Phys1402-Fall18 - Part 3 – Waves and Light

Monday, October 15, 2018 8:52 PM

- Our course notes are now broken into 3 parts on OneDrive:
  - Part 1 - Electrostatics and DC Circuits:
    https://tamucc-my.sharepoint.com/:o:/g/personal/jeffery_spirko_tamucc_edu/EhkLJvTU1_pOkB5OmwRTR4IBMn97BZRqrI-ORgvtyty7Zg
  - Part 2 - Magnetism and AC Circuits:
    https://tamucc-my.sharepoint.com/:o:/g/personal/jeffery_spirko_tamucc_edu/EuR1xpOWEK5LqEaOjXrgoQkBZ7sy3B5pL6QA4wlUziZVxQ
  - Part 3 - Oscillations, Waves, and Light:
    https://tamucc-my.sharepoint.com/:o:/g/personal/jeffery_spirko_tamucc_edu/EnXylWa4gm5FhPXWNb-bb4kB_7YX7TQsxRdh7HcSKATncg
- Our course notes are also periodically exported to PDF in:
  http://faculty.tamucc.edu/jspirko/Phys1402/

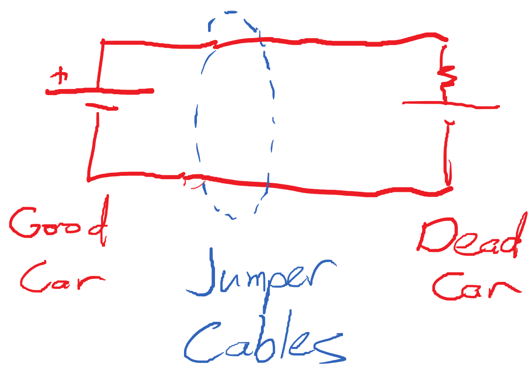
- Professor: Dr. Jeff Spirko, jeffery.spirko@tamucc.edu, NRC-1111 (inside NRC-1100 suite)
- Office Hours: See Live Caledar http://faculty.tamucc.edu/jspirko/calendar.html
- Course Web Folder: http://faculty.tamucc.edu/jspirko/Phys1402/ - Lecture Notes, Web Links
- Course YouTube Playlist: Phys1402-Fall18
- SI Info: [TBD]
- Sessions: [TBD]
- Office Hour: [TBD]
- Lab Web Folder: http://physlab.tamucc.edu/ - Lab Policies, Practice Exercises, Lab Instructions, Auxiliary Files
- Textbook: Serway/Vuille, College Physics, 11th Edition (electronic version in WebAssign).
- Homework: Will appear on WebAssign.
- Lab Reports: Due 1 week after the lab, by midnight. Submit in the Lab Reports area in the Course Menu.

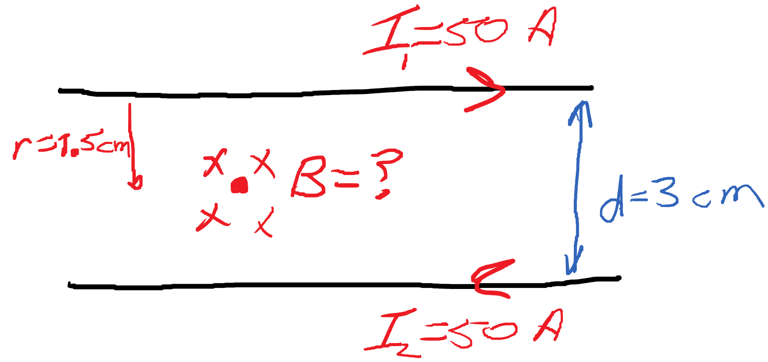
Lec 12 - Oscillations

Monday, November 5, 2018 1:56 PM

Exam 2 Avg: 62%

13) Jump Start a car: $I = 50\ A$ $d = 3\ cm$





$$B = B_1 + B_2 = \frac{\mu_0 I_1}{2\pi r_1} + \frac{\mu_0 I_2}{2\pi r_2}$$

$$= \left(\frac{\mu_0 (50 A)}{2\pi (0.015\ m)}\right) 2 = 0.00133\ T$$

#9 Levitate a wire, $I = $ (east)

#19, 20 $C = 8\,\mu F$ $I = 20\ mA$ $f = 500\ Hz$

Double f: $C = 8\,\mu F$ $f = 1000\ Hz$

Same voltage

$$X_C = \frac{1}{2\pi f C} \quad \text{(Cut in half)}$$

$$V_{rms} = I_{rms} Z \qquad Z = X_C$$

I_{rms} must double.

#18 $\mathcal{E} = -\frac{\Delta \Phi_B}{\Delta t}$ Change in flux

Series RLC from the exam

Monday, November 5, 2018 2:24 PM

$L = 1.5\ H$

$C = 1.56\ \mu F$

$R = 300\ \Omega$

$V_R = 14 \sin(800\, t)$

$V_{max} \sin(2\pi f t)$

$2\pi f = 800$

#25 $f = \frac{800}{2\pi} = 127\ Hz$

#28 Reactance of Capacitor

$$X_C = \frac{1}{2\pi f C} = \frac{1}{(800)(1.56 \times 10^{-6})} = 800\ \Omega$$

#29 Need

$$X_L = 2\pi f L = (800)(1.5) = 1200\ \Omega$$

$$X = X_L - X_C = 1200 - 800 = 400\ \Omega$$

$$Z^2 = R^2 + X^2 = 300^2 + 400^2 = (500)^2$$

Cost of energy

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DC Power $P = VI = (480\,V)(250\,A) = 120000\,W$

Energy: $P = \dfrac{\Delta Energy}{\Delta t}$

$$\Delta Energy = P\Delta t = (120000\,W)(20\,min)\left(\frac{1\,hour}{60\,min}\right)\left(\frac{1\,kW}{1000\,W}\right)$$

$$= 40\,kWh$$

Cost: $\left(\$0.12/kWh\right)(40\,kWh) = \$4.80$

$(Rate)\,(Amount) = (Cost)$

Oscillations Intro

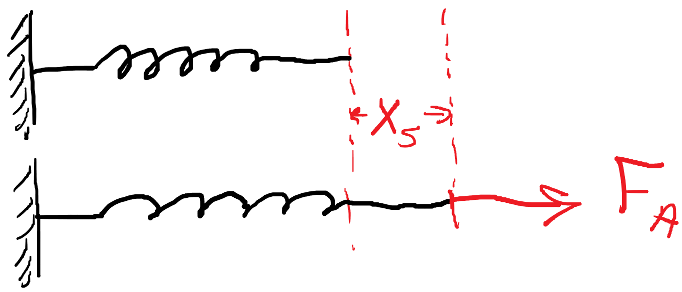
Monday, November 5, 2018 2:52 PM

Springs generate a force that depends on their stretch.

$$|F_s| = k\,|x_s|$$

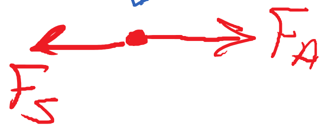
k = spring constant in N/m

When we exert a force, the spring stretches in that direction.



From my perspective, the spring is pulling back.

"object" is my hand.



This F_s is opposite to the stretch x_s.

$$F_s = -k x_s$$

$$x_s = (\text{Length}) - (\text{Relaxed Length})$$

Oscillations are allowed when you attach a mass to a spring.

Analyze the mass:

$$F_{net} = ma$$

$$F_s = ma$$

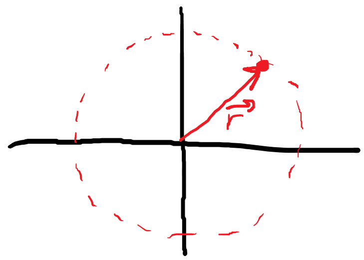
$$-kx = ma$$

The acceleration is proportional to the displacement of the mass, but in the opposite direction.

This is similar to circular motion.

$\vec{r}$ = position

$\hat{r} = \frac{\vec{r}}{r}$ = (outward)



$\vec{a} = \frac{v^2}{r}$ (inward)

$\vec{a} = \frac{v^2}{r}\left(-\frac{\vec{r}}{r}\right)$

$\vec{a} = \frac{-v^2}{r^2}\vec{r}$

The acceleration is negatively proportional to the position.
This is the connection between circular motion and oscillations.

In circular motion $\omega = \frac{v}{r}$ = angular speed

$$a = \frac{-k}{m}x = -\left(\frac{v}{r}\right)^2 x = -\omega^2 x$$

$$\omega = \sqrt{\frac{k}{m}}$$

This is related to the frequency of the oscillation. $\omega = 2\pi f$

Frequency of mass-spring osc: $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Lec 22 - Waves, Doppler Effect

Wednesday, November 7, 2018 1:57 PM

Oscillations: • Timing Frequency (f) in hertz (Hz) is # cycles per second

Determined by objects or materials.

• Amplitude = strength of oscillation

Waves: Many coupled oscillations.

The actual oscillators stay in place. They oscillate but don't move (on average).

There is always a velocity of the disturbance. This is called the propagation velocity.

Good pictures: Dan Russell Waves

When coupled oscillators stimulate each other, the frequency of the oscillations is the same. For sound waves, the frequency corresponds to the pitch of the sound.

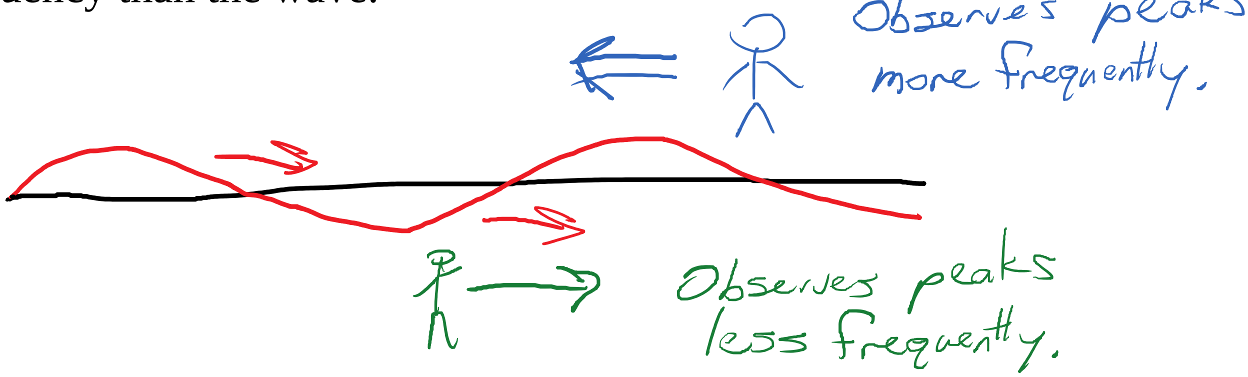
The exception is when the Doppler Effect happens.

Doppler Effect refers to a shift in the frequency of a wave caused by relative motion. There are two possible motions:

- The source could be moving.
- The observer could be moving.

When the source is moving, the actual waves are "squished" in front of the source and "stretched" behind it.

When the observer is moving, their oscillations happen at a different frequency than the wave.



The source and observer velocities combine to form a relative velocity:

$$v_{rel} = v_s - v_o$$

⊕ = toward

For small relative velocities, the frequency shift is simply proportional to the velocity.

$$\frac{\Delta f}{f} = \frac{v_{rel}}{v_{wave}}$$

This method works for fractions < 10%.

The frequency shift is positive when the objects are moving toward each other.

- Initial Frequency: 4897 Hz — Toward
- Final Frequency: 4513 Hz — Away
- Actual Horn Frequency: Average = 4705 Hz — Middle

$$\frac{\Delta f}{f_0} = \frac{v_{rel}}{v_{wave}}$$

Average = 4705 Hz — Middle

- Frequency Shift:
  Half Difference = 192 Hz
- Car Speed: 13.9 m/s = 31 MPH

$V_{sound} = 340 \ m/s$

$$\frac{192}{4705} = \frac{V_{rel}}{340}$$

$V_{rel} = 13.9 \ m/s$

Doppler Radar

Wednesday, November 7, 2018 2:52 PM

Doppler radar involves reflection. The initial source and final observer are actually the same. But each oscillation has to travel a different distance because the reflector is moving.

Because the wave makes a two-leg journey, simply apply the doppler effect twice.

$$\frac{\Delta f}{f} = 2\frac{v_{rel}}{v_{wave}}$$

General relationship for all waves:

$$v_{wave} = \frac{\lambda}{T} = \frac{\text{wavelength}}{\text{period}}$$

Since $f = \frac{1}{T}$ $\boxed{v = f\lambda}$

Sound Waves: $v \approx 340\ m/s$ $f = 20 \ldots 20{,}000\ Hz$

Light Waves: $v = c = 3\times10^{8}\ m/s$ $f = 400 \ldots 750\ THz$

$T = \text{tera} = 10^{12}$

Shortest wavelength of light:

$$\lambda_{violet} = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{750\times10^{12}\ Hz} = 4\times10^{-7}\ m = 400\ nm$$

Max wavelength

$$\lambda_{red} = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{400\times10^{12}\ Hz} = 7.5\times10^{-7}\ m = 750\ nm$$

Lec 23 - Standing Waves

Monday, November 12, 2018 1:57 PM

All oscillating waves: f = frequency in Hz = cycles/s
λ = wavelength in m = length of a cycle

$v = f\lambda$

Reflection: wave bouncing off a change in material.
For a direct reflection: $\vec{v} \Rightarrow -\vec{v}$
$|v|$ stays the same

When there is a fixed-length region with reflectors at each end, waves that are generated in the region reflect back and forth and can additively or subtractively combine.

If the round-trip distance is an integer number of wavelengths, these special "standing waves" appear.

$PV = nRT$

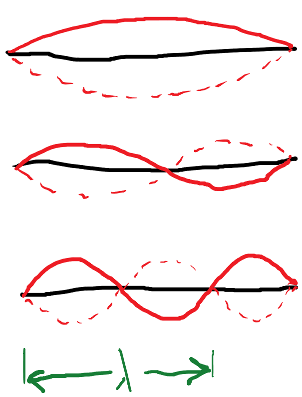
$P = \frac{n}{V}RT$

Round trip = $2L$ $\qquad m\lambda = 2L$

Integer # λ = $m\lambda$

As long as the wave is identical after a round trip, compared to what it was before, this holds true.
If both ends have same type of reflection, this is true.

What does m do to the shape? $\qquad m\lambda = 2L$



$m=1 \quad \lambda = 2L \quad f_1 = \frac{v}{2L}$

$m=2 \quad \lambda = L \quad f = \frac{v}{2L}2 = 2f_1$

$m=3 \quad \lambda = \frac{2L}{3} \quad f = \frac{3v}{2L} = 3f_1$

$v = f\lambda \Rightarrow f = \frac{v}{\lambda}$

The Standing Wave idea gives us specific wavelengths, depending on the size of the cavity. But as waves move, it's the frequency that is maintained.
After we solve for f, we see each standing wave is a multiple of the original frequency, called the Fundamental.
The other frequencies are called Harmonics.

Similar Ends: $\quad 2L = m\lambda \qquad f = mf_0$

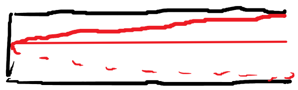
f_0 or f_1

Use v of the oscillating wave.

It's common to have musical instruments where the ends are "different".
A pipe can have one end closed and one opened.

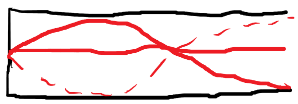
- Closed end causes reflection with inversion.
- Opened end causes reflection without inversion.

The standing waves that "fit" in the pipe must be open/closed to match the ends.



$\lambda = 4L$

the broadest standing wave starts at zero and ends at the first peak.
This is $\frac{1}{4}$ cycle in the cavity.



$\lambda = \frac{4L}{3}$

This is $\frac{3}{4}$ cycle in the cavity.
$\frac{3}{4}\lambda = L$

$\lambda = \frac{4L}{5}$

$m\lambda = 4L$ but only odd m's are "allowed"

For sound waves, this makes sounds with the fundamental and the odd harmonics.

Standing waves of electricity are used in antennas.

$f = 106.5$ MHz
$v = 3\times10^8$ m/s

$\lambda = \frac{v}{f} = \frac{3\times10^8}{106.5\times10^6} = 2.8$ m

A typical car antenna is a "quarter-wave vertical".

$\frac{\lambda}{4} = \frac{2.8\text{ m}}{4} = 0.7$ m

Lec 24 - Intensity, Decibels, and Polarization

Wednesday, November 14, 2018 1:55 PM

Energy $\xrightarrow[\text{in Time}]{\text{Spread}}$ Power $\xrightarrow[\text{Area}]{\text{Spread in}}$ Intensity

Intensity is proportional to the amplitude squared of the waves.

All of these forms of energy are proportional to each other.
A doubling of the initial energy doubles the intensity.
It's frequent to have proportional losses: Efficiency = $\frac{E_{out}}{E_{in}}$

A math that easily handles multiplication and division is logarithmic math.

The unit of "level" is called the decibel.

As an energy-like quantity is multiplied or divided,
the corresponding level is added or subtracted.

- Our eyes and ears detect "level" instead of raw intensity.
- Many orders of magnitude are described with small numbers.

Decibel levels are *ALWAYS* relative to something.
For each decibel amount, there is a corresponding multiplication factor for the energy, power, or intensity.

Level (dB)	Factor	
0 dB	1	(Equal to the reference.)
3 dB	2	Doubling energy = adding 3dB
5 dB	≈3	
7 dB	5	
10 dB	10	This actually defines dB

Factor = $10^{\left(\frac{Level}{10}\right)}$

10^0.3 = 1.9953

$$\text{Factor} = 10^{\left(\frac{\text{Level}}{10}\right)}$$

10^0.3 = 1.9953
10^0.5 = 3.1623

What decibel level represents a factor of 100? 20 dB = 10 dB + 10 dB

What factor does 68 dB correspond to?

68 dB = 60 + 5 + 3

$$\text{Factor} = (10^6)(3)(2) = 6\times10^6$$

Check: 10^6.8 = 6.3096E6

Sound Levels in decibels

Wednesday, November 14, 2018 2:23 PM

Reference sound $I_0 = 10^{-12}\ W/m^2$

Normal Conversation $\beta = 60\ dB$ Factor $= 10^6$

$$I = I_0(\text{Factor}) = (10^{-12}\ W/m^2)(10^6) = 10^{-6}\ W/m^2$$

Using a calculator to find decibel levels:

$x = 10^{\beta/10}$ ← level

↑ Factor of energy multiplication

$\log x = \frac{\beta}{10}$

$$\beta = 10 \log x$$

What is the sound level corresponding to $4 \times 10^{-4}\ W/m^2 = I$

$$x = \frac{I}{I_0} = \frac{4E{-4}}{1E{-12}} = 4 \times 10^8$$

$$\beta = 10 \log(4E8) = 86\ dB$$

If one screaming child can produce 70 dB of sound,
what is the sound level of two equal screaming children?
(Twice as much energy, and 3 dB is a factor of 2.
70 dB + 3 dB = 73 dB

Intensity Variation with distance

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$I \propto \frac{1}{r^2}$

I = Intensity
r = distance from source

What effect does doubling the distance have?
The intensity would be 4 times less.
This has the effect of subtracting 6 dB from the level.

$\beta = 10 \log x = 10 \log(0.25) = -6$ dB

What is the level change caused by another doubling of the distance?
Intensity decreases by another factor of 4.
The level will decrease by another 6 dB.

10 * log10(1/16) = -12.04119982655925

Application: Radio signals are measured with a reference of 1 mW.
This is the measure of Power moving along a wire.

Ex: Wifi Level = -51 dBm

$x = 10^{-5.1} = 7.9 \times 10^{-6}$

$P = P_0 \cdot x = (10^{-3}\,W)(7.9 \times 10^{-6}) = 7.9 \times 10^{-9} = 7.9\,nW$

What decibel level corresponds to a 1% increase? $x = 1.01$

$\beta = 10 \log(x) = 10 \log(1.01) = 0.04$ dB

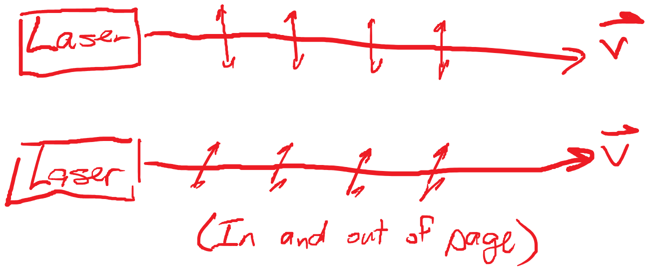
What decibel level corresponds to a 1% decrease?

$10 \log(0.99) = -0.04$ dB

Polarization and Polarizers

Wednesday, November 14, 2018 2:50 PM

Transverse waves oscillate perpendicular to the propagation direction.



Vertical Polarization

Horizontal Polarization

Most sources produce unpolarized light.
Lasers, LCD screens, and glancing reflections are polarized.

Polarizers (like polarized sunglasses) selectively filter out some light more than others. We name the polarizer by the light that passes.

For a vertical polarizer, this is what gets through:

- Vertically polarized light: 100%
- Horizontally polarized light: 0%
- Diagonally polarized light:

$$I_{out} = I_{in} \cos^2(\theta)$$

Ex: $\theta = 45°$ $\cos^2(45°) = \frac{1}{2}$

- Unpolarized light: 50% gets through

The light that gets through is always re-polarized in the direction of the polarizer.

- Horizontally polarized light gets blocked by a vertical polarizer.
- Inserting a diagonal polarizer in between allows some light to get through.

Application: Viewing stress in blown glass or in bent metals.

Lec 25 Intro Geometric Optics

Monday, November 19, 2018 1:59 PM

First: Reviewing decibels for the last HW problem.

Known dB level at one distance.
Want dB Level at another distance.

Assume $I \propto \frac{1}{R^2}$

$I = \overbrace{(c)}^{\text{some constant}}\left(\frac{1}{R^2}\right)$

$$\frac{I_2}{I_1} = \frac{\cancel{c}\,(1/R_2)^2}{\cancel{c}\,(1/R_1)^2}$$

$$\text{Ratio of } I\text{'s} = \frac{1}{(\text{Ratio of } R\text{'s})^2}$$

$$\frac{I_2}{I_1} = \frac{R_1^2}{R_2^2}$$

Ex: 180 dB @ 161 km, ?? dB @ 4800 km

$$\text{Ratio of } R\text{'s} = \frac{4800}{161}$$

$$\text{Ratio of } I\text{'s} = 1\Big/\left(\frac{4800}{161}\right)^2 = 0.001125$$

1/(4800/161)^2 = 0.0011 not enough accuracy

$$\text{Factor} = 10^{\beta/10}$$

$$\beta = 10 \log_{10}(\text{Factor})$$
$$= 10 \log_{10}(0.001125) = -29.49 \text{ dB}$$

New level = 180 - 29.49 = 150.51

The relationship between levels and intensities is the same as that between exponents and values.

$(x^2)(x^5) = x^7$ Multiply values = add exponents.

$(x^3)^2 = x^6$ Power = multiply exponents

Intensity proportional to inverse R squared. = -2 power

Ratio of R's = 4800 / 161 = 29.8137

10*log10(29.8) =
14.74216264076255

-2 * 14.74 = -29.48

The distance increased by 14.74 "dB", so the intensity decreased by (2)(14.74 dB) = 29.48 dB. Technically, dB are only for energy ratios.

Geometric Optics

Monday, November 19, 2018 2:22 PM

Geometric optics is changing waves by tinkering with the speed of the waves.

Light: $v = 299792548 \text{ m/s} = c$ (exactly)

In a material, light slows down.

$$v = \frac{c}{n}$$ n = index of refraction

Any given material has an index of refraction.

Glass $n \approx \frac{3}{2} = 1.5$

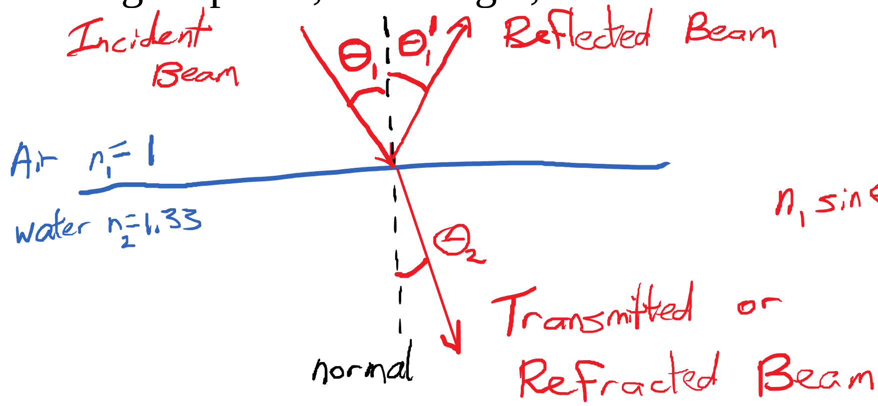
Water $n \approx \frac{4}{3} = 1.33$

Air $n \approx 1.0004$ Only 0.04% slower

There are other material effects that can happen:

- Absorption
- Reflection
- Scattering
- Refraction

Reflection and refraction occur together.
When a wave changes speeds, at an angle, the beam bends.



$$\theta_1 = \theta_1'$$

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

$n_1 = 1$
$n_2 = 1.33$
$\theta_1 = 30°$

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

$$\frac{1}{1.33} \sin 30° = \sin\theta_2 = 0.376$$

$$\theta_2 = \sin^{-1}(0.376) = 22°$$

If the index of refraction increases, the angle decreases.

If the index decreases, the angle increases, but there is a limit.

$\sin \theta_2 < 1$ okay. $\quad \sin\theta_2 = 1$ threshold $\quad \sin\theta_2 > 1$ forbidden

$n_1 \sin\theta_c = n_2 \qquad \theta_c$ = Threshold θ_1 value

$\sin\theta_c = \frac{n_2}{n_1}$

Water-air: $\quad \sin\theta_c = \frac{1}{1.33} = 0.752 \qquad \theta_c = 48.8^\circ$

If theta_1 > theta_C, there is no refraction, and we call it "Total Internal Reflection".

Lec 26 Thanksgiving

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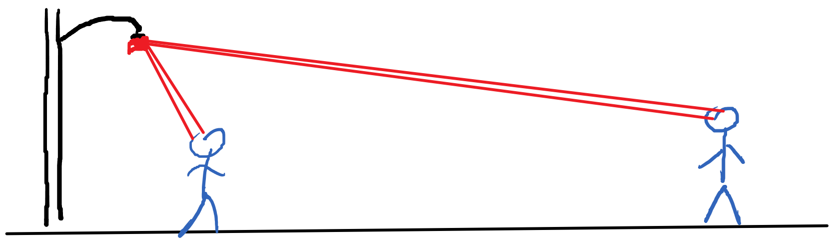
Going from single rays to "seeing".

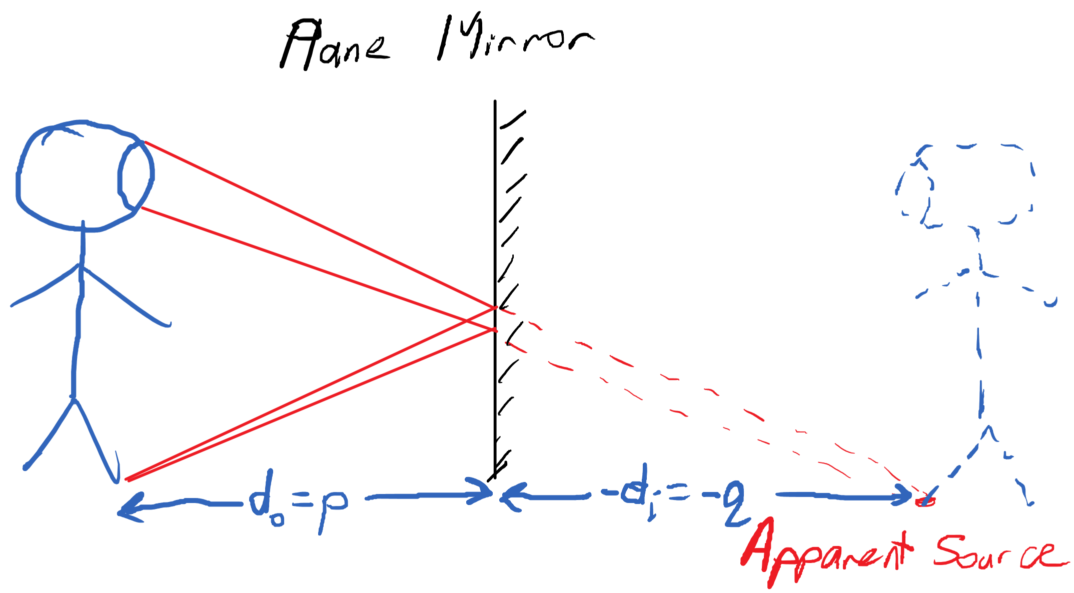


Far-away object;
Weakly diverging rays.

Nearby object;
Strongly diverging rays.

All objects produce diverging rays of light.
The divergence is inversely related to the distance.

Our eyes can be fooled. If we see rays of light apparently diverging from a common point, we think there is something there.



When a lens/mirror creates rays that we observe, the rays are coming from the "image" created by the lens/mirror. In the case of a plane mirror, the rays of light appear to intersect at the location of the "virtual image".

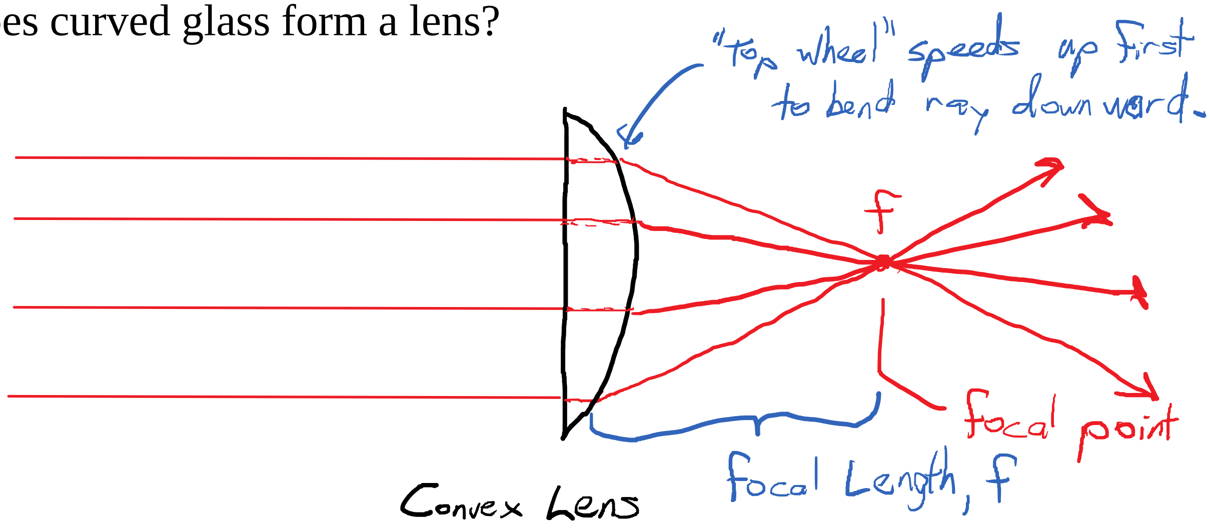
Plane Mirror:
$d_o = -d_i$

d_i is negative for virtual image.

Lenses

Monday, November 26, 2018 2:20 PM

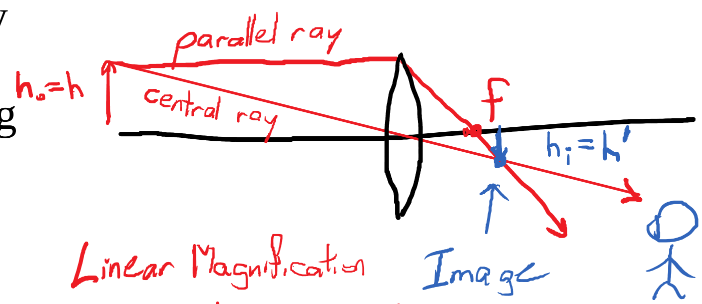
How does curved glass form a lens?



A convex lens makes parallel rays converge and intersect. We call it a "converging lens".
For incoming-parallel rays, they intersect at the focal point.

When the incoming rays of light aren't parallel, the lens still tries to make them converge.

- Incoming converging rays: This is unusual. The rays must be coming from another lens. This is called a "virtual object". The new converging lens would make the rays converge more.
- Incoming diverging rays: This is normal. What happens depends on how strongly diverging the rays are.
  - Weakly diverging: The lens is strong enough to make the rays converge.



Calculations:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Linear Magnification

$$M = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

Ex: $f = 2$ cm
$d_o = 8$ cm

$$\frac{1}{d_i} = \left(\frac{1}{2} - \frac{1}{8}\right) = \frac{3}{8}$$

$$d_i = \frac{8}{\ } = 2.7 \text{ cm}$$

$$M = \frac{-2.7}{8} = -0.33$$

Inverted

$d_o = 8$ cm

$d_i = \frac{8}{3} = 2.7$ cm

Inverted

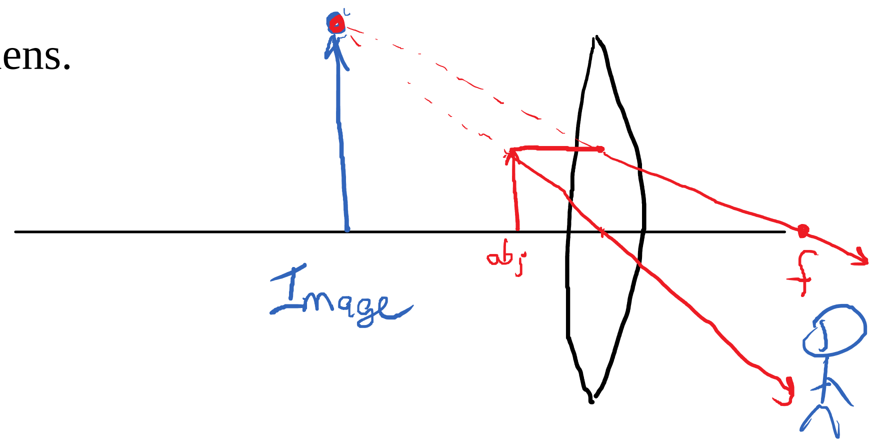
Less than one so reduced.

- Strongly Diverging rays hit a converging lens: The lens isn't strong enough to make the rays converge, it just makes them diverge less.
  The "image" is behind the lens.

$f = 2$ cm

$d_o = 0.95$ cm

$d_i = \left(\frac{1}{2} - \frac{1}{0.95}\right)^{-1} = -1.8$ cm



The image is at approx the focal distance, but on the other side of the lens. The negative value signifies a virtual image (like the mirror).

$M = \frac{-d_i}{d_o} = \frac{-(-1.8)}{0.95} = +1.9$

The image is enlarged and upright.

Can the lens equation handle the plane mirror?

$d_i = -d_o$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{d_o} + \frac{1}{-d_o} = \frac{1}{f}$$

$$0 = 1/f \qquad f = \infty$$

The plane mirror acts like it has infinite focal length.

Lens power is the inverse of the focal length (in meters).

- Infinite f -> zero power.
- Long positive f -> small positive power.
- Short positive f -> high positive power.

Negative focal lengths are possible and common. They are for diverging lenses which are also concave lenses.
Since all objects produce diverging rays, and diverging lenses try to make the rays diverge, they just make the rays diverge more.

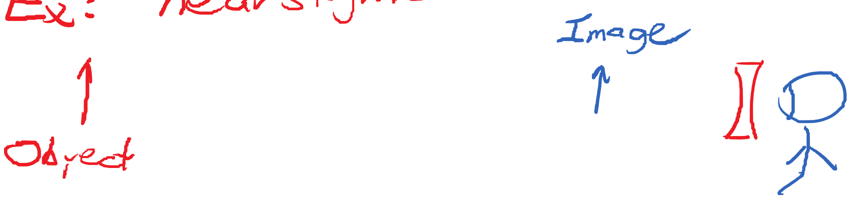
Corrective Lenses

Monday, November 26, 2018 3:04 PM

A nearsighted person can see near things.
Near things produce strongly diverging rays.
The nearsighted person requires strongly diverging rays.
A far object produces weakly diverging rays.
Pass the weakly diverging rays through a diverging lens,
and now they are strongly diverging so they can see them.

d_{np} = near point: want 25 cm
d_{fp} = far point: want ∞ ← nearsighted has less

Ex: nearsighted w/ 100 cm far point.



$d_o = \infty$
$d_i = -98$ cm

$$\cancel{\frac{1}{d_o}} + \frac{1}{d_i} = \frac{1}{f}$$

$$f = d_i$$

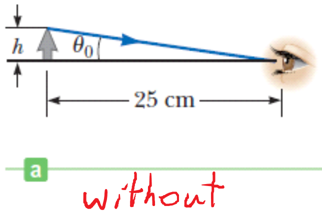
The image distance must be negative, and it could be the same or a little smaller than the required viewing distance.

$$\text{Power} = \frac{1}{f} = \frac{1}{-0.98\,\text{m}} = -1.02$$

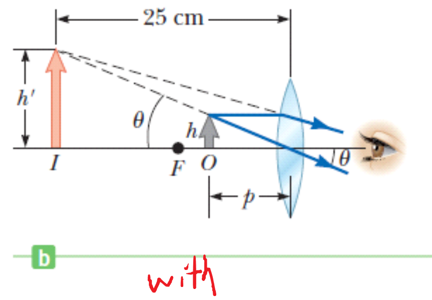
Lec 28 Optics Instruments

Wednesday, November 28, 2018 1:58 PM

Magnifying Glass



without



with

Tiny Feature

$\theta_0 = \frac{h}{25\text{ cm}}$ (in radians)

($\tan\theta \approx \theta$ for small angles)

- Object gets to be closer.

$\theta = \frac{h}{p}$ ← $p = d_o$ for lens, which is smaller than 25 cm.

Let's calculate the magnification for an image at infinity.

- Bigger (negative) image distance, so object is further away.

$q = d_i = -\infty$ $\qquad \frac{1}{q} = 0$

Lens eqn: $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \Rightarrow \frac{1}{d_o} = \frac{1}{f} \Rightarrow d_o = f$

$\theta = \frac{h}{f}$ (with magnifier)

$\theta_0 = \frac{h}{25\text{ cm}}$ (without)

Angular Magnification $= m = \frac{\theta}{\theta_0} = \frac{h/f}{h/25\text{ cm}} = \frac{25\text{ cm}}{f}$

A smaller focal length is a stronger lens that has more magnification.
For the drawing above, the image is at q = -25 cm, which gets another "click" of magnification.

max mag $= \frac{25\text{ cm}}{f} + 1$

If I buy a "10 times" magnifier, what is f?

$$10 = \frac{25\,cm}{f} + 1$$

$$f = \frac{25\,cm}{9} = 2.8\,cm$$

A person can read 12-point text at 50 cm, what magnifier is required to read 5-point text?

Required $\theta = \frac{12}{50} = 0.24$

5-point @ 25 cm $\theta_0 = \frac{5}{25} = 0.2$

$\Big\}$ Ratio = 1.2

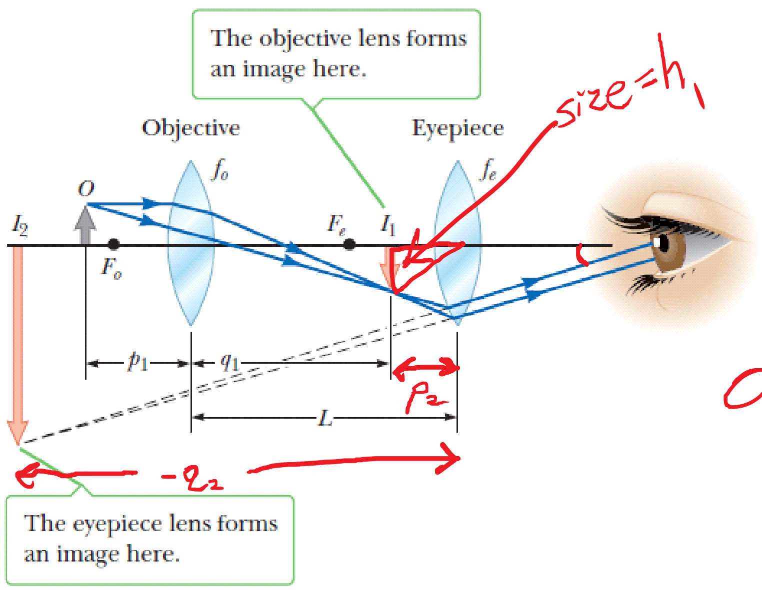
For "relaxed" viewing

$$m = 1.2 = \frac{25\,cm}{f}$$

$$f = \frac{25\,cm}{1.2} = 20.8\,cm$$

Microscope

Wednesday, November 28, 2018 2:25 PM



To have final image @ infinity:

$-q_2 = \infty$

$p_2 = f_e$

I_1 should be at focal point of eyepiece.

Observed Angular size $\frac{h_1}{f_e}$

Since the eyepiece is basically acting as a simple magnifier, let's just use that relationship.

$$m_e = \frac{25\text{ cm}}{f_e}$$

So what does the objective lens do? It's a "projector" that causes linear magnification.

$$M = \frac{-d_i}{d_o} = \frac{-q_1}{p_1}$$

Approximations:

- Lenses are "far apart" compared to their focal lengths.

$q_1 \approx L$

$p_1 \approx f_o$

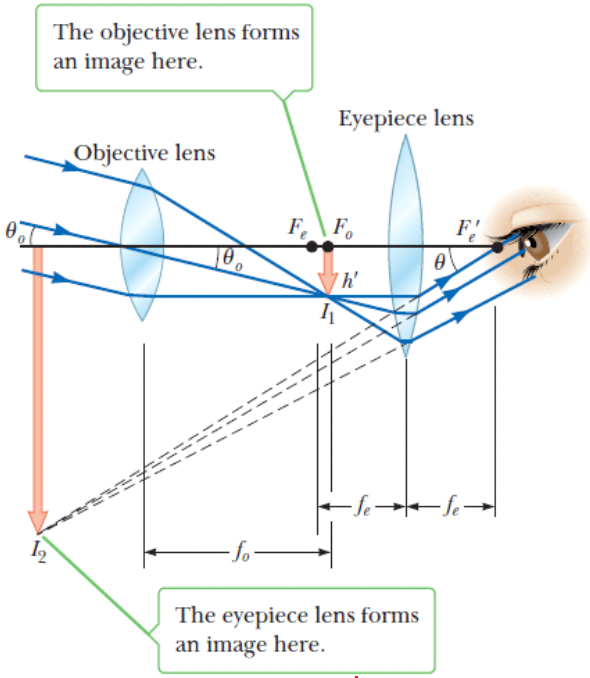
$$M_o = \frac{-L}{f_o}$$

Overall: $m = M_o m_e = \dfrac{-L(25\text{ cm})}{f_o f_e}$

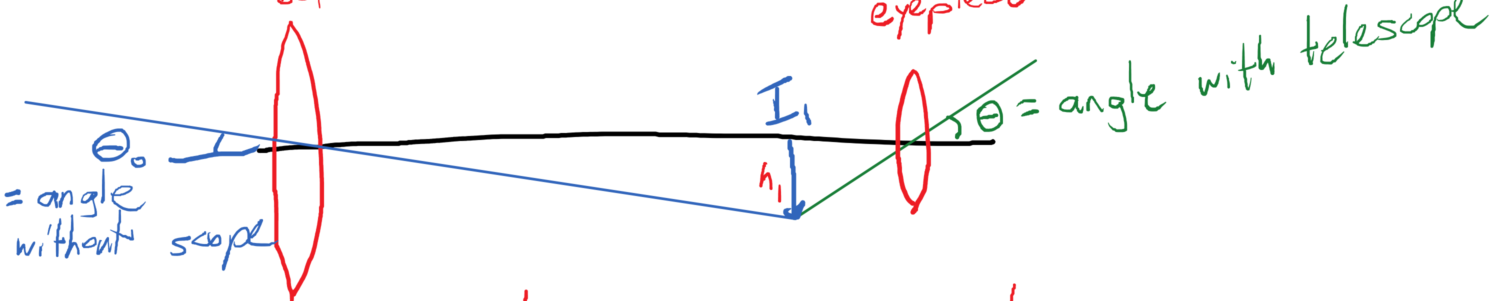
For a "strong" microscope, both f_o and f_e are small.
The distance L also affects magnification.

Telescope

Wednesday, November 28, 2018 2:42 PM



- θ_o is small because the object is so far away.
- I_1 (intermediate image) is at focal point of objective.
- To view "relaxed", put focal point of eyepiece on I_1.



$$\theta_o = \frac{h_1}{f_o} \qquad \theta = \frac{h_1}{f_e}$$

$$m = \frac{\theta}{\theta_o} = \frac{h_1/f_e}{h_1/f_o} = \frac{f_o}{f_e}$$

To have a "strong" telescope, large f_o and small f_e.
The length is always f_o + f_e (approx same as f_o).