Light Refractions

Snell's Law

$$\boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

Critical Angle

$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

Index of Refraction

$$\boxed{n = \frac{c}{v_m}}$$

Lenses

Sign Conventions:

f: positive for convex/positive/converging lenses
negative for concave/negative/diverging lenses

s: positive on left of lens
negative on right

s': positive on right of lens / real image
negative on left / virtual image

y: positive above optical axis
negative below

y': positive above the optical axis
negative below

Image/Object/Focal Distance

$$\boxed{\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}}$$

Object/Image Distance/Height

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

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

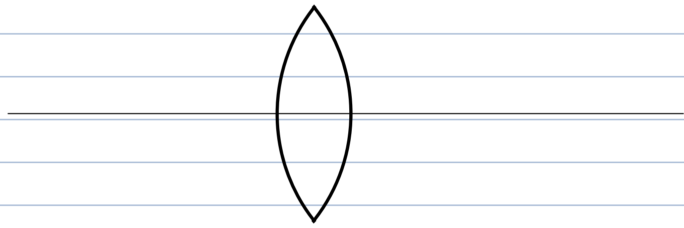
Mirrors

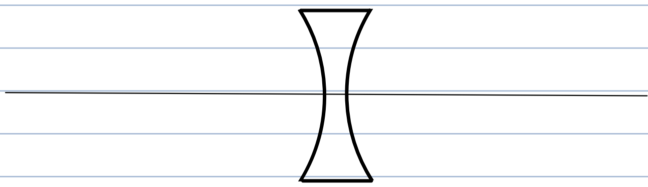
Different Sign Conventions

real vs virtual from s' on mirror

f: positive for concave mirrors
negative for convex mirrors

s': positive on left of mirror — Real
negative on right of mirror — Virtual





Lenses

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Mirrors

Different Sign Conventions

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negative for convex mirrors

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negative on right of mirror

Thermals

Area Expansion

$\Delta A = A_0 \gamma \Delta T$

Linear Expansion

$\Delta L = L_0 \alpha \Delta T$

Volumetric Expansion

$\Delta V = V_0 \beta \Delta T$

Table 20.1 Specific Heats of Some Substances at 25°C and Atmospheric Pressure

Substance	Specific Heat (J/kg · °C)	Substance	Specific Heat (J/kg · °C)
Elemental solids		*Other solids*	
Aluminum	900	Brass	380
Beryllium	1 830	Glass	837
Cadmium	230	Ice (−5°C)	2 090
Copper	387	Marble	860
Germanium	322	Wood	1 700
Gold	129	*Liquids*	
Iron	448	Alcohol (ethyl)	2 400
Lead	128	Mercury	140
Silicon	703	Water (15°C)	4 186
Silver	234	*Gas*	
		Steam (100°C)	2 010

Note: To convert values to units of cal/g · °C, divide by 4 186.

Table 19.1 Average Expansion Coefficients for Some Materials Near Room Temperature

Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(°C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(°C)^{-1}$
Aluminum	24×10^{-6}	Acetone	1.5×10^{-4}
Brass and bronze	19×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Concrete	12×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Gasoline	9.6×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Turpentine	9.0×10^{-4}
Lead	29×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Steel	11×10^{-6}	Helium[a]	3.665×10^{-3}

For Solids:
$\gamma = 2\alpha$
$\beta = 3\alpha$

Length + Area for gasses/liquids defined by container

Electrical Charges & Magnetism

Gravity

$$F_g = G\frac{m_1 m_2}{r^2}$$

Force from e^- Charge

$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

$$k_e = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2}$$

Elementary Charge:

1 proton: $1.602 \times 10^{-19} C$

Voltage & Potential Energy

$\Delta V = Ed$ $\quad$ $V = k\, q/r$

$\Delta q = -q\Delta V$ $\quad$ $U = k\frac{q_1 q_2}{r}$

$\Delta q = -qEd$ $\quad$ $\vec{E} = k\, q/r^2$

$\vec{F} = q\vec{E}$

$\varepsilon_0 =$ permittivity of free space

$\varepsilon_0 = 8.85 \times 10^{-12}\, C^2/N \cdot m^2$

Electric Flux

$\Phi = EA$ (when parallel)

$\Phi = E \cdot A\cos(\theta)$ (θ is angle from normal)

$\Phi = Q_{encl}/\varepsilon_0$

Oscillations

$$F = |q| v_\perp B = m\frac{v_\perp^2}{R}$$

Angular Frequency

$\omega = v/r$

$= 2\pi/T$ $\quad$ $T =$ period (seconds)

$= 2\pi f$

Magnetism

$F = |q| v_\perp B = |q| v B \sin\phi$ $\quad$ $T = \frac{N}{A \cdot m}$ $\quad$ $A = C/s$

1 Gauss $= 1 \times 10^{-4}\, T$

Magnetic & Electric force:

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

Magnetic Constant:

$\mu = 4\pi \times 10^{-7}\, \frac{Tm}{A}$

Magnetic Field From Long Conductor

$$\vec{B} = \frac{\mu_0 I}{2\pi r}$$

$I =$ current

$\mu =$ mag const

$r =$ dist from cond

Positron: mass of e^-
positive charge of e^- $(+1.609 \times 10^{-19} C)$

Antiproton: mass of p^+
negative charge of p^+ $(-1.609 \times 10^{-19} C)$

Waves

$$y(x, t) = A \sin\left[kx - \omega t + \phi\right]$$

A: Amplitude (usually in m)
k: wave number ($1/m$)
ω: angular velocity ($\frac{rad}{sec}$)
t: time (sec)
ϕ: phase constant
f: frequency (Hz)
T: period (s)
λ: wavelength (m)
V: speed of wave (m/s)

$f = \frac{1}{T}$ or $T = 1/f$

$\omega = 2\pi f = \frac{2\pi}{T}$

$k = \frac{2\pi}{\lambda}$ rad/m

$V = f/\lambda = \omega/k$

Doplar Effect

$$f' = f \frac{v \pm v_o}{v \mp v_s}$$

v_o moving towards the source
v_o moving away
v_s moving toward observer
v_s moving away

Simple Harmonic Motion

$$x(t) = A\cos[\omega t + \phi]$$

$$v(t) = -A\omega\sin[\omega t + \phi]$$

$$a(t) = -A\omega^2\cos[\omega t + \phi]$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

f: # of times in 1 sec

T = tim to do one cycle

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

$$F_s = kx$$

k: spring constant