1 Motion.

Physics.

1. Mass. doesn't change if you move it to a new place, even another planet.

2. Displacement: it is a vector, has direction. m.

$$\vec{\Delta S} = \vec{S_2} - \vec{S_1}$$

3. Velocity: $V = \frac{\Delta X}{\Delta t} = \frac{X_2 - X_1}{\Delta t}$ (Uniform Motion). m/s.

average velocity: $V_{avg} = \frac{\vec{\Delta S}}{\Delta t}$ (velocity changes during ΔS).

special: $V_{avg} = \frac{V_1 + V_2}{2}$ (Uniform Acceleration)

4. Acceleration: $\vec{a} = \frac{\vec{\Delta V}}{\Delta t} = \frac{\vec{V_2} - \vec{V_1}}{\Delta t}$ m/s^2.

5. Uniform Acceleration: $V_{avg} = \frac{V_1 + V_2}{2}$

$$\Delta X = V_{avg} \cdot \Delta t = \frac{(V_1 + V_2) \cdot t}{2}$$

$$\Delta X = V_1 \cdot \Delta t + \frac{1}{2} a \cdot \Delta t^2$$

$$V_2 = V_1 + a \cdot \Delta t$$

$$V_2^2 - V_1^2 = 2a \cdot \Delta X$$

2 Laws of Motion

1. First law of motion:

If the force on an object are balanced, then the object moves with constant velocity. (in a straight line).

If the net force on an object is not zero the object can not be undergoing uniform motion. It is either speeding up / slowing down / *changing direction

2. Second law of motion:

$\vec{F}_{net} = \vec{a} \cdot m$ $N. = kg.m/s^2$.

3. Third law of motion:

To every action there is an equal & opposite reaction.

If object 1 exerts a force $\vec{F}_{12}$ on object 2.
then object 2 exerts a force $\vec{F}_{21}$ on object 1.

$\vec{F}_{12} = -\vec{F}_{21}$

3 Gravitation.

1. The law of gravitation.

$$F_{grav} = \frac{G m_1 m_2}{d^2}$$

$$G = 6.67 \times 10^{-11} \, m^3/kg \cdot s^2$$

on the surface of earth: $F_{grav} = m \cdot g$.

2. Horizontal & Vertical Motion:

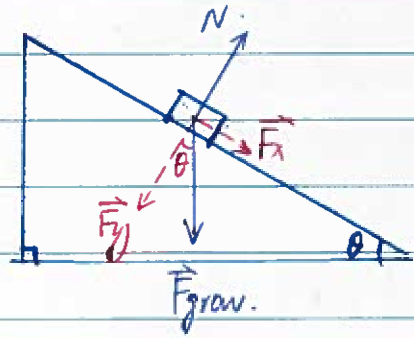
Horizontal & Vertical Motion are independent.

$$(F_{net})_y = m \cdot a_y.$$

$$\Delta y = \frac{1}{2}(V_{1y} + V_{2y}) \cdot \Delta t.$$

$$(F_{net})_y = F_{1y} + F_{2y} + \cdots \qquad a_y = F_y/m.$$

$$(F_{net})_x = F_{1x} + F_{2x} + \cdots \qquad a_x = F_x/m.$$

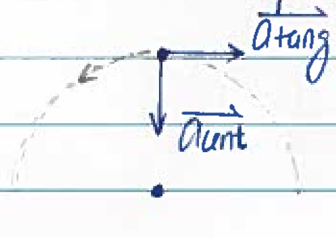


4 Planes & Circles.

1. Circular Motion.

If an object is moving at constant speed in a circle, then the net force on the subject points toward the center of the circle. and a vector also points toward the center.

☆ $a_{cent} = \frac{V^2}{r}$



slowing down.

$a_{tang} = \frac{\Delta V}{\Delta t}$

$V = \frac{2\pi R}{T}$

5. Friction & Air Resistance.

1. Static friction:
   No slipping surface. $a_x = 0$, $a_y = 0$.
   $F_{s\,max} = \mu_s \cdot N$.

2. Kinetic friction:
   slipping between surfaces.
   $F_k = \mu_k \cdot N$

* 与物体滑动的 v 无关.
* 与接触面积 A 无关.

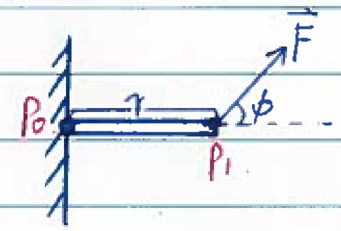
3. Air Resistance.
   $F_{drag} = C \cdot \rho \cdot A \cdot v^2$

   $C = 0.2$. ρ density of the fluid/air.
   A. cross-section area of the moving object.

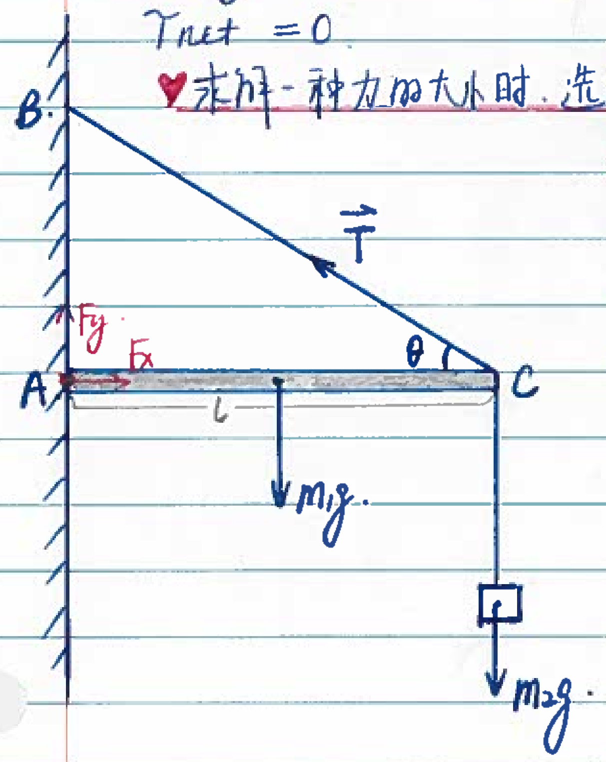
4. Determine whether air resistance can be neglected:
   1. 先假设可忽略. 计算出 v_2
   2. 将 v_2 值代入 $F_{drag} = C \cdot \rho \cdot A v_2^2$ 得到 F_{drag} 值.
   3. 比较 F_{drag} 与 F. 若 $F_{drag}/F \ll 1$ 则可忽略.

6. Torques

1. Moment of inertia of a ring shape object:
   $I = M \cdot R^2$ 半径大的物体 不易被转动
2. Spinning wheel. frequency $f = 1/T$
3. Torques: $\tau = r \cdot F \cdot \sin\phi$
   P_0 pivot, the point of axis
   P_1 受力点
   counterclockwise: +. clockwise −.



4. Equilibrium. ★
   $(F_{net})_x = 0$
   $(F_{net})_y = 0$ no matter which point you choose
   $\tau_{net} = 0$ as the pivot



♥求解一种力的大小时，选择该力可产生τ的点为pivot. eg 求解T:

I. A as the pivot.

可对A点产生torques的力有: $\vec{T}$, m_1g, m_2g

∵ the system is equilibrium ∴ $\tau_{net} = 0$

∴ $\tau_{net} = +l \cdot \sin\theta \cdot T - \frac{1}{2} l \cdot m_1 g - l \cdot m_2 g = 0$

∴ $T = \dfrac{m_1 g + 2m_2 g}{2\sin\theta}$

eg 求解 vertical force exerted by the wall on the pole. (F_y)

II. C as the pivot.

可对C产生τ的有 $\vec{F_y}$, m_1g.

$\tau_{net} = l \cdot \vec{F_y} - \frac{1}{2} l \cdot m_1 g = 0$

7 Solid Properties:

1. For object made with same material:
A force will stretch a long wire more than a short wire.
strain = $\Delta L / L$.
A force will stretch a thin wire more than a thick wire.
stress = F/A

eg. A force F on the two ends of rod A which length is L will cause ΔL; when apply F on the two ends of rod B, which length is 3L, will cause elongation $\sim 3\Delta L$

F on the two ends of rod A with radius r cause ΔL.
F on the two ends of rod B (the same length as A) with $2r$.
will cause $1/4 \Delta L$ ($\because$ in this case $A = \pi r^2$).

2. Scale models
When the linear dimensions of a structure are all ↑ by a facto[r] x, the cross section area ↑ by x^2, the volume & mass ↑ by x[illegible]
the stress = F/A ↑ by x.

8. Momentum.

1. momentum of a single object

$\vec{p} = m \cdot \vec{v}$

2. Conservation of momentum:

If a system of objects is isolated (external forces are balanced) then the total momentum of the system stays constant.

$\vec{p}_{before} = \vec{p}_{after}$.

eg. collision.

3. External Forces & Impulse.

When the external forces are not balanced:

$\Delta\vec{p} = \vec{p_2} - \vec{p_1}$

$$\vec{F_{net}} = m \cdot \vec{a} = m\frac{\vec{V_2} - \vec{V_1}}{\Delta t} = \frac{m\vec{V_2} - m\vec{V_1}}{\Delta t} = \frac{\vec{\Delta p}}{\Delta t}$$

$\therefore \Delta\vec{p} = \vec{F_{net}} \times \Delta t$.

9. Energy

1. **Work:** $W = F \cdot \Delta x \cdot \cos\phi$. $kg \cdot m^2/s^2 = N \cdot m = J$

ϕ is the angle between the direction of $\vec{F}$ & the direction of the displacement $\vec{\Delta x}$.

$$W_{tot} = F_{net} \cdot \Delta x \cdot \cos\phi.$$

*F与位移方向相同时 $\cos\phi = 1$. 相反时 $\cos\phi = -1$. 垂直时 $\cos 90° = 0$.

2. **Energy of Motion:**

$$W = F \cdot \Delta x = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \Delta E_k.$$

$$F = ma = \frac{m\Delta v}{\Delta t} = \frac{m(v_2 - v_1)}{\Delta t}$$

$$\Delta x = \frac{v_2 + v_1}{2} \cdot \Delta t.$$

$$E_k = \frac{1}{2}mv^2.$$

3. **Potential Energy:** $E_p = mgh$.

4. **Conservation of Energy:**

eg. $E_{k1} + E_{p1} = E_{k2} + E_{p2}$.

5. **Efficiency of Energy Conversion.**

$$\text{Efficiency} = \frac{\text{Energy in desired form}}{\text{Energy in original form}} \times 100\%.$$

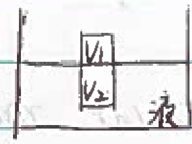
6. **Power:** $P = \frac{\Delta E}{\Delta t}$

7. **Pulleys:** 1. 在一根绳上 the tension is the same along the rope.
2. rope pulled @ v. by hand = on some load.

10. Fluids

1. Density. $\rho = \frac{m}{V}$ mass/volume

Specific gravity $= \frac{\rho}{\rho_{H_2O}}$.



$\frac{V_1}{V_2} = \frac{\rho_{液} - \rho_{物}}{\rho_{物}}$.

$\rho_{H_2O} = 1 g/cm^3 = 10^3 kg/m^3$.

2. Pressure $P = F/A$. N/m^2

$1 N/m^2 = 1 Pa$.

$1 atm = 1.01 \times 10^5 Pa = 14.7 psi = 760 mmHg$.

3. Buoyant force: $F_B = \rho V g$.

* ρ: density of the fluid.

V: volume of the displaced fluid.

4. Law of Hydrostatic Equilibrium: In a body of fluid:

① the pressure at 2 points separated vertically by height h.

$P_2 = P_1 + \rho g h$.

② the pressure at 2 points separated horizontally are the same

③ the pressure at a given point is the same in all directions.

5. Gauge Pressure: $P_{gauge} = P - P_{atm}$.

6. Surface Tension: $F_{max} = \gamma \cdot L^*$.

* L为浸入水中的边长总合.

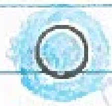
eg. ① A needle floats on the surface of the water. length = 3cm. width very small. Fmax by the surface tension of water?

$L = 2(l+w) \approx 2l = 6cm$.

针的周长.

② A wire circle. radius: r. Fmax?

$L = 2 \cdot C = 2 \times 2\pi r = 4\pi r$.



里外均接触水.

③ A solid circle. radius: r. Fmax?

$L = C = 2\pi r$.

仅外周接触水.

7. Continuity: The flow rate f of the water in the same flow eg. river is the same at each point along the flow.

$$f_1 = f_2$$

$$f = A \cdot V$$

* A: area of the cross-section
  V: flow speed / velocity.

8. Viscosity & Turbulence.

$$F_{viscous} = \eta \cdot \frac{A v}{d}$$

* η: viscosity in kg/m.s
  d: depth of the fluid.

$$Re = \frac{L \cdot \rho v}{\eta}$$

* L: size of the obstacle in the flow. m
  ρ: density of the fluid. kg/m
  V: flow velocity m/s.
* Re 越大液体越稀 越易 turbulen

9. Bernoulli's Principle:

For incompressible, laminar, inviscid flow. if point 1 & 2 are on the same streamline:

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$P \cdot \Delta V + mgh + \frac{1}{2}mv^2 = \text{constant}$$

$$P \cdot A \, \Delta X = F \cdot \Delta X$$

11. Periodic Motion & Waves.

1. Hooke's law of spring

If a spring has resting length l_0, and it's stretched or compressed to length $(l_0 + x)$. then it exerts a force:

$F_{spring} = k \cdot x$

* k: spring constant. N/m.

F_{spring} direction is opposite the direction of pull or push.

2. Potential energy of springs:

$E_p = \frac{1}{2} k \cdot x^2$

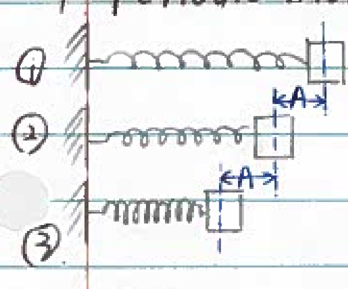
3. Conservation of Energy.

$E_k + E_p = constant$ $\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = constant$.

eg: One end of a horizontal spring ($k = 20$ N/m) is connected to a wall. and the other end is connected to a mass $m = 0.2$ kg. The spring is compressed 0.1 m from equilibrium. After it's released, how much work does the spring do in order to push the mass to the equilibrium position?

$W = \Delta E_k = -E_p = \frac{1}{2} k \cdot x^2 = 0.1 J$.

4. Periodic Motion: One Oscillator.



① $t=0$. $x=A$. $v=0$. $a=-\frac{kA}{m}$ $E_p = \frac{1}{2}kA^2$ $E_k=0$.

② $t=\frac{1}{4}T$ $x=0$. $v=-v_{max}$ $a=0$ $E_p=0$. $E_k=\frac{1}{2}mv_{max}^2$

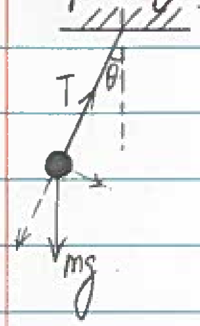
③ $t=\frac{1}{2}T$ $x=-A$ $v=0$. $a=\frac{kA}{m}$ $E_p=\frac{1}{2}kA^2$ $E_k=0$.

② $t=\frac{3}{4}T$ $x=0$ $v=v_{max}$ $a=0$. $E_p=0$ $E_k=\frac{1}{2}mv_{max}^2$

① $t=T$ $x=A$ $v=0$ $a=-\frac{kA}{m}$ $E_p=\frac{1}{2}kA^2$ $E_k=0$.

5. Frequency of a spring: $f = 1/T = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Frequency of a pendulum: $f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$



$F_\perp = mg \cdot \sin\theta$ 当 $\theta \to 0$ 时. $\sin\theta \to \theta$

$= mg \cdot \theta$

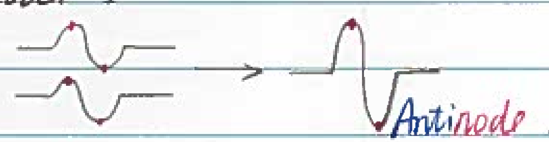
6. Waves: $f = 1/T$ $v = \lambda \cdot f$

water wave	longitudinal & transverse
wave on plucked string	transverse
sound	longitudinal
earthquake	longitudinal & transverse
Light	transverse

7. Interference & Node & Antinode

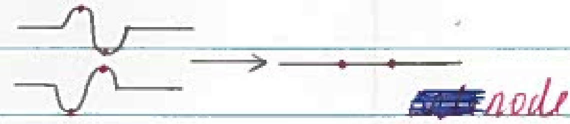
① Constructive interference

two waves are "in phase"



② Destructive Interference

two waves are "out of phase"



* Constructive interference occurs when 2 waves differ by no wavelengths, or 1, 2, 3 ...

Destructive interference occurs when 2 waves differ by 1/2 wavelengths, or 3/2, 5/2, ...

8. Standing Waves. * have only certain allowed f.

★ For a string held at both ends.

① fundamental.  $l = \frac{1}{2}\lambda$.

② second harmonic  $l = \lambda$.

③ third harmonic  $l = \frac{3}{2}\lambda$.

12. Sound

1. Intensity & Pitch

① Intensity $I = \frac{\Delta E}{A \cdot \Delta t} = \frac{P}{A}$ W/m^2

* $A = 4\pi r^2$ 球形表面积

$I_0 = 10^{-12}\ W/m^2$ 为 human ear barely perceptible intensity.

② $\beta = 10 \times \log_{10} \frac{I}{I_0}$

* $\Delta(I/I_0) = 10^n$. 则 $\Delta\beta = 10 n$

③ power going through surface A = power going through surface B.

$P_A = P_B$.

$I_A = \frac{P_A}{4\pi r_A^2}$ $I_B = \frac{P_B}{4\pi r_B^2}$

$4\pi r_A^2 \cdot I_A = 4\pi r_B^2 \cdot I_B$. $\therefore I_A = \left(\frac{r_B}{r_A}\right)^2 I_B$

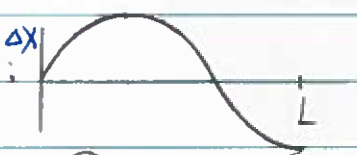
2. Resonating Cavities

For one end closed, one end open pipe:

① Fundamental:

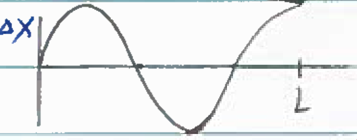
$\frac{1}{4}\lambda = L$.

② Second harmonic:



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

③ Third harmonic:



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

④ n. harmonic $[\frac{1}{4} + \frac{1}{2}(n-1)]\lambda = L$

For open pipe with two open ends:

① Fundamental

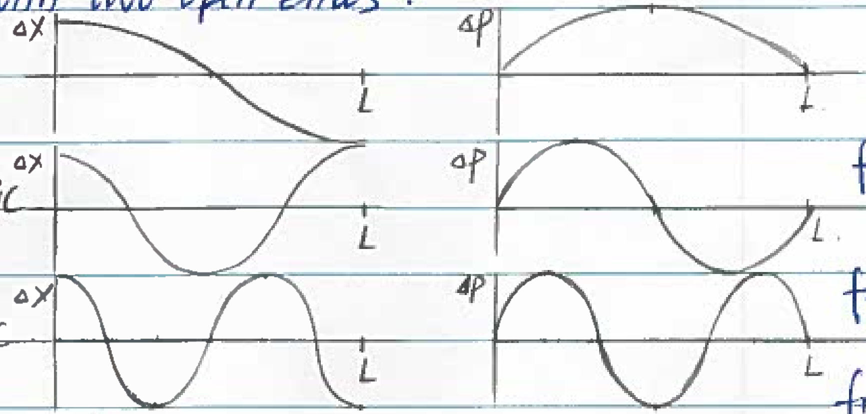
$\frac{1}{2}\lambda = L$

② Second hormonic

$\lambda = L$

③ Third hormonic

$\frac{3}{2}\lambda = L$



f_1

$f_2 = 2f_1$

$f_3 = 3f_1$

$f_n = nf_1$

ⓝ n hormonic $[\frac{1}{2} + \frac{1}{2}(n-1)]\lambda = L$

3. Beats. $f_{beat} = |f_1 - f_2|$

*① Firstly 2 similar f waves are in phase.

② Then gradually out of phase.

③ Then in phase again.

4. Doppler Shift.

When the emitter of a wave & the detector are moving relative to each other. the detector detects a different f from the one emitted. The f is higher if they are coming together. lower if they are going apart.

Application: $f_{det} = f_{em} \cdot \frac{V_s \pm V_{det}}{V_s \pm V_{em}}$

A police officer uses an emitter emits a $f_{em} = 60$ kHz to determine the speed of an approaching car ($V_{car} = 38$ m/s). The speed of sound is 343 m/s.

① What f would the car detect if it could detect the emitter?

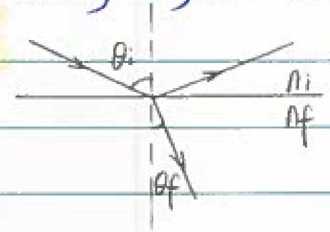
② What f would the officer detect from the reflection?

① $f_{car} = f_{em} \cdot \frac{V_s + V_{car}}{V_s}$ ② $f_{det} = f_{car} \cdot \frac{V_s}{V_s - V_{car}}$

13. Light

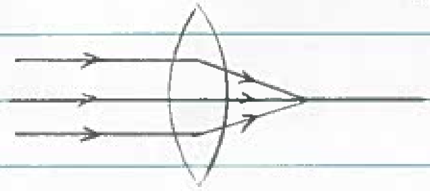
1. Radio wave → Microwave → infrared → visible Light → Ultraviolet → X → γ rays
   $\lambda \downarrow$ $f \uparrow$

2. Light speed : ① in vaccum : $c = 3 \times 10^8$ m/s
   ② non vaccum : $v = c/n$. *n : index of refraction.
   Snell's Law : $n_i \sin\theta_i = n_f \sin\theta_f$
   critical angle : $\theta_f = 90°$ 时的 θ_i
   $\sin\theta_i = \frac{n_f}{n_i}$



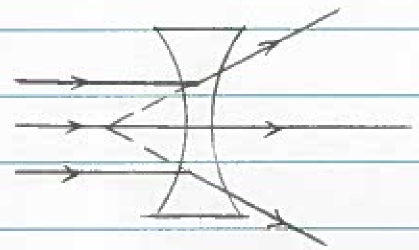
3.

Converging Lens



$f > 0$

Diverging Lens :



$f < 0$.

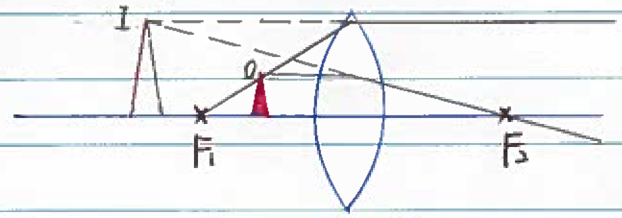
do : distance from lens ~ object . di : distance from Lens ~ image .
m : magnification of the image .

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

$$m = -\frac{d_i}{d_o}$$

* $d_i < 0$. image & object @ same side $d_i > 0$. image @ the other side
* $m < 0$. image is inverted . $m > 0$. image is upright .

4. Ray tracing for converging lens:

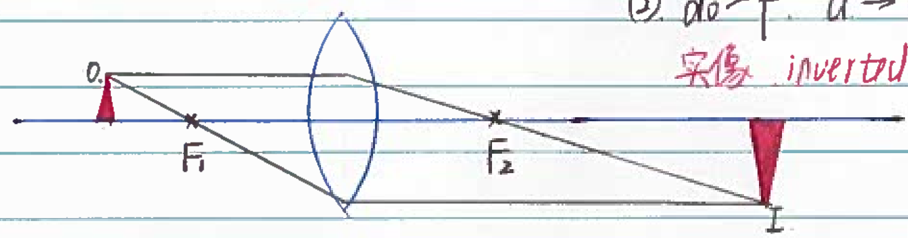


① $d_o < f$. a. F_1 O → lens → 平行线.

虚像 upright

b. O 平行线 → lens → 过 F_2

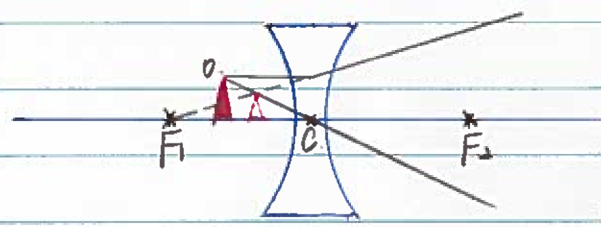
c. 延长线交点即为 I.



② $d_o > f$. a → b → c.

实像 inverted

5. Ray tracing for diverging lens:



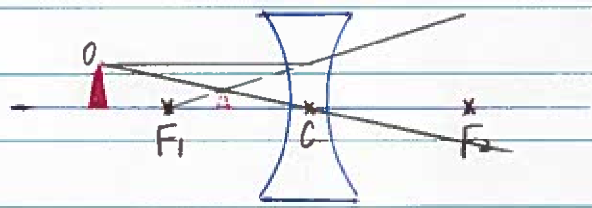
a. O 平行线 → lens → 反延过 F_1

b. OC 直线过 lens.

c. 反延与OC交点为 I.

① $d_o < f$. upright. vitral image.

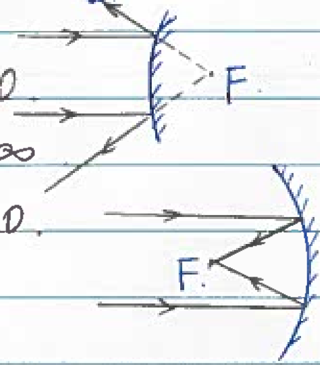
② $d_o > f$.



6. Mirrors.

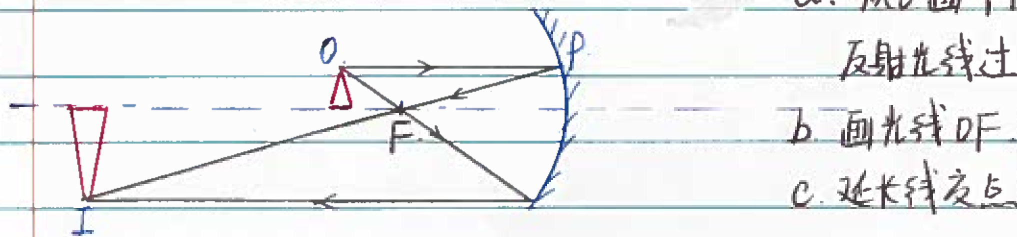
$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $m = -\frac{d_i}{d_o}$

* convex mirrors $f<0$
  plane mirrors $f=\infty$
  concave mirrors $f>0$.

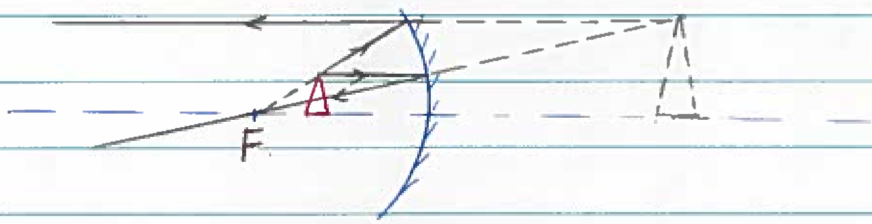


* $d_i > 0$. image & object @ same side.

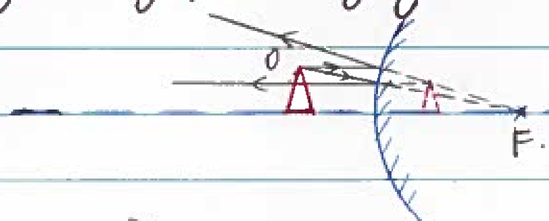
① Ray tracing for converging mirrors.



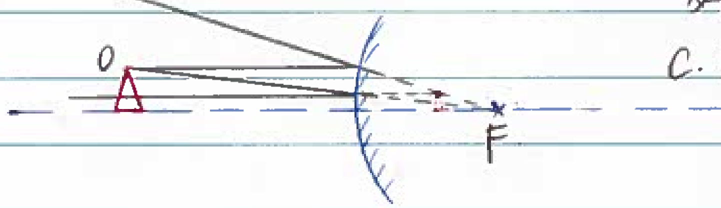
a. 从O画平行线→mirror→反射光线过F.
b. 画光线OF. 反射光线平行.
c. 延长线交点为I.



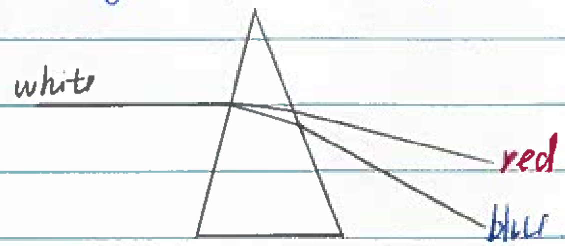
② Ray tracing for diverging mirrors.



a. 从O画平行线→mirror→反射光线延长线过F.
b. 从O画光线延长过F. 反射光线为平行光线.
c. 延长线交点为I.



7. Dispersion: Different colors refract slightly differently, causing a separation of colors in a prism.

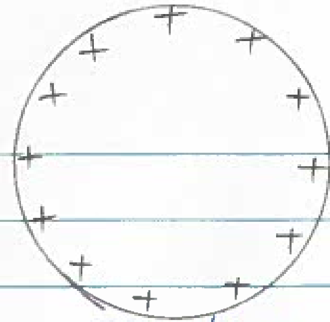


8. Combination of Lenses.

$$\frac{1}{f_{total}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \cdots$$

power of lens $m^{-1} = D = \frac{1}{f}$.

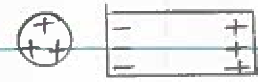
14. Electrodynamics



1. Charge & Materials.

① Conducting material: if given some charges, will evenly distributed on the surface; A charged object can induce a charge in a conductor.

② Nonconducting material: The induced charge in the nonconducting object is less than in a conductor.

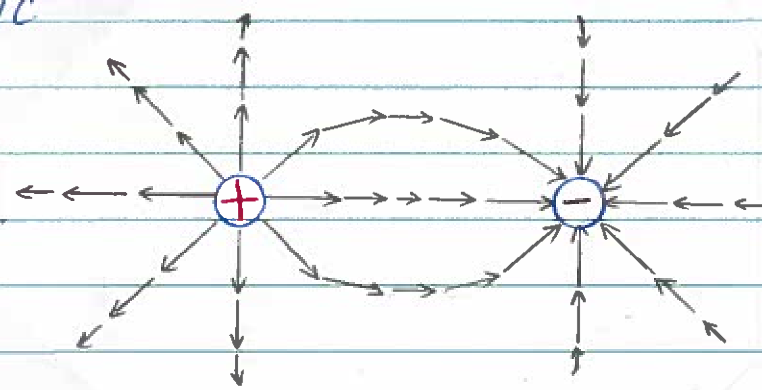


2. Coulomb's Law.

$$F_{coul} = \frac{k\cdot q_1\cdot q_2}{d^2} \qquad F_{grav} = \frac{GM_1M_2}{d^2}$$

* $k = 9\times 10^9\ N\cdot m^2/C^2$

3. Electric Field.



$$E = \frac{k\cdot Q}{d^2}$$

$$\vec{E} = \vec{E_1} + \vec{E_2} + \cdots$$

A charge q placed @ point P will experience a force:

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

4. Electric Potential: 无方向.

For a lone charge Q. The potential at point P.

$$V = k\frac{Q}{d}$$

unit: J/C = volts = V.

If there are several charges: Q_1, Q_2 ...

$$V = \frac{kQ_1}{d_1} + \frac{kQ_2}{d_2} + \cdots$$

5. The work required to bring a charge from infinity to point P.

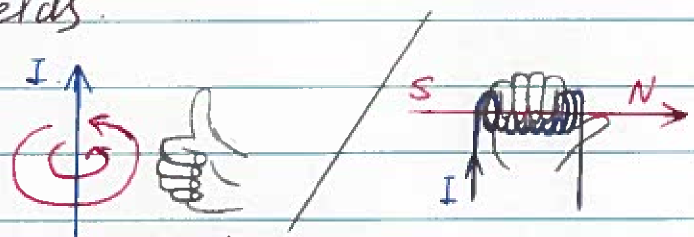
$W = q \cdot V_P$.

The work required to move a charge q from A to B:

$W = q \cdot \Delta V_{AB} = q \cdot (V_B - V_A)$

6. Magnetic Fields.

① 右手定则：



右手螺旋定则

I方向为⊕方向　　判断感应电流方向.

伸开右手，拇指⊥四指且在手掌平面，让磁感线从手心进入，拇指指向导线运动，四指即为感应电流

② 左手定则：判断安培力的方向.

伸开左手，拇指与四指垂直且与掌在同一平面，让磁感线从掌心进入，四指指向电流方向，拇指方向即为通电导线在磁场中所受安培力方向

③ 判断移动带电粒子在磁场中受力方向：

⊕ 右手半握拳（四指与手掌垂直）拇指指向粒子运动方向，四指指向磁场方向，手掌→前臂方向为受力方向.

⊖ 用左手.

Electric Circuits

1. Ohm's Law: $\Delta V = I \cdot R$.
   V A Ω

2. For several resistors in series: $R_T = R_1 + R_2 + \cdots$

   For several resistors in parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

3. Real DC cells $\Delta V = V_{emf} - I \cdot R_{cell}$.
   Real Wires $R = \rho \frac{L}{A}$.
   * L: length of the wire. m.
   A: cross-sectional area m^2.
   ρ: Ω·m

4. Power: $P = I \cdot \Delta V$ J/s = Watts.
   $P = I^2 \cdot R = \frac{(\Delta V)^2}{R}$
   when comparing 2 bulbs which one is brighter. we are comparing P.

5. Capacities: $Q = C \cdot \Delta V$.
   Coulombs Farads · Volt.

   ① $W = q \cdot \Delta V$ the work needed to move a charged q cross capacity
   ② $W = F_{elec} \cdot \Delta X$
   ③ $F_{elec} = q \cdot E$. E: magnitude of the electric field inside of the capacity.

   $\therefore \Delta V = E \cdot \Delta X$.

Atomic & Nuclear Physics

1. $q_{proton} = +1.6\times10^{-19}C$.

2. $E_n = -\frac{R_y}{n^2}$ $\qquad \frac{-2.18\times10^{-18}}{n^2}$

For an isolated atom. it only has certain energies according to the upper equation.

3. $E_{photon} = h\cdot f$.

* $h = 6.63\times10^{-34} J/Hz$. Plank's constant

$c = \lambda\cdot f$.

* $c = 3\times10^8 m/s$

4. α decay: $^{232}_{90}Th \longrightarrow \boxed{^4_2He} + ^{228}_{88}Ra$.

β decay: $\begin{cases} ^9_3Li \longrightarrow \boxed{^0_{-1}e} + ^9_4Be + \bar{\nu} \\ ^{11}_6C \longrightarrow \boxed{^0_{+1}e} + ^{11}_5B + \nu. \end{cases}$

γ decay: $^{60}_{28}Ni^* \longrightarrow ^{60}_{28}Ni + \boxed{\gamma}$.

excited. ground. (photon).

5. $E = M_{def}\cdot c^2$.

* $M_{def} = M_{reactant} - M_{product}$.