Chapter 3 – ForCES

Force

- Interaction between of two distinguishable objects
- Throw a ball towards the wall (in air)
  - No interaction = non force
- Throw a ball up
  - Interaction due to force of gravity

Properties of a Force

- Push or pull
- Acts on material object
- Applied by a material object
- Contact or contact-free force
- Vector
- Paired – e.g. interaction forces: forces of the pair are simultaneously exerting a force on each other
- Additive

1 N = kg·m/s^2

1 m^3 = 1 000 000 cm^3

Fundamental Forces (contact free)

- Gravity

$$F = \frac{G \times M1 \times M2}{r^2}$$

Universal Gravitational Constant:
G = 6.674 * 10 $^{-11}$ N·m^2/kg^2

- Electromagnetic
  - 2 charged objects/particles interact
  - Muscle force on tendon
  - Wind force

$$F = k\frac{q1 \times q2}{r^2}$$

k = 8.99 * 10^9 N·m^2/c^2

- Strong nuclear forces (strongest)
  - Holds protons and neutrons together in nucleus
  - Overcomes repulsive electric force
  - Short-range force
- Weak nuclear force
  - Disintegration of certain radioactive nuclei
  - Shorter-range force

Convenience Forces (Contact Forces)

- Normal force
  - Perpendicular to contact surface
- Force of Friction
  - Parallel to contact surface
  - Independent to contact area and proportional to normal force
- Tension
- Spring Force
- Drag

Translational Equilibrium

- Static Equilibrium
  - Net force is 0
  - Does not move
- Dynamic equilibrium
  - Net force is 0
  - Constant velocity

Chapter 4 – Newton's Laws

Newton's First Law

- An object at rest or in motion with constant velocity remains in its state unless acted upon by a net force
- Inertia
    - Heavier objects have fewer tendencies to change velocity
- Inertial Frame of Reference
    - Valid in first law
    - Noninertial frame of reference for accelerated frames
- Problem solving
    - Tension and string at equilibrium

Newton's Second Law

- If a Fnet is applied to an object of mass m, it accelerates in the direction of the Fnet
- Problem solving
    - Block on slope
        - Free body diagram for hanging block: draw gravity horizontally
        - Break force of gravity into x and y components (x parallel to slope)
    - Applied force
    - Human arm and dumbbell
        - Diagram for arm: Tension in arm = weight of arm – force pulled by dumbbell
        - Diagram for dumbbell: force pulled by dumbbell – weight of dumbbell

$$\boldsymbol{F_{net} = m \times a}$$

Newton's Third Law

- If an object exerts a force on another, they will exert a force equal in magnitude and opposite in direction
- Action – reaction pair
    - Act on two different objects
- Sprinters (pg. 89)
- Problem Solving
    - Push two blocks side by side
        - Only block that is being contacted has applied force
        - Overall system ignores action reaction forces
    - Tension in muscles
        - Fnet = F tendon on bone – F tendon on muscle
    - Pulley
        - Draw diagram so vertical (one of Fg is going up)
        - Tension on both sides of pulley are the same
        - Held by 2 strings = 2 tensions going up
        - Tension of string attached to ceiling = force of gravity since at rest

$$\boldsymbol{F_{A\ on\ B} = -F_{B\ on\ A}}$$

Weight and Apparent Weight

- Apparent weight
    - Weight measured by a contact force
    - at rest acc = 0   gravity (down direction)

$$\boldsymbol{N = m \cdot g}$$

$$\boldsymbol{N = m(a + g)}$$

+ a = accelerating up
- a = accelerate down

+ a = decelerate down
- a = decelerate up

Chapter 3 and 4 Example Questions

How many normal forces act on a polar bear?
- 4 (one per leg)

Which of the following forces has always the same orientation relative to the vertical direction?
- Weight

Are you heavier or lighter on the moon?
- Lighter on the moon because the mass of the moon is less

If you are moving at a constant speed, which law do you use to describe your motion?
- Newton's First Law

Due to Newton's third law we can make the following statement:
- The arm exerts on the trunk a force which equals – T

An object of mass m accelerates with acceleration magnitude a. How does the magnitude of the acceleration change if we double the mass of the object but keep the accelerating force unchanged?
- Acceleration is halved

Pulley one string attached to ceiling and another string attached to pulley with another mass.
- mass attached to string that is attached to ceiling is heavier

When is the tension equal in magnitude to the weight for an object suspended from a single massless string?
- only when the string is vertical

A spider hangs from its spider silk string, half way down from a leaf. Is the following statement correct? "The silk string pulls the spider up, and this represents the reaction force to the spider's weight acting downward"
- never

Consider the weight of the arm as 7% of the weight of the person, and include the force due to the bar. Express the result in the unit [N].
- weight would be only 7% of the weight of the person or standard man

Lift force of birds
- lift force = force of gravity

Angles on slant
- angle to horizontal – angle of ramp

Angle between horizontal and normal on a slant
- 90 – angle of ramp

Chapter 7 – Energy and Its Conservation

Basic Concepts

- Work
  - Energy that is transferred in or out of a system
  - Theta is the angle between force and displacement
    - If the angle is 90, work = 0
  - Positive work
    - Work is done on the system (block) by the environment (piston)
  - Negative work
    - System does work on the environment
    - E.g. work done by a person lowering an object

$$W = F \cdot d \cdot cos\theta$$

1 J = N·m = kg·m²/c²

- System/environment interface
  - Isolated system: no transfer of energy or matter, environment ignored
  - Closed system: transfer of energy only
  - Open system: transfer of energy and matter
- Power
  - Rate at which work is done $P = \frac{W}{\Delta t}$

Kinetic Energy

- $E_{kin} = \frac{1}{2} \cdot m \cdot v^2$ $\quad W = E_{kin\,f} - E_{kin\,i}$

Potential Energy

- $E_g = m \cdot g \cdot \Delta h$ $\quad W = E_{g\,f} - E_{g\,i}$ Height can be relative to anywhere

Is Mechanical Energy Conserved?

- $E_{ki} + E_{gi} = E_{kf} + E_{gf}$ $\quad E_{ki} + E_{gi} = \textit{constant internal energy}$

Sample Questions

How does the kinetic energy of an object change when its speed is reduced to 50% of its initial value?

- The kinetic energy becomes 25% of the initial value

An isolated object, only E_{kin} and E_{pot} of object change. If object accelerates from 5 m/s to 10 m/s, its Eg has:

- decreased by a factor we cannot determine from the problem as stated

kinetic energy graph is a parabola **internal energy graph** is constant (0 slope)

The person is too weak and object drops to ground under its own weight W.

- The object has done work on the person; this work is calculated as Work = F Δs

Which object has at the end of the process the higher kinetic energy?

- The mass has to be given in order to know

Represent an isolated system: In midair **Same total energy:** Depends on mass of the object

Hot Air Balloon: Pressure in balloon = pressure outside

Chapter 8 – Gases

The Basic Parameters of the Respiratory System at Rest

- Gas Parameter I: Volume (Pg. 188)
  - Spirometer: clinical instrument that allows us to measure gas volume in lungs
  - Tidal volume: inhales and exhales about 0.5 L
  - Inspiratory and expiratory reserve volume: short term additional air exchange
  - Residual volume: remaining gas volume
- Gas Parameter II: Pressure
  - $F = Area \cdot pressure\ (Pa)$ $\quad$ $1\ L = 0.001\ m^3$ (SI unit) $\quad$ **1 atm = 101300 Pa**, **1 torr = 1 mmHg = 133.33 Pa**
- Gas Parameter III: Temperature
  - Zeroth law of thermodynamics
    - In a thermal equilibrium, every part of the system has the same temperature

Pressure-Volume Relations of the Air in the Lungs (Pg. 193)

- Respiration Curve at rest
  - Transmural pressure = P alveoli – P pleura — always positive
  - Gauge pressure = P alveoli — positive or negative
    - Negative = lung volumes are smaller than 3L = pressure in lungs is less than atm pressure
  - Respiratory equilibrium V = 3L
    - Gauge pressure = 0 lung capacity — pressure in lungs = atmospheric pressure
  - V = 4.5 L, alveoli and pleura are positive

Empirical Gas Laws

- Boyle's Law
  - PV = const
  - Isotheral process (constant temperature)
  - Graph: left side of parabola final ← intial
- Charles's Law
  - V/T = const
  - Isobaric conditions (constant pressure)
- Gas Law
  - $P \cdot V = nRT$ $\quad$ $M = \frac{\rho}{P} \cdot R \cdot T \qquad \rho = density$

Kinetic Gas Theory

- The individual volumes of the particles are negligible
- The gas consists of a very large number of identical particles so size smaller than inter-particle distane
- The particles are in continuous random motion
- The only form of interaction between particles or between particles and the container walls are elastic collisions
- Treat particles as point-like objects (only translational motion – straight lines)

$$P \cdot V = \frac{1}{3} \cdot N \cdot m \cdot v^2$$

Internal Energy (U)

- Independent of pressure and volume of the gas

$$E_{kin} = U \qquad U = \frac{3}{2} \cdot n \cdot R \cdot T$$

Root Mean Square

$$V_{rms} = \sqrt{\frac{3 \cdot R \cdot T}{mm}}$$ **mm = kg/mol**

Air is a Gas Mixture

- Humid air is lighter than dry air
  - Water lighter than nitrogen and oxygen molecules

Assume that no external force is applied to the piston. Can you predict in which direction the piston accelerates?

- Not enough information
- If in mechanical equilibrium, $p = p_{air}$
- Accelerate left if $p > p_{air}$

Horses and cross sectional area

- $F = (\text{pressure})*\pi r^2$

We consider 1 mol of an ideal gas under isothermal conditions. If the pressure is doubled ...

- The volume is halved

Charles' law can be written as V/T = *const* if ...

- V is measured in non-standard unit cm^3

A person inhales air at 20°C. By the time the air arrives in the lungs, its temperature has risen to 37°C. Treating air as an ideal gas, the change in internal energy is:

- about a 85% increase over the initial value

If a gas has an internal energy of U = 0 J, we conclude:

- The temperature of the gas is 0 K

Rewrite the ideal gas law by combining n and V as ρ/M, in which ρ is the density of the gas (in unit kg/m^3) and M is the molar weight (in unit kg/mol). Which parameter in this rewritten ideal gas law MUST **decreases from inside to outside across the envelope of a hot air balloon for it to stay airborne?**

- temperature

The ideal gas law is a macroscopic description of a gas, i.e., all parameters can be measured without a model of the microscopic properties and structure of the gas. Still, when Boltzmann, Maxwell and Clausius developed such a model, called the <u>kinetic gas theory</u>, our understanding of the atomic and molecular nature of gases advanced. In their model, which of the following is a result, not an assumption made to develop the model?

- The internal energy of an ideal gas depends linearly on the temperature (in unit kelvin).

Charles' law can be written as V/T = *const* if ...

- V is measured in non-standard unit cm^3

We compare two components of the air in a typical lecture hall: oxygen (O_2 , M = 32 g/mol) and nitrogen (N_2, M = 28 g/mol). What is true?

- The oxygen molecules are slightly slower than the nitrogen molecules

The Maxwell-Boltzmann velocity distribution of an ideal gas in thermal equilibrium allows us *not* to predict ...

- the temperature of the gas
- the root-mean-square speed of the gas molecules
- the most common speed of gas molecules in the gas
- **the speed of a single gas particle we let escape from the gas container**

Chapter 9 – Work and Heat for Non-Mechanical Systems

Dynamic Breathing Pg. 218

- PV diagram for breathing and not at rest
- Pressure in the lungs (alveoli) remains at atmospheric pressure (0)
- Transmural pressure does not depend on the breathing itself
- Pleura pressure is negative
  - Decreases lung volume for very slow breathing
- Tidal breathing (dynamic breathing)
  - Exhalation
    - Pressure larger than atmospheric
    - Top dotted lines
  - Inhalation
    - Bottom dotted lines
- Solid lines = slow breathing

Work on or by a Gas

$$\boldsymbol{W = -P \cdot \Delta V}$$

- positive
  - Compression of a gas
  - Initial > final (final on left side of the PV graph)
  - Work is done on the system (gas)
  - Exhale
    - work is done the gas and active muscles
    - lungs collapse and pleura expands
- Negative
  - Expansion of a gas
  - Initial < final (final on right side of PV graph)
  - System does work on surroundings e.g. gas does work on environment
  - Inhale
    - work is done by the active muscles
    - Lungs expand and pleura collapses

Work for Systems with Variable Pressure

- Area under the curve of PV graph = work
  - Sign is determined whether if Vf > Vi or Vi < Vf
- Work for a full breathing cycle = 0

Heat and the First Law of Thermodynamics

$$\boldsymbol{Q = m \cdot c \cdot \Delta T}$$

$$\boldsymbol{Q = \Delta E_{thermal}}$$

- Heat
  - Energy flow
  - heat flowing into the system and work done on the system are positive
    - increase total energy of the system
- first law of thermodynamics
  - conservation of energy
    - sum of all energy forms (internal energy) in an isolated system is constant (0)
- second law of thermodynamics
  - $$\Delta \boldsymbol{U_{closed\ system} = Q + W}$$
- Problem solving
  - Include E thermal into the law of conservation of energy
  - Staircase pg.228
    - **E chemical → 1 cal = 4.19 J**

Example Questions

A gas expands which is sealed in a container by a mobile piston. The following statement is correct:

- The gas does work on the piston

Which statement about this p-V diagram (Pg.219) is correct?

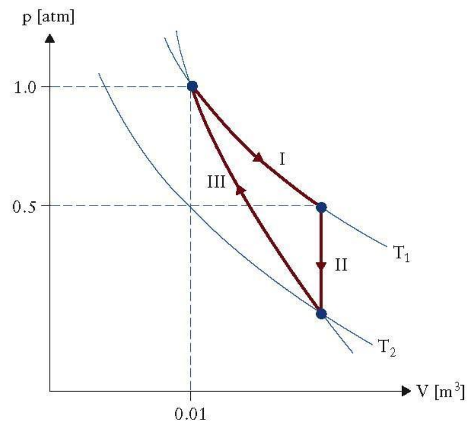
- The work done during inhalation is a negative value.

A container with an ideal gas is heated from 10°C to 20°C. As a result, its thermal energy ...

- increased by less than a factor of 2

The graph shows three steps, labeled I, II, and III, that form a cyclic process in a p-V diagram. Rank the work from smallest to largest for each individual step (Note -5 J < -2 J, but +2 J < +5 J).

- I < II < III



I compress 1 mol of an ideal gas from 20 L to 10 L in an isothermal process? How does the internal energy of the gas change?

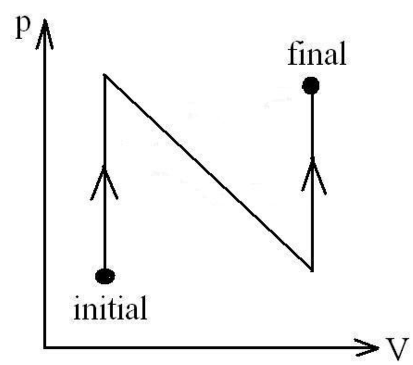
- It stays unchanged

The Carnot process is a cyclic process in a p-V diagram we focus on the process step labeled III. In this step, the system ...

- receives work

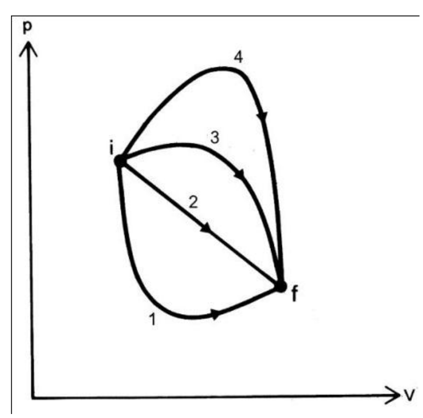
The figure shows a p-V diagram with the initial and final state of a system indicated. The system undergoes a process that follows the shown line in the diagram. During this process, the system ...

- released a net amount of work



The figure shows four curves for the pressure of a gas varying with the volume in different ways. The gas expands in each case from the initial volume (labelled i) to the final volume (labelled f). Rank the work W_j, where j refers to the index of a path, in each of the four cases, starting with the highest value.
Hint: - 5 J < - 2 J but + 5 J > + 2 J.

- 0 > W1 > W2 > W3 > W4



Mass lost per time assuming the body of the person consumes body fat reserves to produce energy to walk.

- Pg.63 #9.5 in solution manual

How much heat given mass, molar mass, temperature change and constant volume.

- U = 3/2nRT

Chapter 10 – Thermodynamics

Basic Thermodynamic Processes in a Closed System

- Fundamental thermodynamic processes
  - Process should be important enough that we benefit from studying it
  - Sufficiently simple that its properties are easily applied in a wide range of practical cases
- Isochoric Process
  - Constant volume
  - Temperature and internal energy increase
  - Work is 0 because there is no change in volume
  - C_v = molar heat capacity at a constant volume
    - For an ideal gas

$$\Delta U = Q \qquad \Delta U = n \cdot C_v \cdot \Delta T$$

$$C_v = \frac{3}{2} \cdot R$$

- Isothermal process
  - Constant internal energy and temperature
  - Heat does not change the temperature or the internal energy of the gas
    - Transfer through the system and is released as work to the piston

$$\Delta U = 0 \qquad Q = -W \qquad W = -n \cdot R \cdot T \cdot$$
$$\cdot \quad Vf \; or \; Pf$$

- Isobaric Process
  - Constant pressure
  - Temperature and internal energy increases

$$C_p = C_v + R = \frac{5}{2} \cdot R$$

- Adiabatic Processes
  - No heat exchange with environment **Q = 0**
  - **Internal energy (U) = W**
  - $V_i \cdot T_i^{3/2} = V_f \cdot T_f^{3/2}$ Poisson's Equation **k = Cp/Cv = 5/3 adiabatic coefficient for ideal gas**

$$V_i \cdot T_i^{Cv/R} = V_f \cdot T_f^{Cv/R} \qquad P_i \cdot V_i^k = P_f \cdot V_f^k$$

Cyclic Processes

- Process that returns to its initial state
- The Carnot Process (Pg.247)

$$per\ cycle: \ \Delta U = 0 \qquad Q = -W$$

  - Isothermal expansion
    - System in thermal contact with high temperature heat reservoir
    - Gas does work on piston
  - Adiabatic expansion
    - No thermal contact
    - Decreased to low temperature
    - Expand to largest volume and lowest pressure
    - Gas does work on piston
  - Isothermal compression
    - System in thermal contact with low temperature heat reservoir
    - Heat released to reservoir
    - Piston does work on the gas
  - Adiabatic compression
    - Increased to high temperature
    - Piston does work on gas

Reversibility

- Reversible expansion
  - Heat transferred from heat reservoir through system and deposited as work done by piston
- Irreversible expansion
  - Allowed a change that suddenly converted the initial equilibrium state into a non-equilibrium state

Sketch the following processes for 1 mol of an ideal gas in a p-V diagram. Which one leads to a linear plot, i.e., a plot which can be described by the linear formula p = a + bV?

- An isobaric heating

When the ATP molecule splits, forming an ADP molecule, the following physical change happens:

- The ATP molecule releases energy

We start with three containers that each hold 1 mol of an ideal gas at $T_{initial}$ = 0^0C and $p_{initial}$ = 1.0 atm. The gas is our system.
► In container I we compress the gas adiabatically to one quarter of its volume.
► In container II we compress the gas isobarically to one quarter of its volume.
► In container III we compress the gas isothermally to one quarter of its volume.
In which container do we measure the highest pressure after the compression took place?

- in container I

To define a temperature scale, Celsius used two reference points: the melting point of ice, which he designated as zero degrees, and the boiling point of water, which he designated as 100 degrees. The figure below shows an experiment in which heat is transferred to a block of ice initially at -25°C. Which of the following statements about the temperature of a system is not correct?

- **The temperature of a single gas particle is determined by its velocity.**
- The temperature measurement in the figure above is correct during the transition from liquid water to water vapour as the continuous addition of heat is not reflected in a temperature change.
- Temperature is a parameter which characterizes a system only when the system is in thermal equilibrium
- The temperature measurement with a Celsius thermometer is only correct when the expanding liquid in the thermometer and the system have the same temperature.
- The temperature of the human body is usually higher than the air temperature in the immediate environment. Therefore, the human body and the surrounding air are not in thermal equilibrium.

Work, mol, pressure given in isothermal expansion.

- W = -nRTln(pi/pf)

Highest pressure after a temperature increase

- Adiabatic process

Work for a cyclic process containing constant pressure, constant volume and constant temperature curve.

- $W = 0.5\,(V_0 - nRT/p_0)(P_0 - nRT/V_0)$

Chapter 11 – Transport and Energy and Matter

Heat conduction

- Flow of energy to eliminate temperature differences
- Fourier's Law
  - Heat flows from high temperature reservoir to low temperature
  - Q/t = flow of heat per time interval
  - $\boldsymbol{\lambda}$ = thermoconductivity coefficient (J/msK)
    - Temperature independent
    - Always positive
  - L = length of the rod

$$\frac{Q}{t} = \lambda \cdot Area \cdot \frac{T\,high - T\,low}{L}$$

Diffusion

- Molecules move from higher concentration to a lower concentration
- Fick's Law
  - Phenomenological law
  - D = diffusion coefficient (m^2/s)
  - Ji = amount of matter passes a location
  - l = width
- Temperature Dependent
  - Diffuse faster in less dense
  - Big particles diffuse slower

$$\frac{Mi}{t} = D \cdot Area \cdot \frac{\rho\,high - \rho\,low}{l}$$

$$J_i = \frac{ni}{t} = D \cdot Area \cdot \frac{C\,high - C\,low}{l}$$

Diffusion Length (Einstein)

- Considering particles that make not one but many jumps
- 2 consecutive jumps bring the atom back to its initial position

$$\Lambda = \sqrt{2 \cdot D \cdot t}$$

Sample Questions

When erythrocyte passes membrane between blood capillary and the alveolus, oxygen diffusion occurs because ...

- a small temperature difference is established between both sides of the membrane

Lord Kelvin's calculation

- Q/A = amount of heat Earth lost since t = 0 (molten Proto-Earth state) through each square-metre of its surface

Based on Einstein's formula, what happens if I ↑concentration gradient across matrix in which the diffusion occurs?

- The particles still move in random but do not hop or heat up faster

In Arrhenius' model, the activation energy does not depend on: the temperature

The geothermal effect of Earth: Surface temperature = low temperature

Material of rod in Fourier's changed such that its λ ↑10%. What change allows us to re-establish previous (Q/t):

- Decreasing the diameter of the rod by 5%

Thermal resistance = length / thermal conductivity coefficient

Heat flows from hot to cold

- Boiling liquid nitrogen is colder than room temperature water

Do not need atomic nature of matter: Fick's law and Fourier's Law

Temperature dependent: diffusion coefficient and rate matter travels from high to low conc. reservoir through bridge

Chapter 22 – Geometric Optics

Ray Model

- Light moves in a straight line within a homogenous medium
- Change direction when reflecting or passing through another medium

Reflection

- Incoming reflected rays are perpendicular to mirror surface
- law of reflection
  - Incoming angle = angle of reflection

$$\boldsymbol{\alpha_{in} = \alpha_{out}}$$

- Real image
  - Light rays actually reach image
- Virtual image
  - Light cannot physically reach the image e.g. behind mirror

Spherical Mirror

- Concave
  - Light rays approach from side of the centre of curvature (C) of mirror
- Convex
  - Light rays approach from opposite side of mirror
- Optical axis
  - Incoming light ray defines this if it passes the centre of curvature (point C)
- Assume
  - Light source is at a very large distance from mirror
  - Light rays from light source approach mirror parallel to each other
- Radius of curvature (R)
  - Length of centre of curvature to the back of the mirror
- Focal point
  - Lies on optical axis
  - Where reflected rays intersect
- Focal length
  - Length of focal point to the back of the mirror

$$\boldsymbol{f = \frac{R}{2}}$$

- Spherical aberration
  - No focal point
  - Apertures
    - Use this to confine the spread of incoming light
    - Must have a focal point
- Problem Solving in Concave (pg.555)
  - One line parallel to radius of curvature and reflects by passing through focal point
  - One line goes through focal point and reflects parallel to the radius of curvature
  - Mirror equation used for thins lens and spherical mirrors as well
    - p = object distance
    - Q = image distance
    - M = magnification

$$\boldsymbol{\frac{1}{f} = \frac{1}{p} + \frac{1}{q}}$$

$$\boldsymbol{M = -\frac{q}{p}}$$

- Sign Conventions for mirrors
  - Object upright and behind C in concave
    - Smaller inverted real image between f and c
  - Image is magnified if p < 2f
    - When object placed closer to the mirror than C
  - Object upright and in front of f in concave
    - Magnified upright virtual image
  - Upright image
    - Object closer to mirror than f

+p	Object in front of mirror = real
-p	Object behind mirror = virtual
+q	Image in front of mirror = real
-q	Image behind mirror = virtual
+f, +R	C in front of the mirror = concave
-f, -R	C is behind the mirror = **convex**
+M	Image is upright
-M	Image is inverted

- Object upright in front of convex
  - Smaller upright image behind mirror and before f

Refraction

- Optical depth
  - Light passes through any medium except a vacuum
- Snell's Law and Law of Refraction
  - Index of refraction
  - Index is never smaller than 1
    - Light is the fastest in a vacuum
- Total reflection
  - Wave from higher index of refraction (lower speed) into a lower index of refraction (higher speed)
  - Refracted wave will not appear above the critical angle (90)

$$\frac{N_\alpha}{N_\beta} = \frac{sin\alpha}{sin\beta}$$

Lenses: Thin-Lens Formula and Magnification

- **Converging** (thicker at optical axis) or diverging lens
- Think or **thin** lenses
- Problem Solving
  - 3 light rays to determine position and size of images
    - Parallel to optical axis
    - Travelling on optical axis
    - Incident ray passing through focal point
- Sign Convention for thing lens
  - R1 = radius of curvature of the front surface of lens
  - R2 = radius of curvature of its back surface
  - Object behind f
    - Inverted image after f on other side
  - Object and its image in converging lens
    - Magnification is negative

+p	Object in front of lens
-p	Object behind lens
+q	Image behind lens
-q	Image in front of lens
+R1, +R2	C for each surface is behind lens
-R1, -R2	C is each surface is in front of lens
+f	converging
-f	diverging

Lens: Refractive Power

- the ability of the lens to refract the light
- Dioptres – dpt = 1/m

$$\mathbf{R} = \frac{1}{f}(thin\ lens) = \frac{\Delta n}{R}(spherical)$$

The Eye

- Cornea
  - Convex external and concave internal
- Near point
  - Shortest object distance for human eye to produce a sharp image on retina
  - Refractive power of corrective lens = 1/p – 1/nearpoint
  - **Standard man near point S_0 = 25 cm**
- Hyperopia
  - Farsightedness
  - Image formed behind retina (convex)
  - Positive refractive power
- Myopia
  - Near-sightedness
  - Elongated eyeball
- Problem solving
  - Thin lens formula
  - Myopia
    - 1/p becomes 1/∞ = 0
  - Artificial lens (Pg.568)

The Light Microscope (Pg. 570)

- Angular magnification
  - Ratio of angle subtended by object and angle subtended by same object under S_0
  - Object farther away is smaller m<1
  - The same object is required to make a relative statement at two distances
- Magnifying glass (Pg. 571)
  - ↓focal length of the magnifying lens = ↑ angular magnification
- The Compound Microscope
  - Objective lens (short focal length) + ocular lens
  - Total angular magnification (Pg, 572)

$$\mathbf{m} = \frac{\theta}{\theta_0} = \frac{S \text{ or } P_0}{P}$$

$$\textbf{relaxed}: \mathbf{m} = \frac{S_0}{f}$$

$$\textit{focus at near point or max angular magnification}$$

$$m = 1 + \frac{S_0}{f}$$

$$\mathbf{m}_{total} = M_{objective}\,\mathbf{m}_{eyepiece} \cong -\frac{L}{f_0}\frac{S_0}{f_E}$$

Sample Questions

A person with a near point of 25 cm tries to see a text with small print magnified by bringing the page closer to the eye. The person will achieve what angular magnification?

- m = 1 (no gain)

An average human eye can see objects as small as 100 µm. When that average person uses a light microscope with an overall angular magnification of m_{total} = 1000, the person can observe objects as small as:

- smallest it can view = average human eye/mtotal

Which mirror has the smallest refractive power?

- Flat surface mirror - Infinity focal length (does not exist but is the greatest distance between mirror surface)

Find the speed of light in NaCl.

- index of refraction * velocity = index of refraction of vacuum (1.0) * speed of light ($3 * 10^8$)

You are unhappy with the overall magnification you achieve with your homemade microscope. Which alternation will improve the results?

- Shorten the distance between the objective lens and the eyepiece.
- Exchange the objective lens for a lens with a larger focal length
- Exchange the eyepiece for a lens with a larger focal length
- Loosen up and look through the microscope with a relaxed eye
- **None of the above**

The total angular magnification quoted for a compound microscope does not depend on the following parameter:

- The near point of the observer

Most commercial microscopes have an additional lens, called the condenser lens. What does this lens do?

- Focus the light from a light source on the object

When observing a object in water from above?

- Object will appear closer than the actual depth

Given angle of incidence, L, speed, find depth.

- Find angle of refraction
- Tan (angle of reflection) = L/2 / depth

Calculate the <u>lateral shift</u> of the light ray, d.

- Solution manual pg 133 #22.5