'}{s} = -\left(\frac{-7.5\text{cm}}{3\text{ cm}}\right) = +2.5$$

$y' = my = (2.5)(2\text{cm}) = 5\text{cm}$ <u>new height</u>

Image is <u>not</u> inverted. Image is virtual.



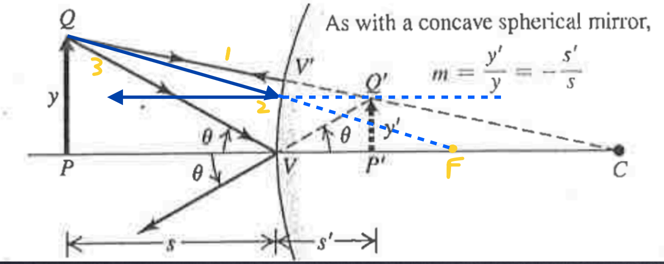
Convex mirror

ray 1: ray through the center

ray 2: ray through focal point

ray 3: ray to vertex

(b) Construction for finding the magnification of an image formed by a convex mirror



As with a concave spherical mirror,

$$m = \frac{y'}{y} = -\frac{s'}{s}$$

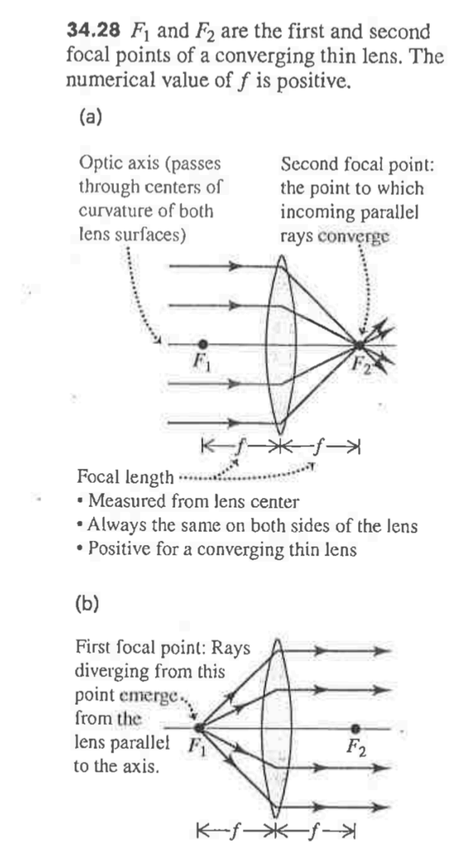
$$\left.\begin{array}{l} s \text{ is } + \\ s' \text{ is } - \end{array}\right\} \quad m = \frac{-s'}{s} = +$$

(not inverted)

Lenses refract light : rays either converge through focal point or diverge from focal point

converging lens

diverging lens



34.28 F_1 and F_2 are the first and second focal points of a converging thin lens. The numerical value of f is positive.

(a)

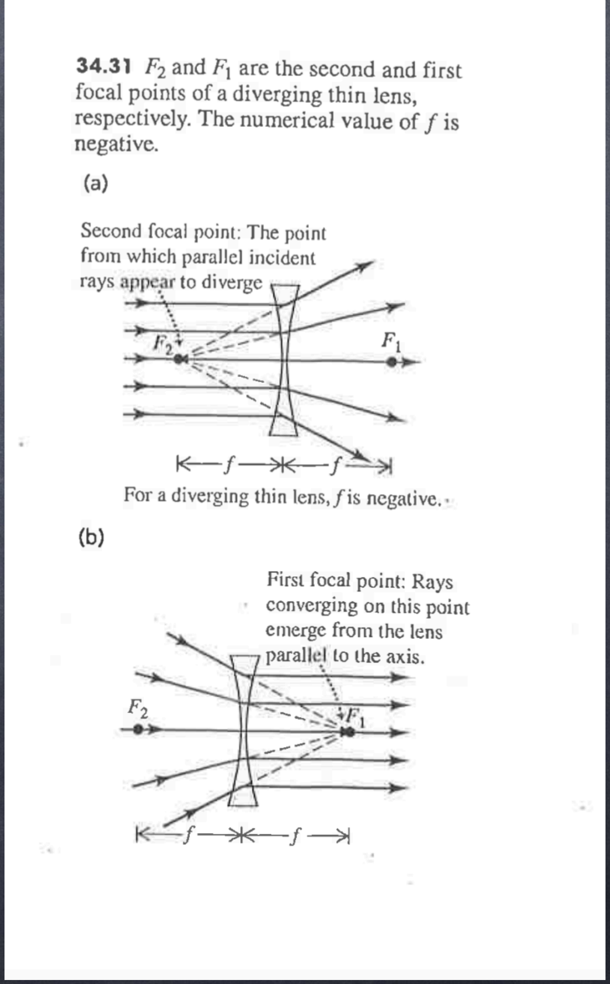
Optic axis (passes through centers of curvature of both lens surfaces)

Second focal point: the point to which incoming parallel rays converge

Focal length
- Measured from lens center
- Always the same on both sides of the lens
- Positive for a converging thin lens

(b)

First focal point: Rays diverging from this point emerge from the lens parallel to the axis.



34.31 F_2 and F_1 are the second and first focal points of a diverging thin lens, respectively. The numerical value of f is negative.

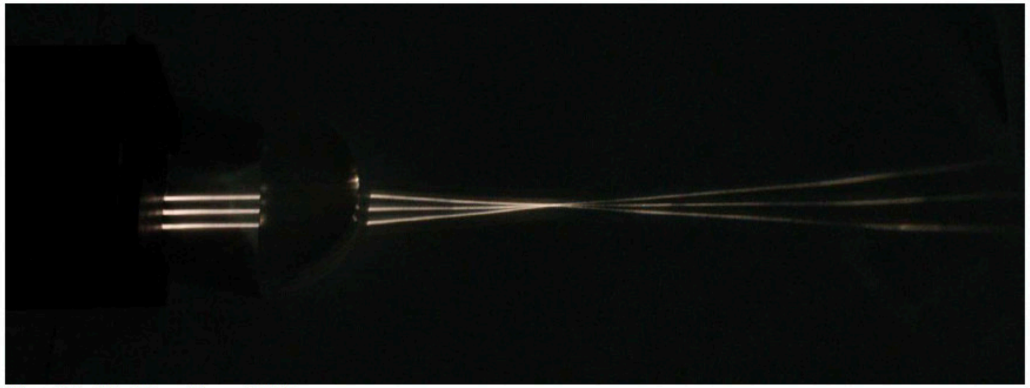
(a)

Second focal point: The point from which parallel incident rays appear to diverge

For a diverging thin lens, f is negative.

(b)

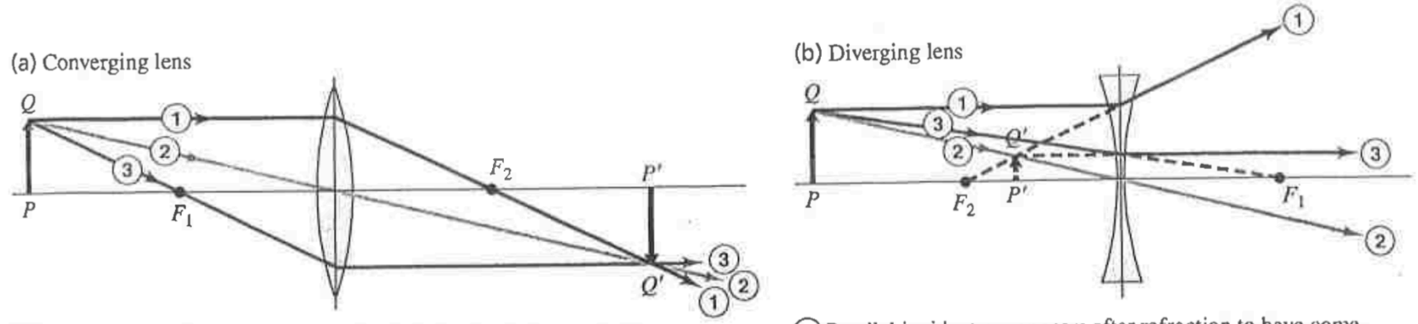
First focal point: Rays converging on this point emerge from the lens parallel to the axis.



Paraxiale Strahlen; Gauss Optik

Rules for lenses

34.36 The graphical method of locating an image formed by a thin lens. The colors of the rays are for identification only; they do not refer to specific colors of light. (Compare Fig. 34.19 for spherical mirrors.)



(a) Converging lens

① Parallel incident ray refracts to pass through second focal point F_2.
② Ray through center of lens does not deviate appreciably.
③ Ray through the first focal point F_1 emerges parallel to the axis.

(b) Diverging lens

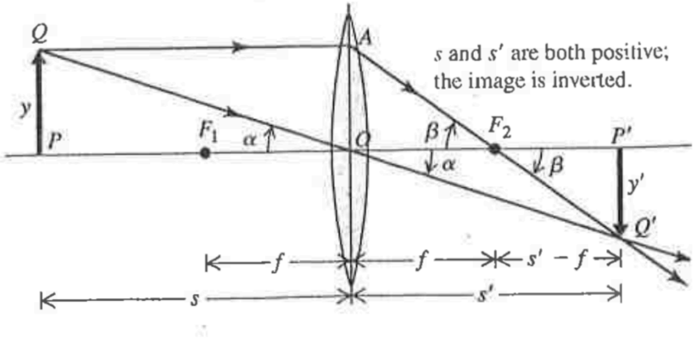
① Parallel incident ray appears after refraction to have come from the second focal point F_2.
② Ray through center of lens does not deviate appreciably.
③ Ray aimed at the first focal point F_1 emerges parallel to the axis.

s	+	(real object) for objects in front of the surface (incident side)
	−	(virtual object) for objects in back of the surface (transmission side)
s'	+	(real image) for images in back of the surface (transmission side)
	−	(virtual image) for images in front of the surface (incident side)
r, f	+	if the center of curvature is on the transmission side
	−	if the center of curvature is on the incident side

As with mirrors,
$f > 0$, converging lens
$f < 0$, diverging lens

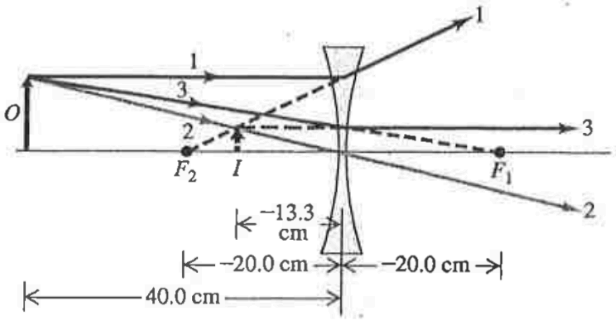
Also, $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $\quad m = \frac{y'}{y} = -\frac{s'}{s}$

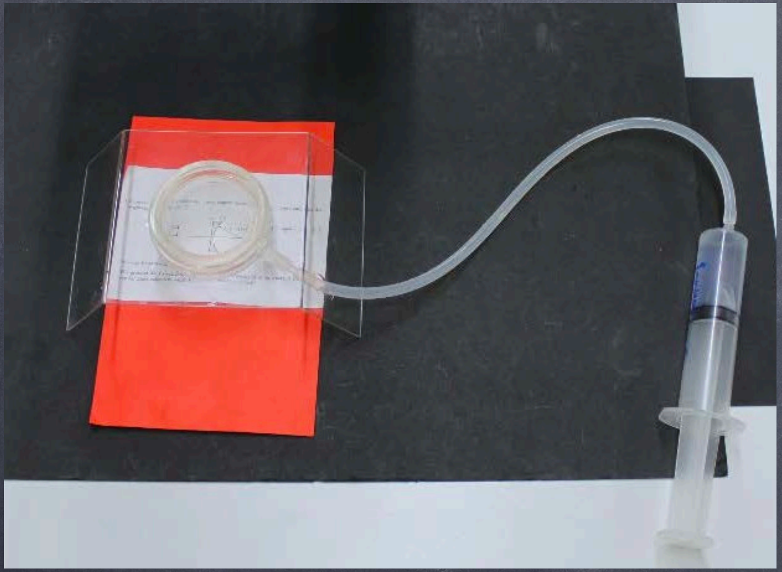
34.29 Construction used to find image position for a thin lens. To emphasize that the lens is assumed to be very thin, the ray QAQ' is shown as bent at the midplane of the lens rather than at the two surfaces and ray QOQ' is shown as a straight line.

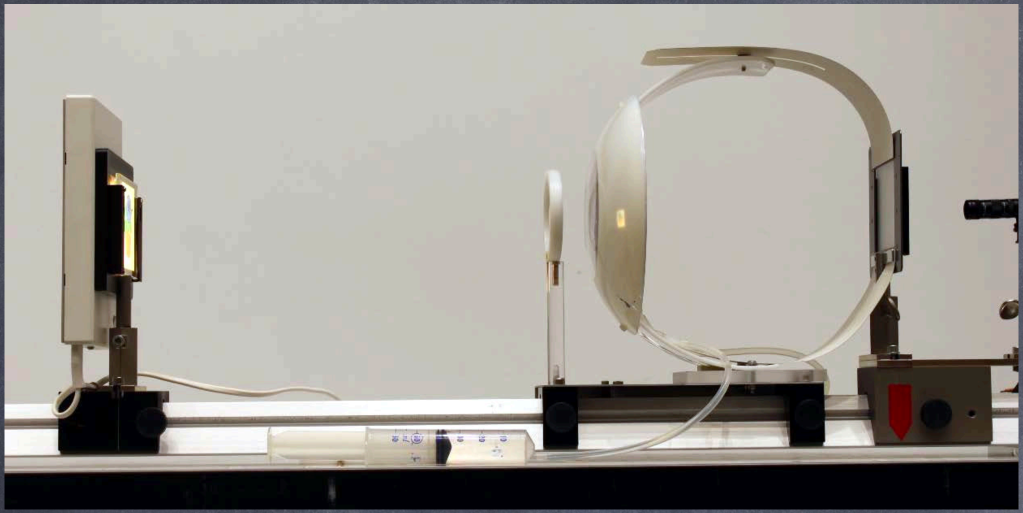


s and s' are both positive; the image is inverted.

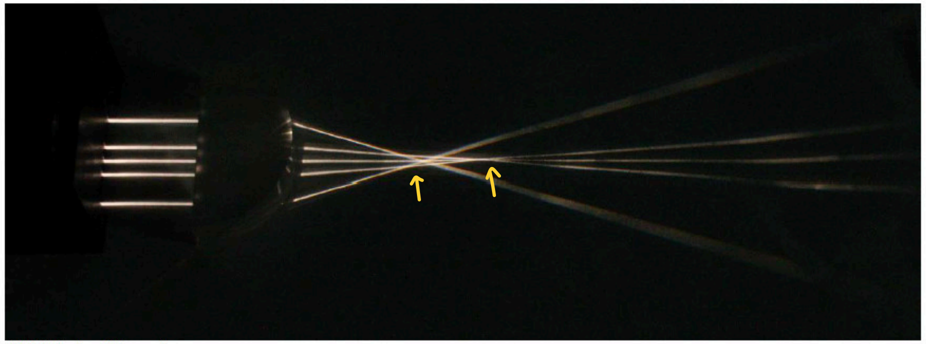
34.38 Principal-ray diagram for an image formed by a thin diverging lens.



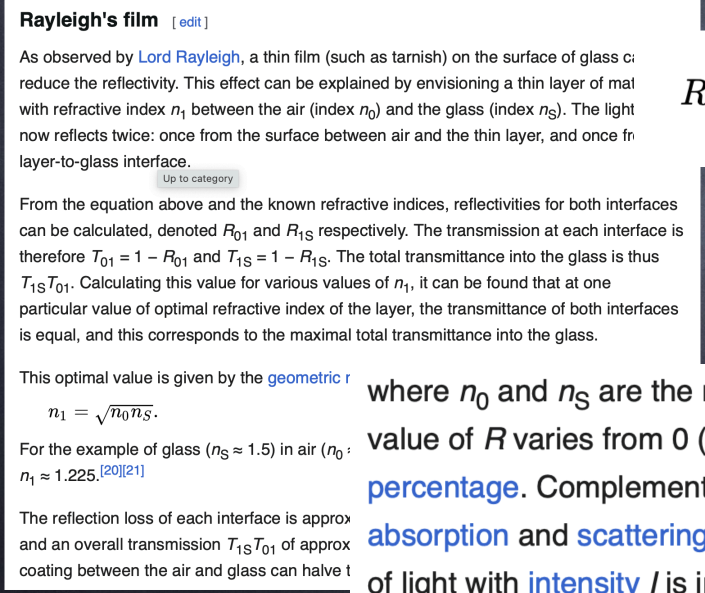




Spherical aberration



Sphärische Aberration



Rayleigh's film

As observed by Lord Rayleigh, a thin film (such as tarnish) on the surface of glass ca
reduce the reflectivity. This effect can be explained by envisioning a thin layer of mat
with refractive index n_1 between the air (index n_0) and the glass (index n_S). The light
now reflects twice: once from the surface between air and the thin layer, and once fr
layer-to-glass interface.

From the equation above and the known refractive indices, reflectivities for both interfaces can be calculated, denoted R_{01} and R_{1S} respectively. The transmission at each interface is therefore $T_{01} = 1 - R_{01}$ and $T_{1S} = 1 - R_{1S}$. The total transmittance into the glass is thus $T_{1S}T_{01}$. Calculating this value for various values of n_1, it can be found that at one particular value of optimal refractive index of the layer, the transmittance of both interfaces is equal, and this corresponds to the maximal total transmittance into the glass.

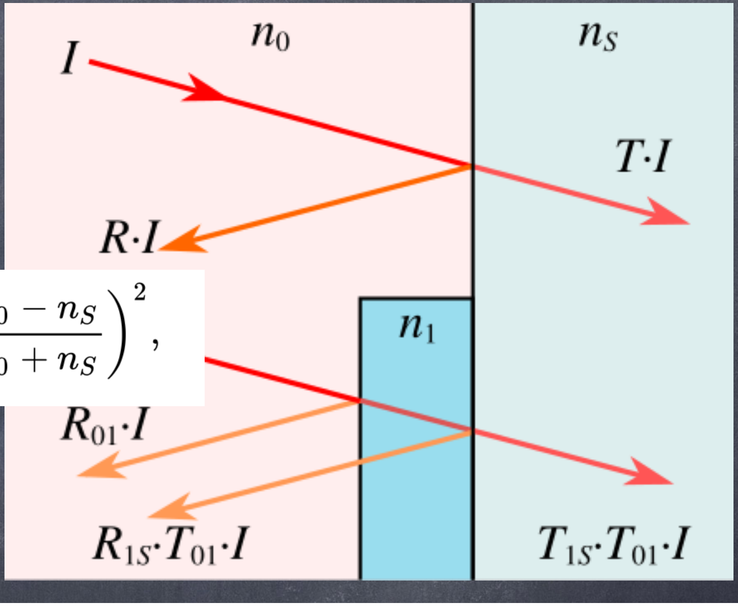
This optimal value is given by the geometric r

$$n_1 = \sqrt{n_0 n_S}.$$

For the example of glass ($n_S \approx 1.5$) in air (n_0
$n_1 \approx 1.225$.[20][21]

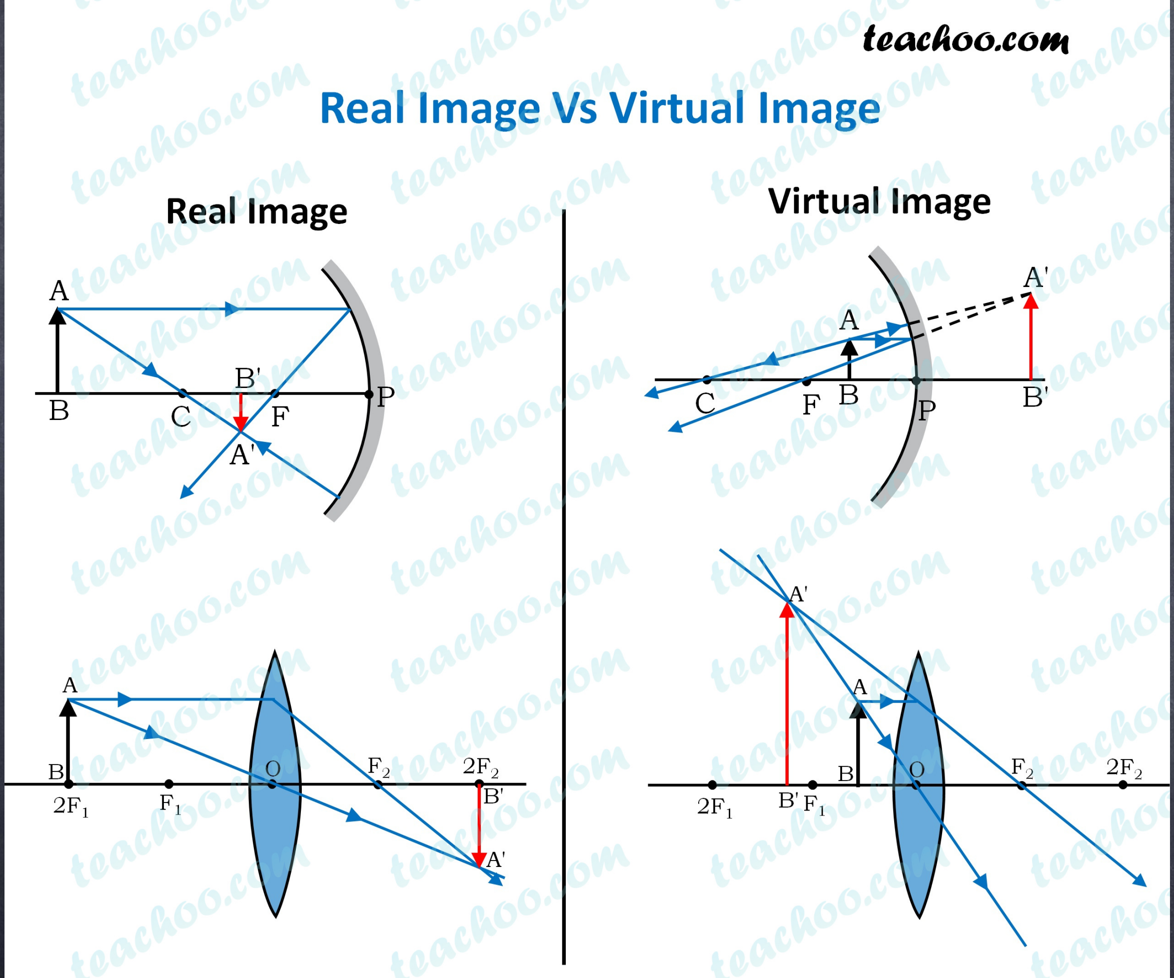
The reflection loss of each interface is approx
and an overall transmission $T_{1S}T_{01}$ of approx
coating between the air and glass can halve t

$$R = \left(\frac{n_0 - n_S}{n_0 + n_S}\right)^2,$$



where n_0 and n_S are the refractive indices of the first and second media respectively. The value of R varies from 0 (no reflection) to 1 (all light reflected) and is usually quoted as a percentage. Complementary to R is the *transmission coefficient*, or *transmittance*, T. If absorption and scattering are neglected, then the value T is always $1 - R$. Thus if a beam of light with intensity I is incident on the surface, a beam of intensity RI is reflected, and a beam with intensity TI is transmitted into the medium.

Summary of lenses & mirrors (real vs. virtual)



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Real Image Vs Virtual Image

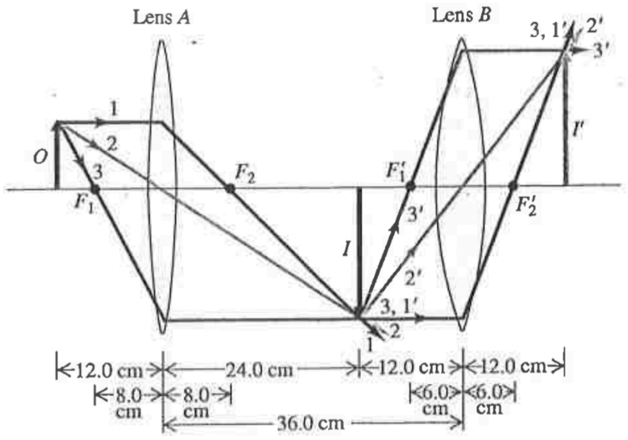
Real Image

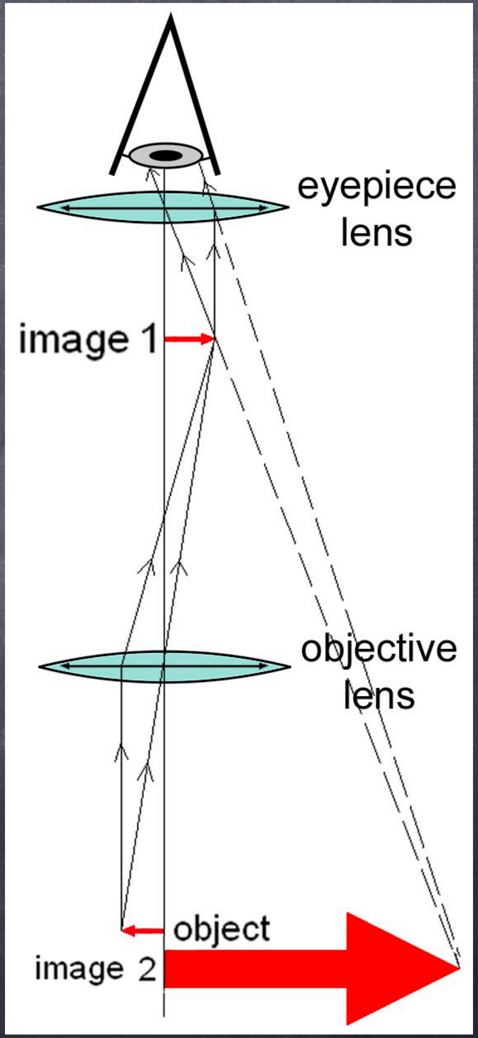
Virtual Image

Note: image depends on object location with respect to Focus combination of lenses:

microscope uses 2 lenses to magnify objects.

34.39 Principal-ray diagram for a combination of two converging lenses. The first lens (*A*) makes a real image of the object. This real image acts as an object for the second lens (*B*).

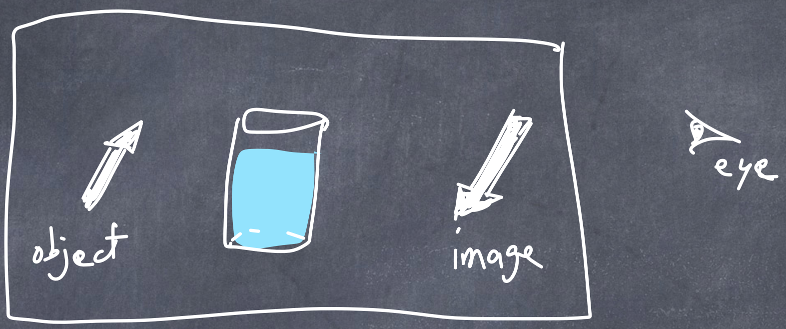




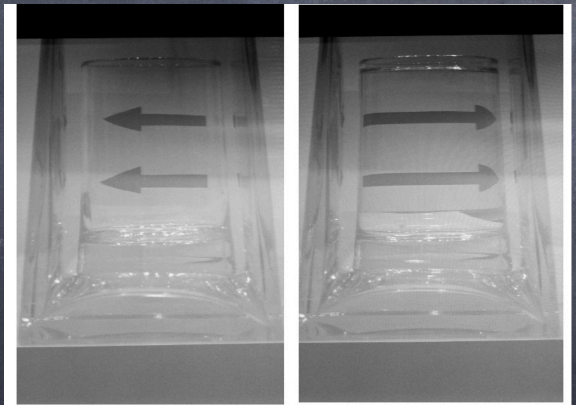
first, find image 1.

second, ignore lens 1, + calculate image 2 using image 1 as object + lens 2.

water glass



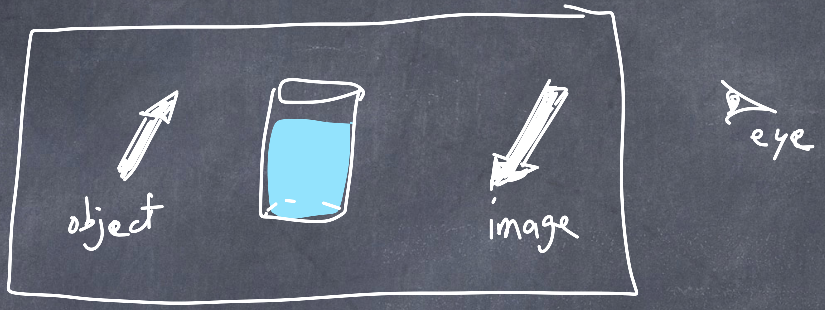
How?


ohne Wasser

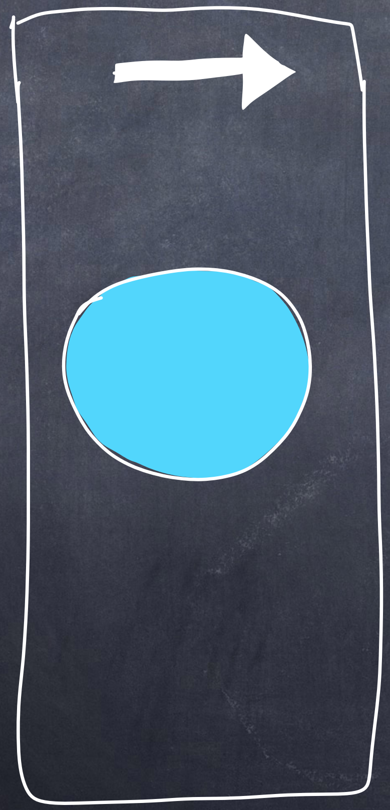
Wasser im Glas

water glass

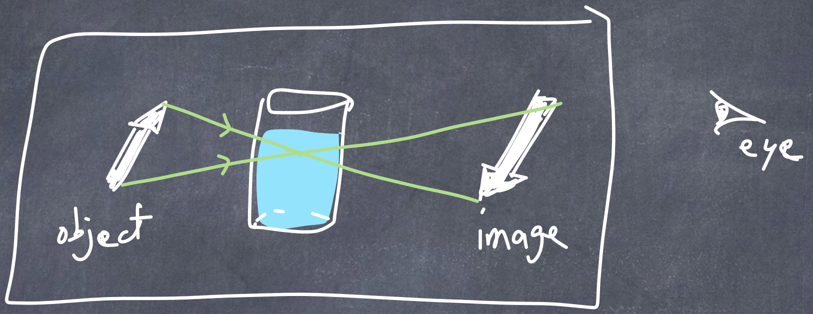
How?



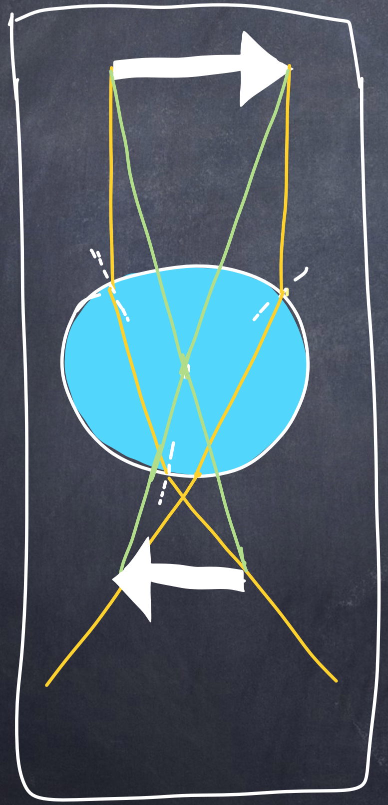
from above:



water glass

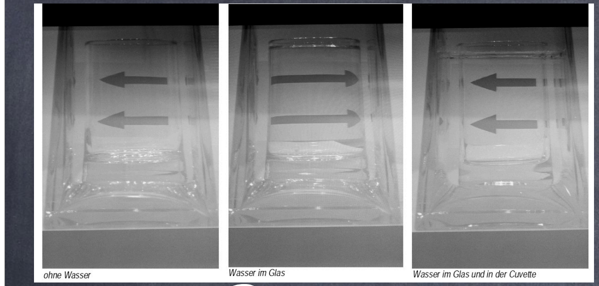


from above:




ohne Wasser
Wasser im Glas

water glass

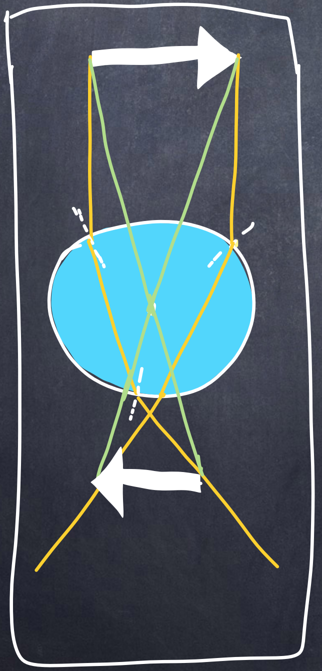


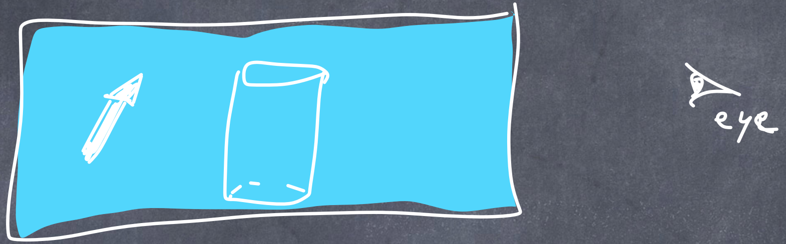
ohne Wasser

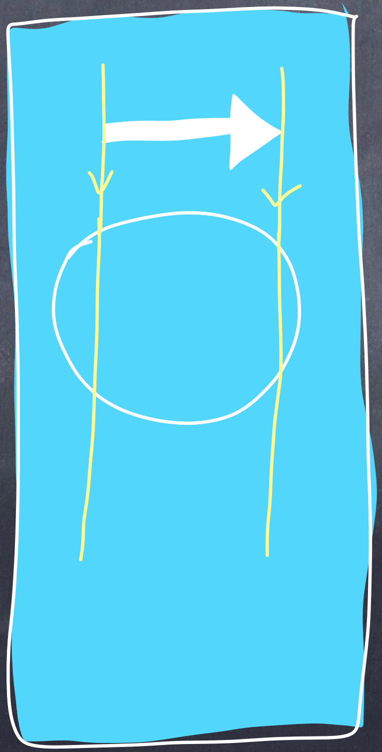
Wasser im Glas

Wasser im Glas und in der Cuvette

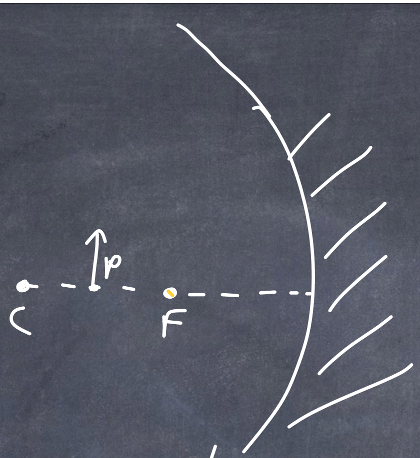
from above:







Other example:



where is p'?

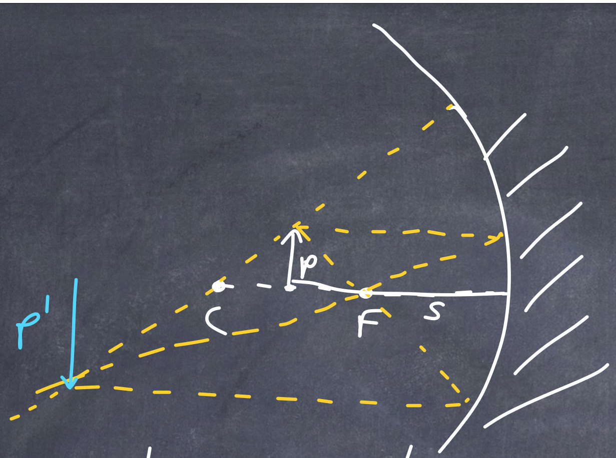
Real or virtual?

Upright or inverted?

Larger or smaller?

Try this example.

Answer on next page.



where is p' ?

s is $+$

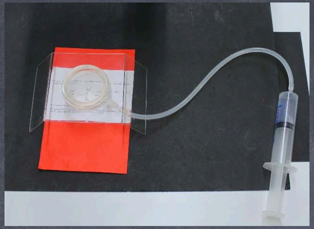
s' is $+$

m is $-$ (inverted)

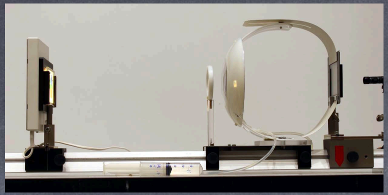
$y' > y$ (image is larger)

$\Rightarrow$ image is real & inverted & larger

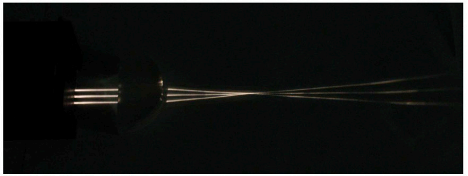
W71



W81

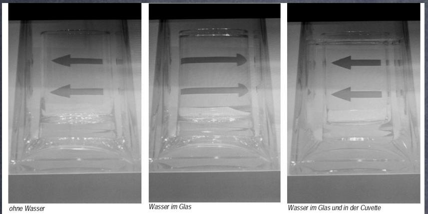


W82



Paraxiale Strahlen; Gauss Optik

W83

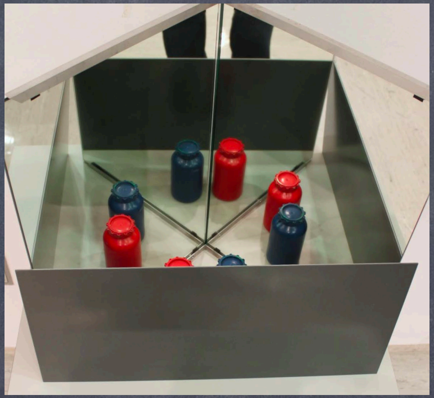


ohne Wasser

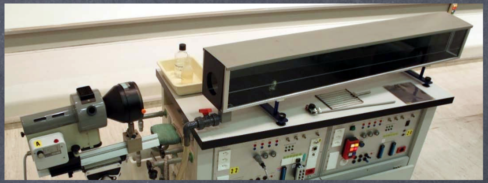
Wasser im Glas

Wasser im Glas und in der Cuvette

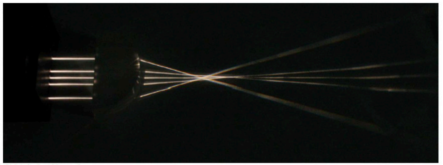
W88



W69

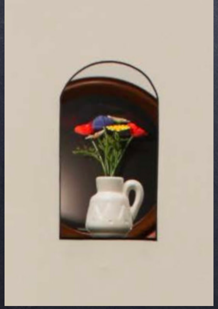


W145

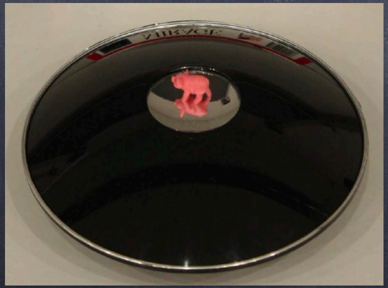


Sphärische Aberration

W84

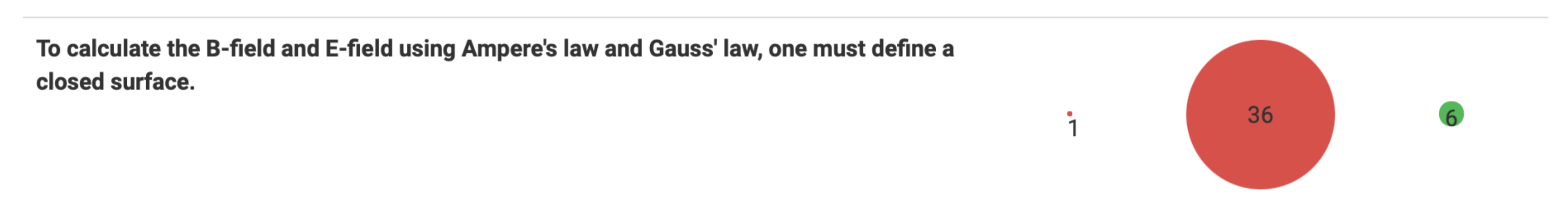


W70



W72

W121



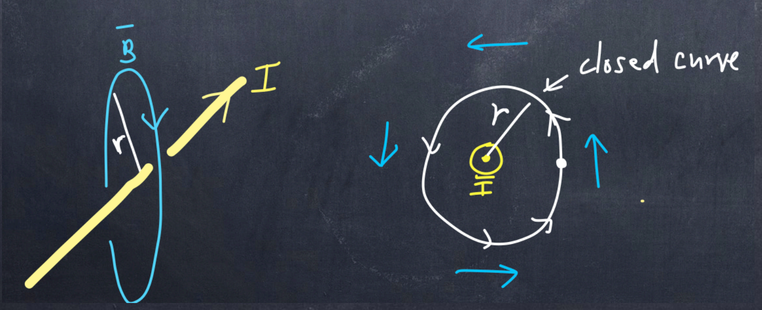
To calculate the B-field and E-field using Ampere's law and Gauss' law, one must define a closed surface.

FALSE

Ampere's Law

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

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.

FALSE

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

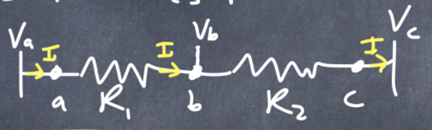
Current decreases when it moves through a resistor.

🟥 17

🟩 26

FALSE

Resistors in series :



Note: opposite rules as for capacitors

Equivalent resistance

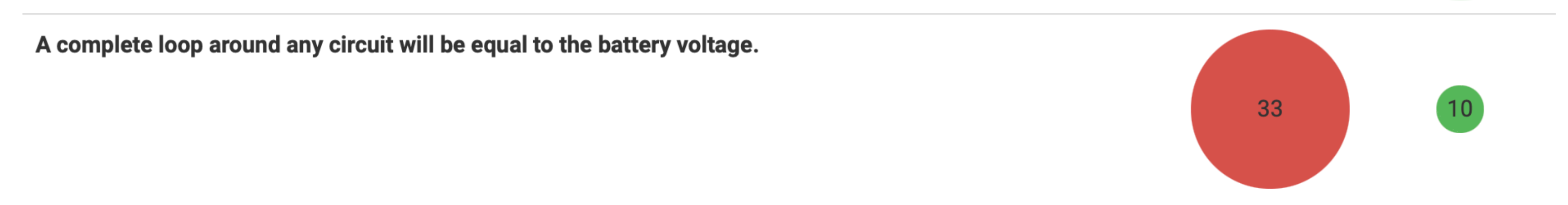
$$\boxed{R_{eq} = R_1 + R_2 + \ldots}$$

$$V_b = V_a - IR_1$$

$$V_c = V_a - IR_1 - IR_2$$

$$\underline{I_a = I_b = I_c = I}$$

Potential decreases, current stays same.



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

FALSE

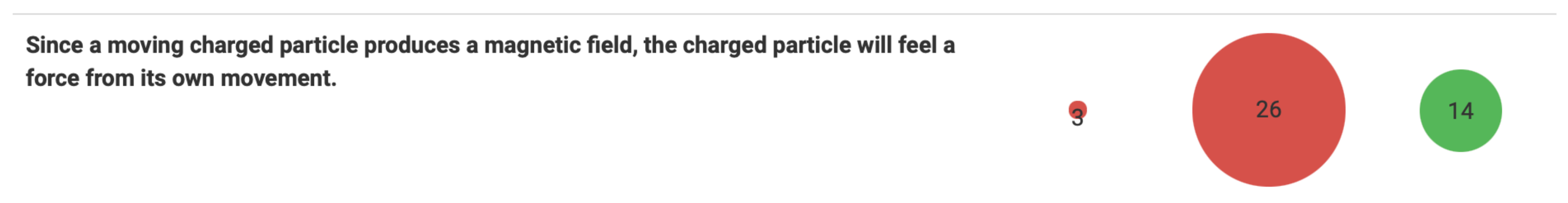
(i) Any complete loop around a circuit has a total potential change of zero.
(Potential difference between 2 points is always the same, no matter which path)

↓

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

$$IR = \mathcal{E}$$

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



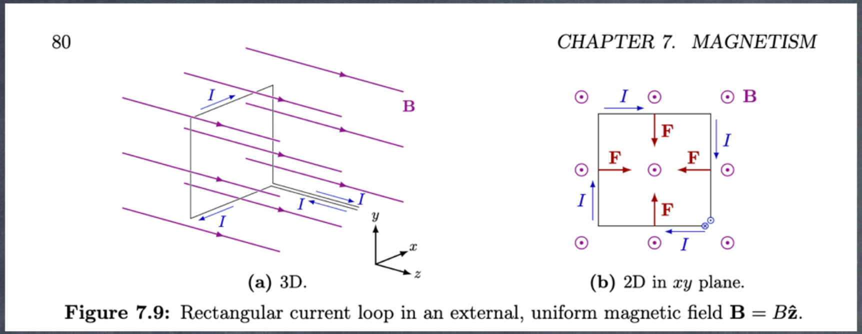
Since a moving charged particle produces a magnetic field, the charged particle will feel a force from its own movement.

FALSE.

Force comes from other B-Fields.

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.

FALSE



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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

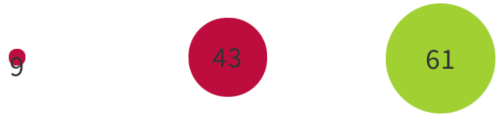
If the pressure of an ideal gas changes, but the volume doesn't change, work is still done.

FALSE

work requires a volume change

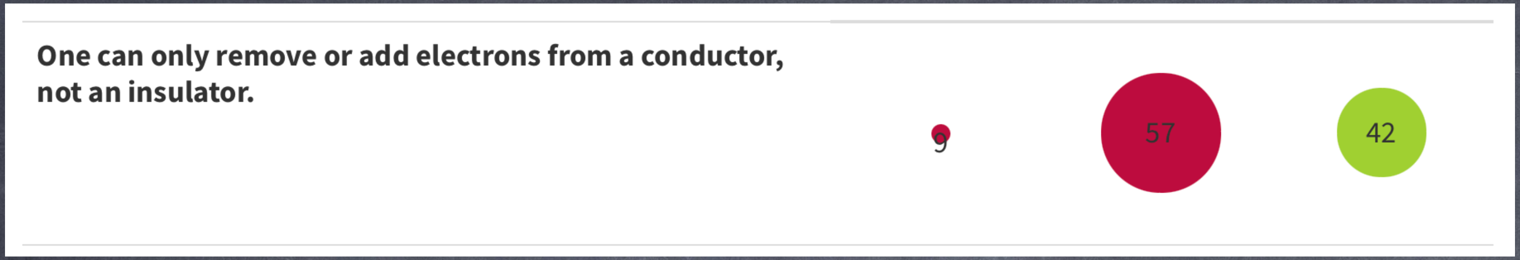
$$W = \int \underline{P}\, dV$$

At equilbrium, a conducting bar connecting a bath of boiling water and a bath of liquid nitrogen, will have a constant temperature, equal to the average of the two baths.



FALSE.

Temperature will vary linearly across bar.
(see lecture expt)



One can only remove or add electrons from a conductor, not an insulator.

FALSE.

we can charge a rubber balloon for instance

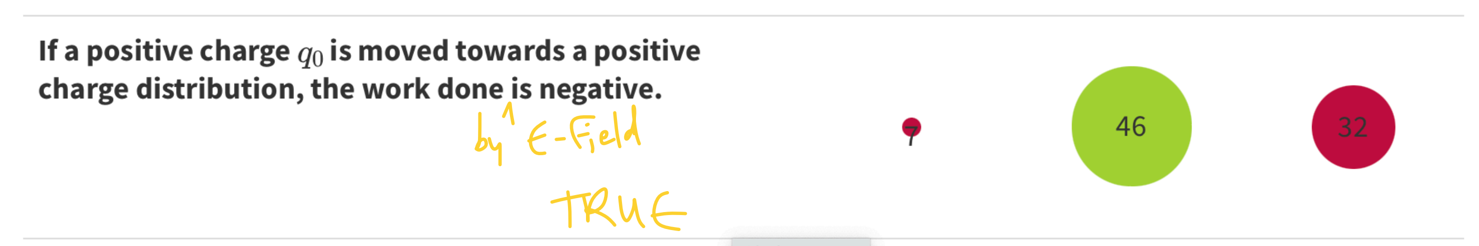
The electric field that an electric charge experiences depends on whether it is positive or negative.

FALSE.

E-Field is always the same no matter what test charge we use.

The force will be different depending on the magnitude & sign of the charge.

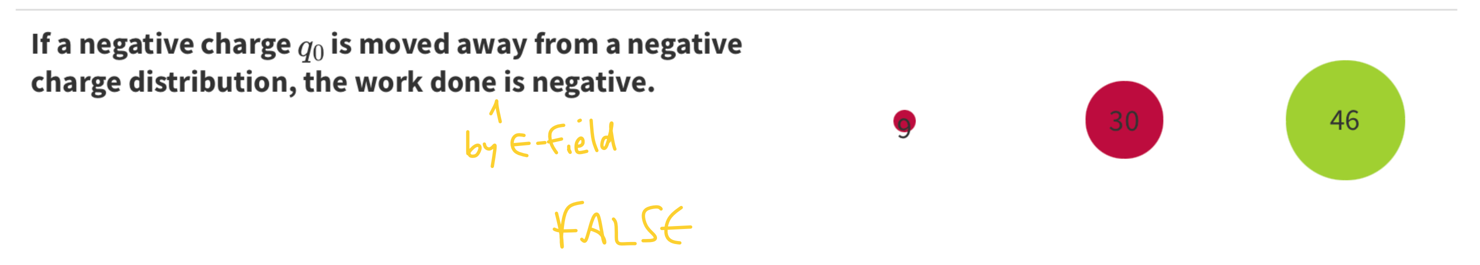
1)


If a positive charge q_0 is moved towards a positive charge distribution, the work done is negative.

by E-Field

TRUE

2)


If a negative charge q_0 is moved away from a negative charge distribution, the work done is negative.

by E-Field

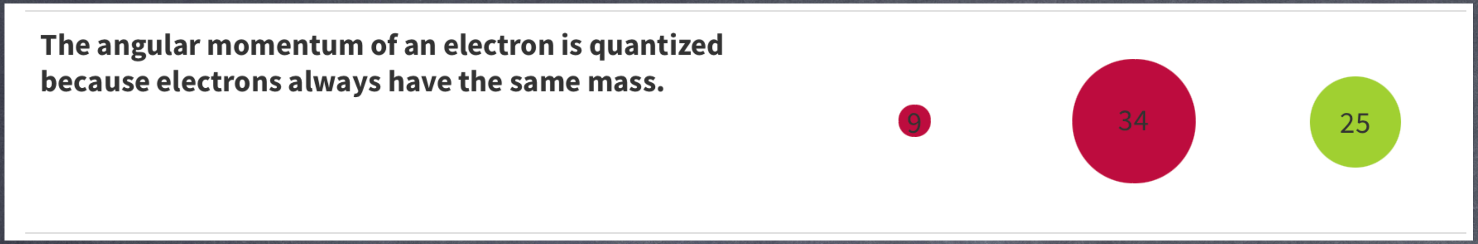
FALSE

we should have said the work done by what.

For 1) negative work is done by the Field, but positive work is done by us to push against the force

$$W = \underset{(\text{Force})}{\underset{(-)}{\bar{F}}} \cdot \underset{(\text{motion})}{\underset{(+)}{\bar{x}}} \quad \text{so}$$

for 2) positive work done by field, negative work done by us.



The angular momentum of an electron is quantized because electrons always have the same mass.

FALSE. Angular momentum is quantized because of the wave-like nature of electrons that can form standing waves.

I understand that if electrons all had different masses, then they would have different angular momentum because of that.

But the fact that $\bar{L}$ is quantized comes from its have-like nature.

Diamagnetic materials are those which are magnetically repelled from electric dipoles.

FALSE.

Magnets are not repelled or attracted to electric dipoles.

The velocity of a standing wave depends on the size of the disturbance.

FALSE

For instance, on a string $v = \sqrt{\frac{T}{\mu}}$,
so it only depends on
tension + mass density.

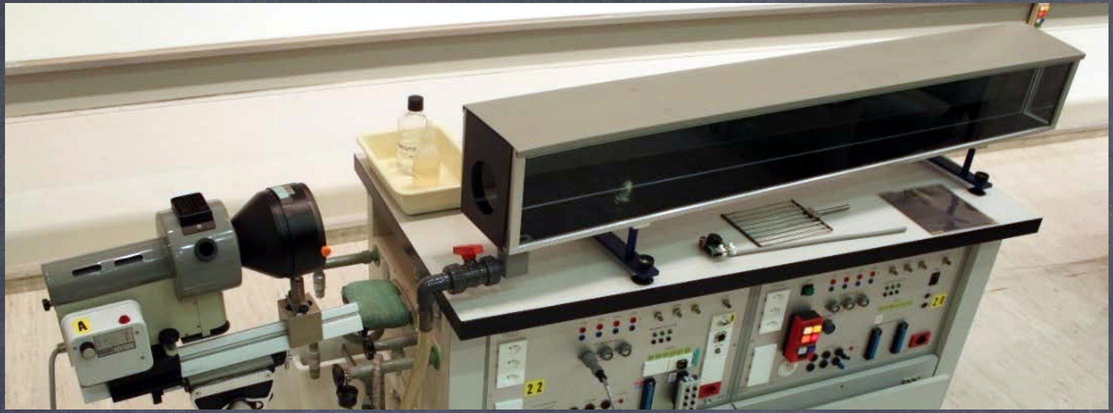
The size of the disturbance is the
amplitude, but this doesn't effect
v, ω, k

- Wednesday lecture will review last exercise sheet

- Learn to do weekly exercise sheets + online quizzes
  → Questions like these will be on the exam

- some of you, I'll see in PHY 127 next semester: modern physics + scientific instruments (NMR, CT scans, etc.)

- Good luck on the exam + thanks!



Until next time!