Chapter 1. Making measurements

1. Physical quantity (**scalar vs vector**)
2. Measurements (numbers + units)

a. SI unit

Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K

b. Standard notation

c. **Prefix**

nano(n)	10^{-9}	kilo(k)	10^{3}
micro(μ)	10^{-6}	mega(M)	10^{6}
milli(m)	10^{-3}	giga(G)	10^{9}
centi(c)	10^{-2}		
deci(d)	10^{-1}		

d. Measuring length

Tool: ruler, more precise: micrometer/screw gauge, vernier

Key techniques:

- check zero
- measure large numbers
- measure multiple times and calculate the average
- avoid parallax

Measuring area

Measuring volume

- Liquid: measuring cylinder
- Regularly shaped solid
- Irregularly shaped solid:

displacement

I. Add water into measuring cylinder
II. Read the volume.
III. **Immerse** the object in the water.
IV. Read the new volume.
V. The difference between two readings is the volume of the object

e. Measuring time

Tool: analogue clock, digital clock(0.01s)

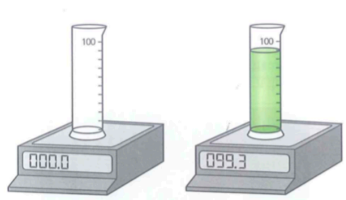
<u>Key techniques:</u>

- **<u>check zero</u>**
- **<u>Measure large numbers and divide the reading by the number</u>**
- **<u>Measure multiple times and calculate the average</u>**
- **<u>Start at a recognize point in the cycle e.g. start when the pendulum is on the highest position</u>**

f. Measuring **density**

$$\rho = \frac{m}{V}$$

Measuring the density of liquid:



1. Place the measuring cylinder on a balance
2. Set the balance to Zero
3. Pour the liquid into the cylinder
4. Read the scale on the cylinder
5. Read the numbers on the balance

$\rho_{oil} < \rho_{ice} < \rho_{water} = 1g/cm^3$

Liquid with different densities:

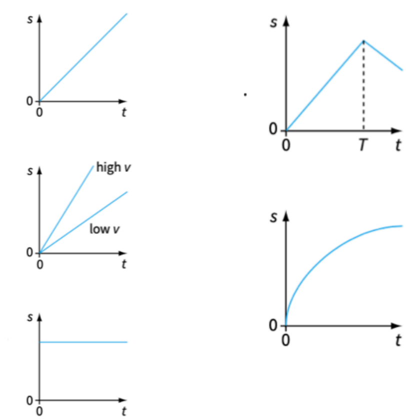
- immiscible: form layers with small densities on the top
- Miscible: dissolve in one another

Chapter 2. Describing motion

1. Average speed: $$v = \frac{s}{t} = \frac{\Delta s}{\Delta t}$$

2. speed vs velocity (in one-direction linear motion: speed = magnitude of velocity)
3. distance-time graph

   slope = speed



4. acceleration: **the rate of change of velocity**

$$a = \frac{\Delta v}{\Delta t} = \frac{v - u}{\Delta t}$$

5. speed-time graph

   slope = acceleration

Slope: magnitude of acceleration

Larger slope: larger acceleration

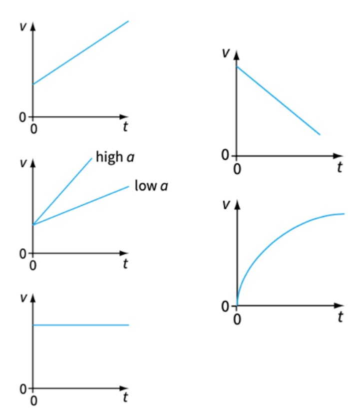
Positive slope: accelerating

Negative slope: decelerating

Slope =0 (a horizontal graph): a = 0, constant speed(including stationary)

Straight line: constant acceleration

Curved line: changing acceleration



distance = area under speed-time graph

6. uniform linear motion: (constant speed) v= constant

7. uniformly accelerated (linear) motion: constant acceleration (**a = constant**)

Average velocity: $v_{ave} = \dfrac{v+u}{2}$

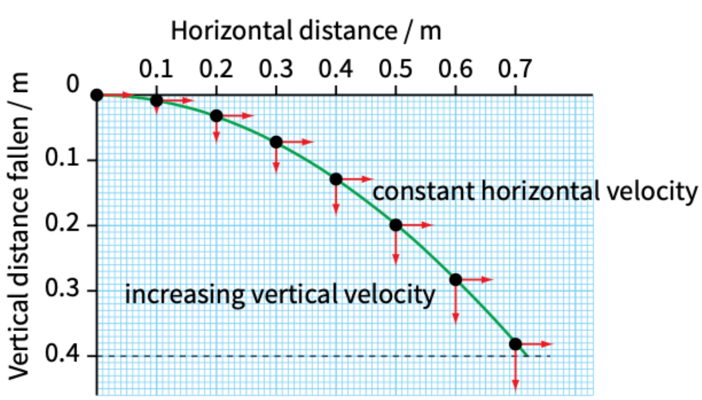
$$v = u + at$$
$$s = \frac{(u+v)}{2} \times t$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

8. free fall(only gravity, ignore air resistance)

$$a = g = 9.8\ m/s^2$$

9. Falling in the air (**decreasing acceleration**)

10. projectile



Chapter 3. Forces and Motion

1. Force

Effects of force		Example
Change size/shape		Spring
Change velocity	Magnitude	Parachutist
	Direction	Projectile

unit of force: N ($kg\ m/s^2$)

representation: arrow (longer -> larger force)

2. Common forces:

Contact force	normal force (F_N or N), friction (F_f or f), air resistance (F_f or f, $\propto v^2$, $\propto A$), tension (F_T or T), elastic force (F_e or F_s), …
Non-contact force	**Gravitational force (F_g)**, Electrostatic force (F_E), Magnetic Force(F_B), …

Weight: downward force due to gravity

W = mg, g = 9.8N/kg, m: 引力质量

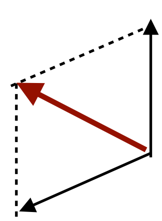
weight vs mass: **mass is the quantity of matter in an object at rest to the observer.**

3. Free-body diagram (受力分析) & resultant force（合力）

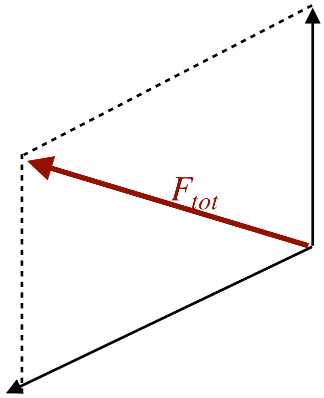
做受力分析： step 1: check weight； step 2: 看谁和这个物体接触，可能有哪些接触力

求合力： a. If forces acting along the same straight line: 同向相加， 异向相减

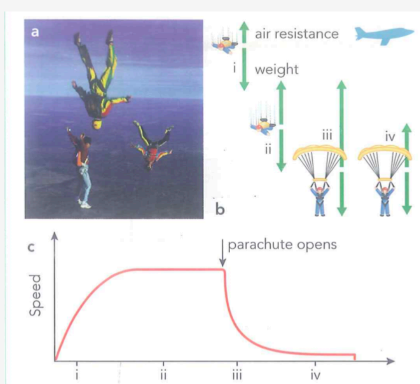
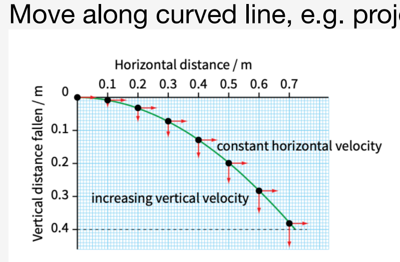
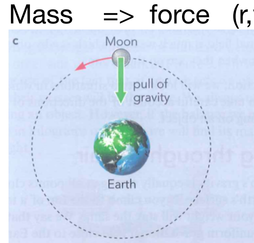
b. Otherwise: vector addition, apply **parallelogram law**(补全平行四边形，画对角线) or **triangle law**（各个向量首尾相连）



Scale diagram（比例图/图示）： 需要把力的大小成比例的画出来，比如1cm 对应1N； 可以用来求resultant force的大小及方向(量出大小和方向)。



4. Newton’s second law

<table>
<tr><td rowspan="5">F_{tot}</td><td>$=0$</td><td>Continue as before</td><td>Stay at rest or move at steady speed along straight line</td></tr>
<tr><td rowspan="4">$\neq 0$</td><td colspan="2"><u>F = ma</u> (常考：已知 a 求 F, 或者反过来)
m: 惯性质量
The resistance of an object to changes in motion</td></tr>
<tr><td>$F \parallel u$</td><td>$F \nparallel u$</td></tr>
<tr><td rowspan="2">Accelerate or decelerate along straight line, e.g. parachutist

</td><td>Move along curved line, e.g. projectile

</td></tr>
<tr><td>When $F \perp u$ => circular motion; F acts as centripetal force (towards the center of the curve). $F = \frac{mv^2}{r}$
Speed => force (m,r const)
Radius => force (m,v const)
Mass => force (r,v const)

</td></tr>
</table>

5. Impulse:

$F\Delta t = mv - mu = \Delta p$ (冲量定理：Impulse equals the **change** of momentum.)

Unit of impulse: Ns

6. Momentum:

$p = mv$

Unit of momentum: $kg\ m/s$

7. Definition of force: force is the rate of change of momentum

$$F = \frac{\Delta p}{\Delta t}$$

why we need airbags/safety belt during car crash:

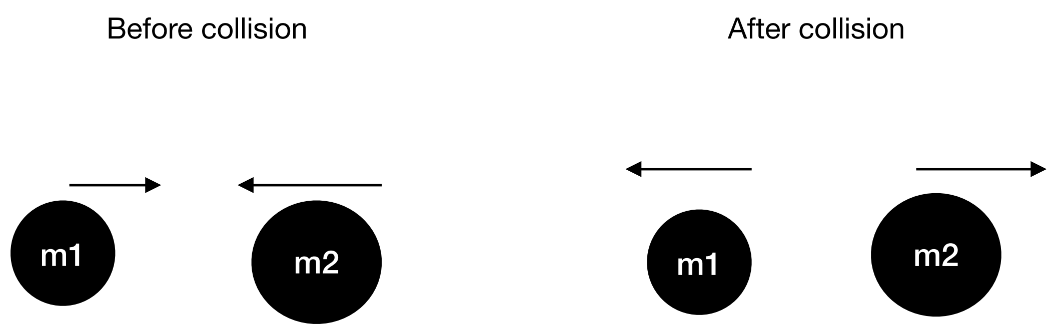
Δp same, Δt **increases** due to airbags/safety belt, so force F is reduced, causing less harm

8. Conservation of momentum

For an isolated system(no external forces applied), total momentum doesn't change, before and after collision, momentum are conserved: $p_i = p_f$

$$m_1\overrightarrow{u}_1 + m_2\overrightarrow{u}_2 = m_1\overrightarrow{v}_1 + m_2\overrightarrow{v}_2$$

Collision example:



运用动量守恒解题步骤:

1. 选取正方向（一般选+x方向）；

2. 与正方向相同的速度为正， 相反为负；如上例中 u_2 v_1均为负。

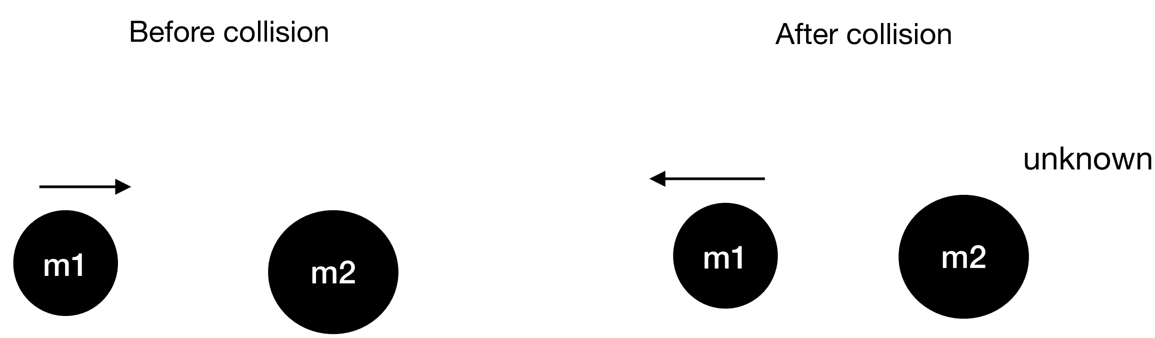
3. 把矢量形式的动量守恒方程写成标量形式，即与正方向相同的，前面符号不变；与正方向相反的前面符号正的变负的。如：

$$m_1u_1 - m_2u_2 = -m_1v_1 + m_2v_2$$

4. 如果有速度方向不确定的，先令其为正，如果最后算到正的就说明它是正方向的，否则是反方向的

Exercise:

write down the momentum conservation equation for the following situation:



Chapter 4. Turning effect

1. Moment: the turning effect about a point

$$M = r \times F$$

r is perpendicular distance to the pivot

To get larger moment:

a. Larger force
b. Act further for pivot
c. Act perpendicular to the object

If (extended) line of force pass through the pivot, then moment of this force to this pivot is 0.

2. Two conditions for **Equilibrium**:

a. No resultant force
b. No net moment (**<u>clockwise moment = anti-clockwise moment</u>**)

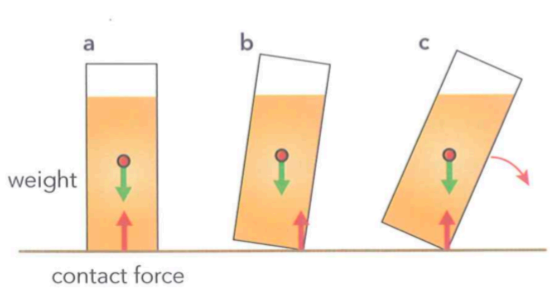
Principle of moment

3. Center of gravity:

All the mass of an object could be located here and the object would behave the same

Finding center of gravity: a. For mass uniformly distributed object: at the geometric center
b. Otherwise: use **Suspension**

4. Stability



Stable: lower center of gravity, wide base

Unstable: higher center of gravity, narrow base

Chapter 5. Forces and Materials

1. Force acting on solids: change shape & size(storing energy)

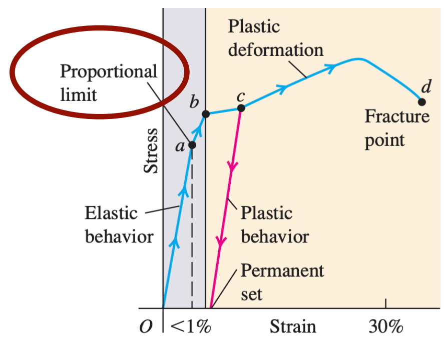
Solids/materials	**Elastic**	Once load removed, can return to original size & shape
	Plastic	Once load removed, can **not** return to original size & shape

2. Limit of proportionality

Up to this limit, the extension on spring is proportional to its load.

常考点： find the limit of proportionality

(首先弯折的点)



3. Hooke's Law

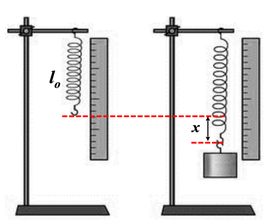
Within the limit of proportionality, the extension is proportional to the load applied to it.

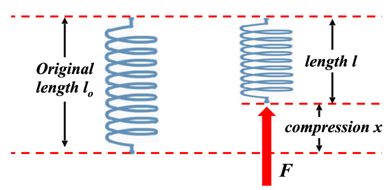
$$F = kx$$

F: load
易错点：当挂的是重物时，load (F)是它的weight， 不是mass。$F = W = mg$

k: spring constant
(A measurement of stiffness of a spring)

x: **extension** (measured length - original length)/**compression**(original length - measured length)



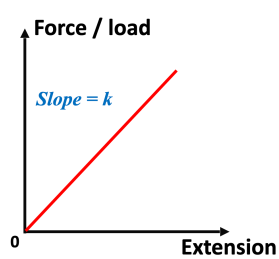


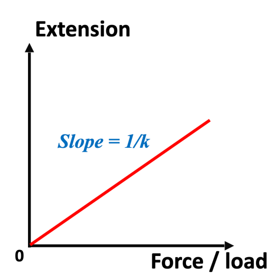
常考点：

求k (根据图像load-extension)

根据 k 和 load 求extension/length

易错点： 看清求的是**extension**还是**length**





4. pressure

$$p = \frac{F}{A}$$

Pressure is a **scalar**

Unit: Pa ($1\ Pa = 1\ N/m^2$)

Pressure depends on:	Force (F)	p directly proportional to F
	Area (A)	p inversely proportional to A

5. Pressure in liquid

Pressure caused by liquid:

$$p = \rho g h$$

Change in pressure: $\Delta p = \rho g \Delta h$

Liquid pressure summary

Pressure increases with depth
Pressure depends on the density of liquid
Pressure doesn't depend on the shape of the container
Pressure acts in all directions
Pressure at a given depth is the same in all directions

6. Pressure in air(atmospheric pressure)

Standard atmosphere(标准大气压) (1 atm = 101325Pa ≈100000 Pa)

atmospheric pressure(气压) changes according to altitude(海拔: height above the sea level).

Acts on every objects in atmosphere, equally in all directions.

7. Total pressure

Total liquid in the liquid: $p = \rho g h + p_{atmospheric\ pressure}$

Chapter 6. Energy stores and transfers

1. Energy (the ability to do work; stores + transfers)

Unit: Joule (J)

Energy is a **scalar**

2. Energy stores:

Gravitational potential energy(g.p.e.): energy due to height; $E_p = mgh$; $\Delta E_p = mg\Delta h$

Kinetic energy(k.e.): energy due to motion $E_k = \frac{1}{2}mv^2$; $\Delta E_k = E_{kf} - E_{ki} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Elastic energy; Internal energy; Chemical energy; Nuclear energy; Electrical energy

3. Energy transfers

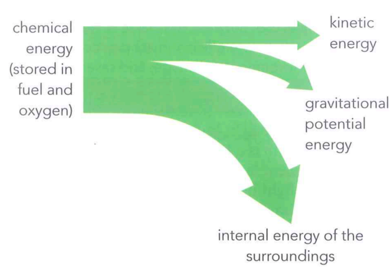
Doing work(W); Heat; Light(Electromagnetic radiation, e.g. Sun); Electrical current

4. **Energy conservation**

In any energy transfer, the total amount of energy before and after transfer is constant

Sankey diagram:

A flow of diagram representing energy conservation. Arrow width proportional to energy. Total width remains constant



Dissipated (Energy loss): energy that is spread out is not useful; usually through: heat (work of friction, conduction), light, sound.

Efficiency $= \frac{useful\ energy\ output}{total\ energy\ input} = \frac{total\ energy - wasted\ energy}{total\ energy\ input}$

常考点:

- **能量转换**：看看物体**状态**发生了什么**变化**，对应什么**能量**改变

e.g. **h** => g.p.e.) ; **v** =>k.e.; change size/shape => elastic energy; T => internal/thermal; nuclear reaction =>nuclear energy; chemical reaction => chemical energy

hydro-electricity(dam, tidal power station): g.p.e => k.e. => electrical energy

a.c. generator: k.e. => electrical

motor: electrical => k.e.

Nuclear power station: nuclear => heat => k.e. => electrical

- **能量守恒:**

e.g. bouncing ball (can not return to original height due to energy loss)

Falling: g.p.e => k.e. + heat(internal)

Bouncing: energy loss(heat, sound)

Bouncing back: k.e. => g.p.e. + heat(internal)

Chapter 7. Energy Resources

Energy resource	Source	From sun / not	Energy forms	Renewable /not	reliable/ not	Use steam/ not
Solar	the Sun	Y	solar	Y	**N**	N
Wind	wind	Y	k.e.	Y	N	N
Wave	water	Y	g.p.e. + k.e.	Y	N	N
Hydroelectric	water	Y	g.p.e.	Y	Y	N
Boimass	biomass	Y	chemical	Y	Y	Y
Fossil	oil gas coal	Y	chemical	N	Y	Y
Nuclear	Uranium	N	nuclear	N	Y	Y
Geothermal	the Earth	N	thermal	Y	Y	Y
Tidal	water	N	g.p.e. + k.e.	Y	Y	N

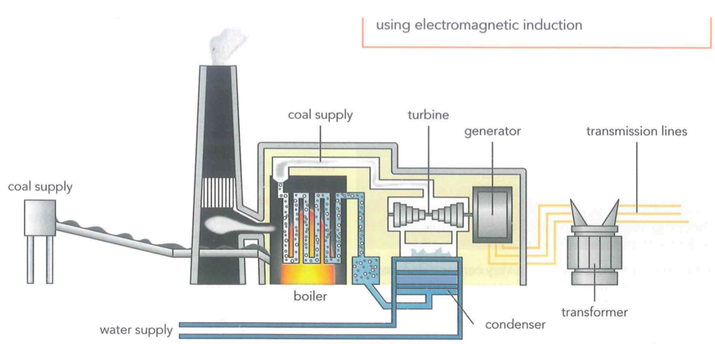
Non-renewables: fossil, nuclear

Renewable (def): An energy resource that will be replaced naturally when used

Not from the Sun: nuclear, geothermal, tidal

Sun's energy comes from **nuclear fusion** (fuse light nuclei into heavy nucleus) in the Sun's core vs **nuclear fission**(splitting heavy nucleus into 2/3 nuclei) used in nuclear power station.

Energy resources to **generate electricity**:



Boiler

↓

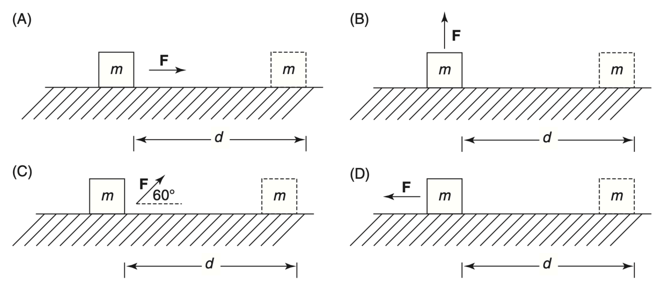
Turbine

↓

Generator

Typical advantages & disadvantages: contribute to global warming or not(CO_2); cause air pollution or not(SO_2); unreliable (e.g. solar energy): only work on daytime; not enough energy on cloudy days.

Chapter 8. Work & Power



1. W = Fd Work done（做功） = force times distance in the direction of force)

2. W = Fd = ΔE work done = energy transfer

Unit: J; scalar (like energy);

a. Increase work done: increase F or increase d
b. 判断做功与否: 力的方向上是否有运动距离
c. work done = energy transfer 从转移能量多少判断做功多少
d. useful work： 增加的useful work，e.g. raise an object from ground to 5m high: useful work W = mgh = ΔE_p; e.g. push an object from 1m/s to 5m/s: useful work W = ΔE_k
e. 物体下落：g.p.e -> k.e.
f. Work against gravity/friction

物体在竖直向上拉力F下缓慢上升，g.p.e increases
work done by gravity 重力做负功：W = -mgh (< 0)
Work against gravity F 抵抗重力做正功：W = mgh (>0)

物体在水平推力F下加速, 运动s米，e.k. increases
work done by friction 摩擦力做负功：W = -fs (< 0)
Work against gravity F 抵抗摩擦力做正功：W = fs (>0)

3. $p = \frac{W}{t}$ power(功率) = work done per second

Unit: Watts

Increase power: increase work or decrease time used

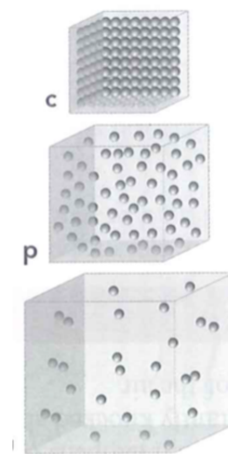
4. percentage efficiency =

$$\frac{useful\ energy\ output}{total\ energy\ input} \times 100\,\% = \frac{useful\ power\ output}{total\ power\ input} \times 100\,\%$$

Chapter 9. The kinetic particle model of matte

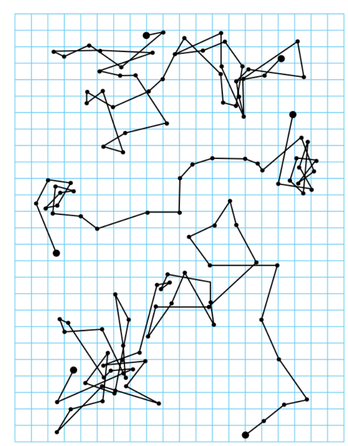
9.1 States of matter

States	Volume	Shape	Arrangement to explain shape	Separation to explain volume	Motion to explain arrangement	Attractive forces between molecules
Solid *(rigid)*	*fixed volume;* ***Cannot be squashed*** *(No space btw molecules; will have repulsion when being compressed)*	*fixed*	*Regular Tightly bonded*	Very close	Vibrate about a fixed point	Very strong
Liquid *(Not rigid)*	*fixed volume; Cannot be squashed*	*Take the shape of its container*	*Irregular Less tightly bonded than solid*	Slightly less close than in a solid	Vibrate and move from place to place within the liquid	Strong, less stronger than that in solid
Gas *(Not rigid)*	*Unfixed volume; can be squashed*	*Expand to fill its container*	*Irregular Not bonded*	Far apart, separate from each other	Move freely in all direction at high speed	Negligible



9.2 The kinetic particle model of matter

Matter is made up of identical, spherical, moving molecules



Particle movement and temperature: Temperature is average kinetic energy of particles in a matter

Absolute zero: the temperature at which the particles have **the minimum/least kinetic energy**

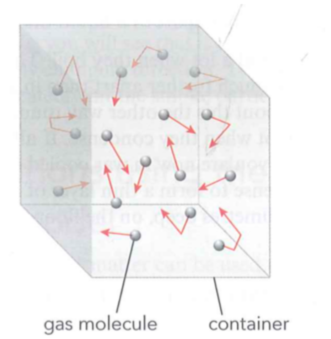
Brownian motion:

The motion of particles suspended in a liquid or gas, caused by molecular bombardment

Explanation:

Smaller, lighter molecules around pollen particles move very fast, they collide repeated with pollen particles. Collision exerts forces on pollen particles and changes the motion of them.

Why do gases cause pressure on the wall of its container?



Gas molecules move randomly at high speed;

collide with/hit the wall and rebound;

momentum of gas molecules change =>cause a force on the wall *(*$F = \dfrac{\Delta p}{\Delta t}$*);*

pressure is the force exerted on the unit area ($p = \dfrac{F}{A}$*)*

Heat the gas =>Molecules hit the wall with **larger forces and more frequently.** So pressure increases.

Compress the gas =>Molecules don't move far before collide with the wall, so collision is **more frequent**, so pressure increases.

The gas laws: Boyle's law

At constant temperature, pressure × volume = constant, ***pV = constant*** *(* $p_1V_1 = p_2V_2$ *)*

9.4 Temperature and the Celsius scale

Temperature vs internal energy:

average k.e. of individual particles in the object

Total energy (k.e. + p.e.) of all particles in the object

Measuring temperature: Thermometer

The Kelvin temperature scale: absolute temperature

$$T(K) = \theta(°C) + 273$$

Chapter 10. Thermal properties of matter

10.1 Thermal expansion

cause： particles gain energy, move faster/vibrate more, pushing each other further apart/take up more space (caution: particle size unchanged as temperature rise)

States	Thermal expansion	Explanation
Solid	*Least*	*tightly bonded, so separate little*
Liquid	*More than solid*	*not so tightly bonded, a small separation*
Gas	*Even more than liquid*	*not bonded, separate most*

10.2 Specific heat capacity

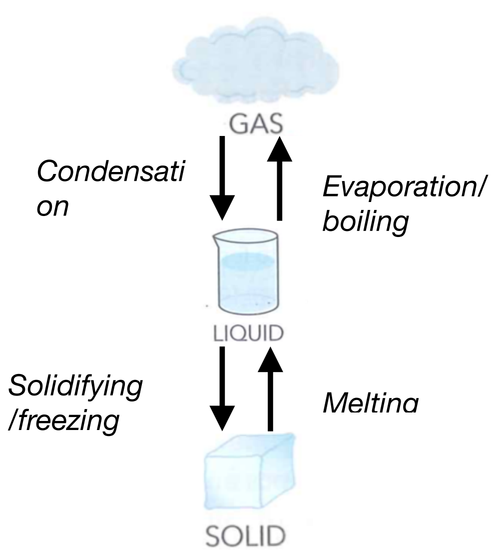
Specific heat capacity of a substance: the energy needed to raise the temperature of 1kg of the substance by 1 degree.

Equation: $c = \dfrac{\Delta E}{m\Delta\theta}$

water: high specific heat capacity =>It takes a lot of energy to heat up water; Hot water takes a long time to cool down.

Experiment of Measuring the specific heat capacity of water: possible reasons for results larger than reality: **<u>Part of energy used to increase the temperature of heater, thermometer, beaker and surrounding air; more heat loss to the surroundings as temperature difference increased</u>**

10.3 Changing state



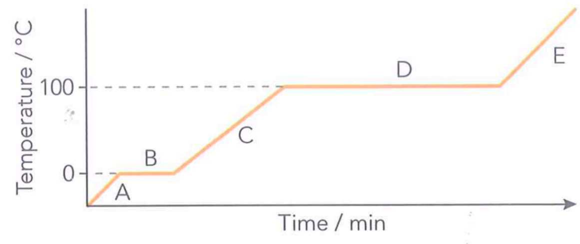
Boiling point/condensing point:

Liquid <=> gas

Melting point/freezing point:

Solid <=> liquid

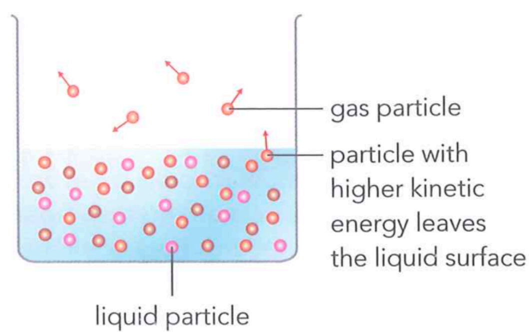
At standard atmospheric pressure:
Melting point of water: 0°C
Boiling point of water: 100°C



from solid to liquid the temperature stays the same.
Energy is taken in and used to **break bonds among molecules.**

from liquid to gas the temperature stays the same.
Energy is taken in and used to **overcome attraction among molecules .**

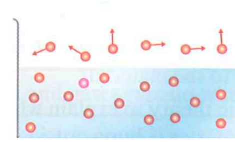
Evaporation
energetic water particles overcome attraction and escape from the surface of the water. And become water vapor in the air.

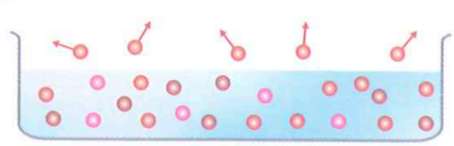


Evaporation causes **cooling of a liquid and an object in contact with the liquid**. e.g. covering a bottle of milk with a damp cloth will help to cool the milk: The water from the damp cloth will evaporate and will take energy away from milk (2'). More energetic molecules escape from damp cloth; less energetic molecules left behind, average k.e. of cloth decreases; temperature of damp cloth drops; energy transfer from milk to damp cloth(4').

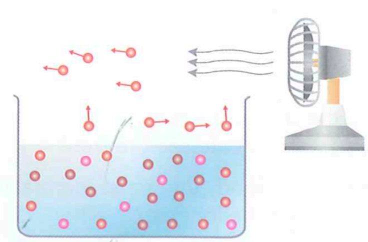
Comparing evaporation and boiling
- Boiling only happens at the boiling point of a substance. Evaporation occurs at all temperatures.
- Boiling happens throughout the liquid. Evaporation only happens at the surface
- A boiling liquid bubbles. A liquid can evaporate without bubbles
- Boiling requires heat, evaporation provides cooling.

Speeding up evaporation
Increasing the **temperature**
The particles on average have more kinetic energy;
More of particles will have enough energy to escape;
Liquid evaporates more quickly





Increasing the **surface area**
More of the particles are close to the surface,
They can escape more easily.
Liquid evaporates more quickly



Blowing air across the surface
When particles escape from the water, they are blown away so that they cannot fall back into water
Helps the liquid evaporate quickly

Ch11. Thermal Energy Transfer

Higher temperature difference => higher energy transfer rate

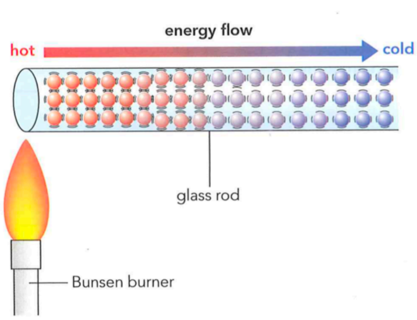
1. Conduction:

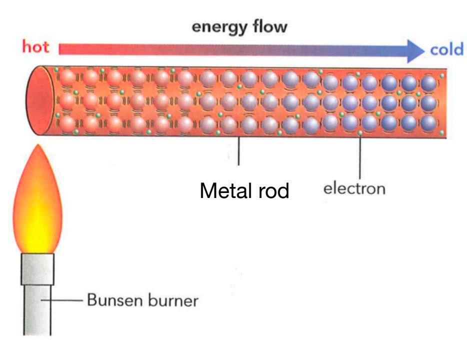
1. a. mainly in solids:

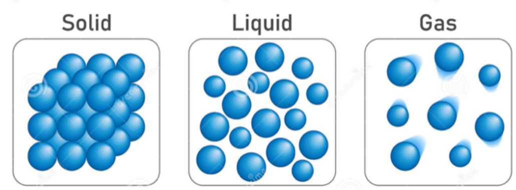
non-metal: atoms/molecules **vibrate**, collide with neighbors, transfer energy.

metal: (main) electrons **move**, strike atoms, carry energy through metal & (minor) atoms/ molecules **vibrate**, collide with neighbors, transfer energy

liquids: are bad conductors, particles free to move vibrations not easily past, bad conductors.

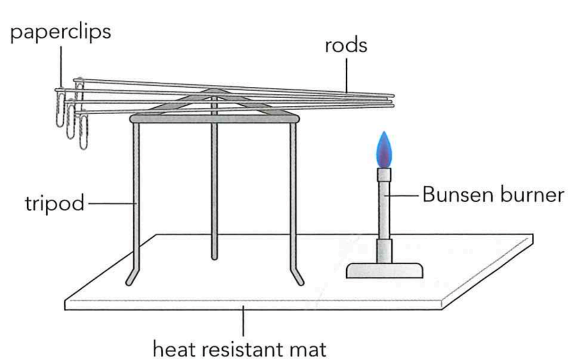






1. b. conductivity: good conductors: good insulators; conductivity better than insulator worse than conductors

1. c. Experiment: good/bad conductors



2. Convection

2. a. Only in fluids

2. b. Convection in fluids: temperature rises -> density decreases -> hot liquid rises

3. Radiation

3. a. Heat/thermal radiation - infrared radiation

3. b. doesn’t require a medium, transfer mainly in empty space

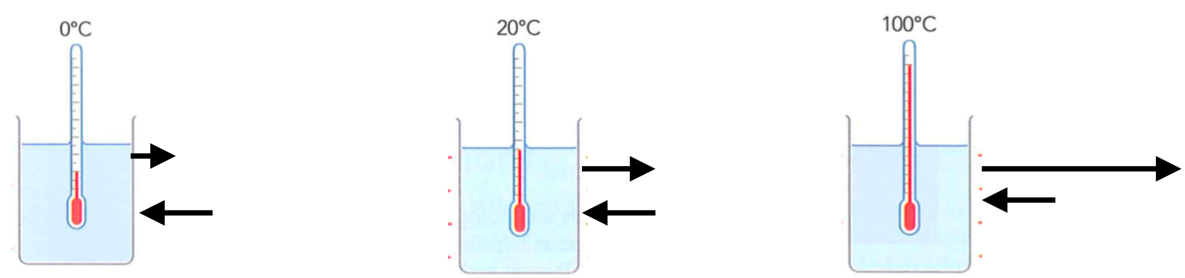
3. c. heat radiation rate: $\frac{dQ}{dt} \cancel{\propto \sigma A T^4}$

σ: determined by surface color and texture

A: surface area; larger surface, higher radiation rate

T: temperature; higher temperature, higher radiation rat

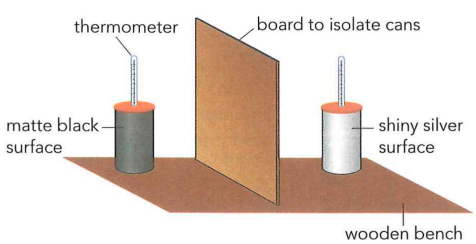
3. d. net radiation energy transfer



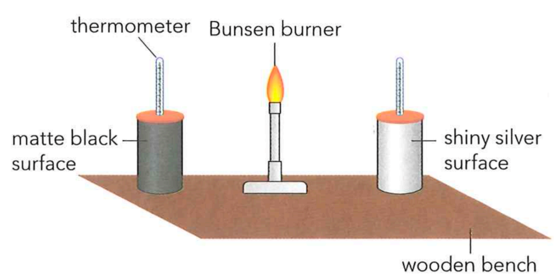
3. e. Temperature of the Earth is affected by the difference of incoming radiation and outgoing radiation; Greenhouse effect

3.f. Experiment:

good/bad emitters of **infrared radiation**



good/bad absorbers of infrared radiation

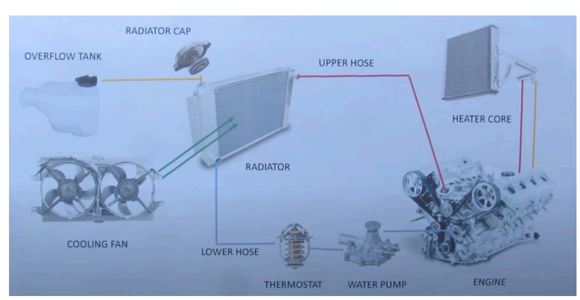


4. Consequence of thermal energy transfer

Kitchen pan: conduction

Heater: convection

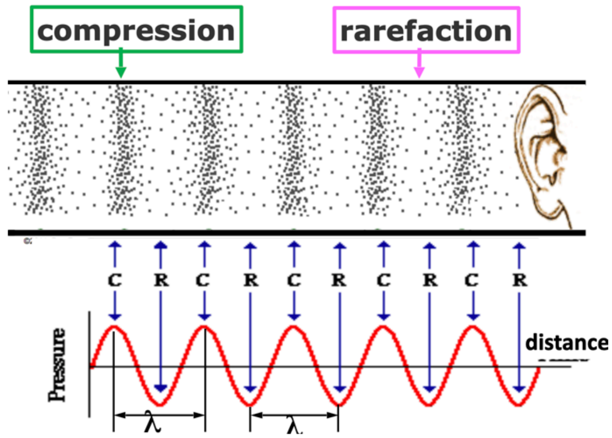
Radiator in a car: conduction&convection & radiation



Chapter 12. Sound

1. All sounds are caused by **vibrations**

2. Sound waves are **<u>longitudinal</u>** waves, made by particles vibrating



Compression: regions where the vibrating particles are closest together

Rarefaction: regions where the vibrating particles are furtherest apart

The medium particles oscillate **backwards and forwards** as the compressions and rarefactions pass through.

When a compression passes, the pressure rises.

When a rarefaction passes, the pressure falls.

3. Sound speed

Sound can travel in solid, liquid, gas; **<u>cannot travel in vacuum</u>**. Light can travel in vacuum.

In vacuum, speed of light = 300000000m/s

In air, **<u>speed of sound = 330-350m/s; how to measure sound speed in air?</u>**

In general, speed of sound **in solid > in liquid > in gas**. **Explanation**: Particles are closer together => vibrations can be passed on more easily

4. Properties of sound

Amplitude: A

The furthest distance the particles move from their undisturbed position

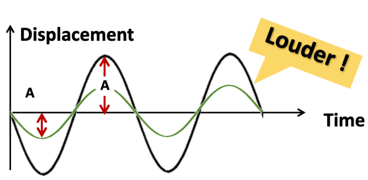
Frequency: f

The number of vibrations each second.

Hertz: Hz

Unit of frequency, 1Hz = 1 wave per second

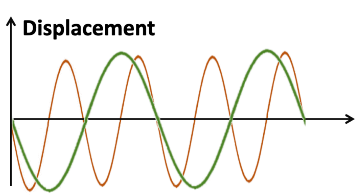
<u>Human hearing: 20Hz - 20kHz</u>; frequency larger than 20kHz: **Ultrasound**



loudness of the sound

How quiet a sound is depends on the <u>amplitude</u> of the sound wave.

The greater the amplitude of the wave the louder the sound.



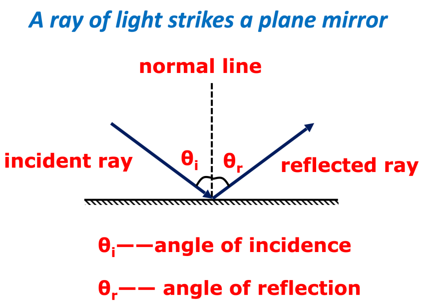
pitch of the sound

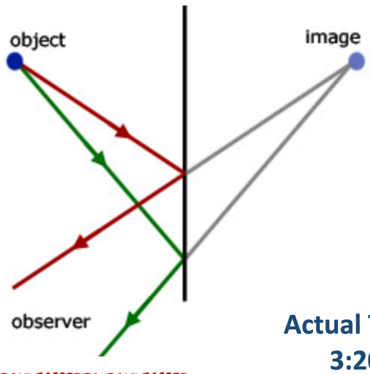
The pitch of a note depends on the <u>frequency</u> of the wave.

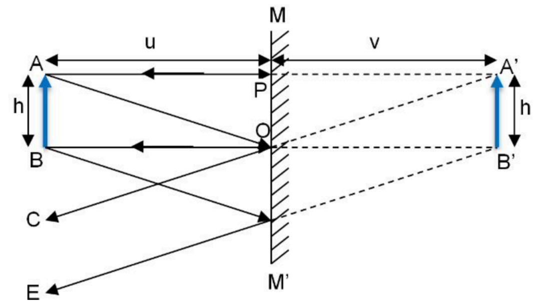
The higher the frequency of the wave the higher the note.

Chapter 13. Light

13.1 Reflection: $\theta_i = \theta_r$

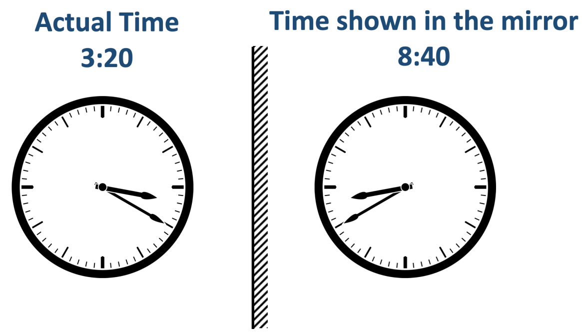




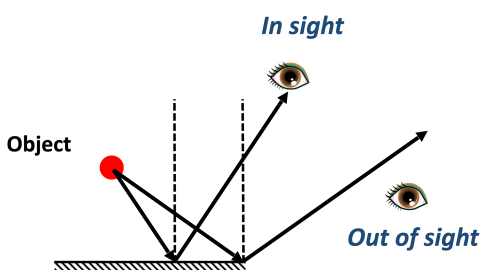


The image in a plane mirror

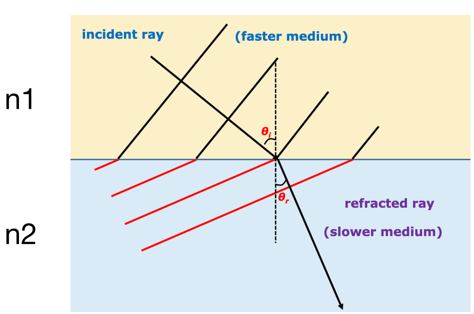
- The **same size** as object
- The **same distance** behind mirror as the object is in front of it
- **Laterally inverted**



In/out of sight:

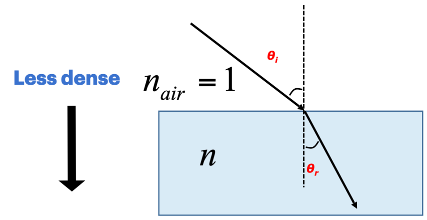


13.2 Refraction: the bending of the path of a light wave as it passes from one material to another material. (Incident angle = 0 => No bending)



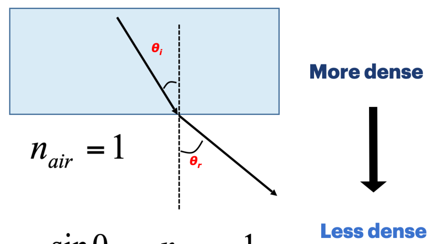
$$\boxed{\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}}$$

Refractive index of a medium: $n = \dfrac{c}{v} = \dfrac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ the\ medium}$



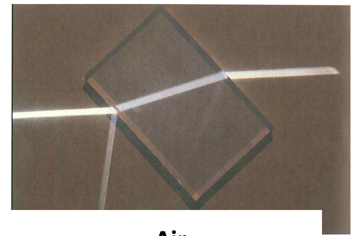
$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n}{n_{air}} = n$$

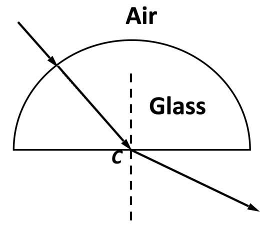
refract towards the normal



$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_{air}}{n} = \frac{1}{n}$$

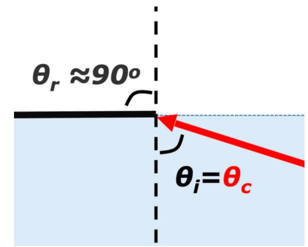
refract away from the normal





13.3 Total internal reflection: when light travels from a more dense material, all light is reflected, NO refracted ray.

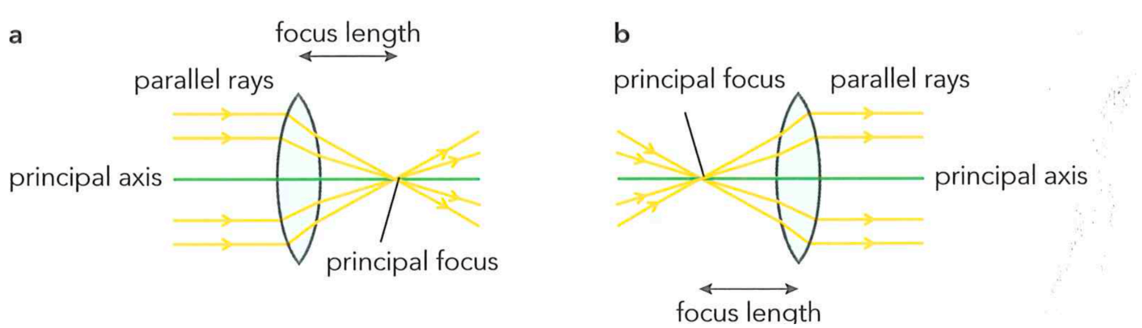
Critical angle: the angle of incidence in the material at which angle of refraction is 90 degrees; the angle of incidence above which total internal reflection occurs



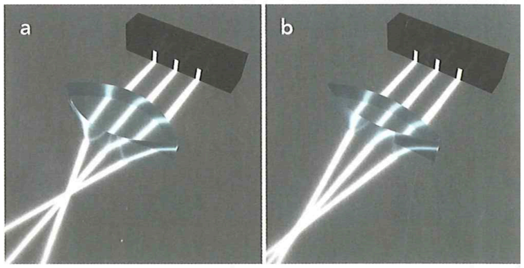
TIR only takes place when:
the light is in the more dense medium and approaching the less dense medium.
the angle of incidence is greater than the critical angle.

$$\sin\theta_c = \frac{1}{n}$$

13.4 Converging lens: bring light together



Principle axis: the line passing through the center of a lens perpendicular to its surface
Focal point/principle focus(F): the point at which rays of light parallel to the principle axis converge after passing through a converging lens
Focal length: the distance from the center of the lens to its principle focus



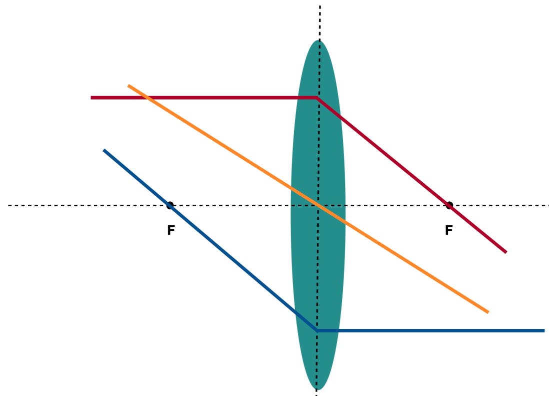
fatter lens bends light more => **shorter** focal length

Drawing ray diagrams

1. central ray: unrefracted through the center of the lens

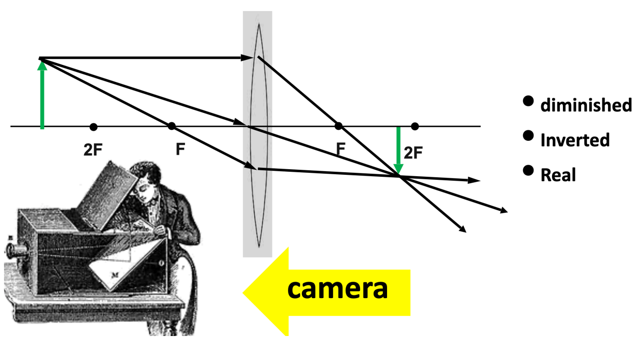
2. principle ray: parallel to the axis and then refracted through the principle focus

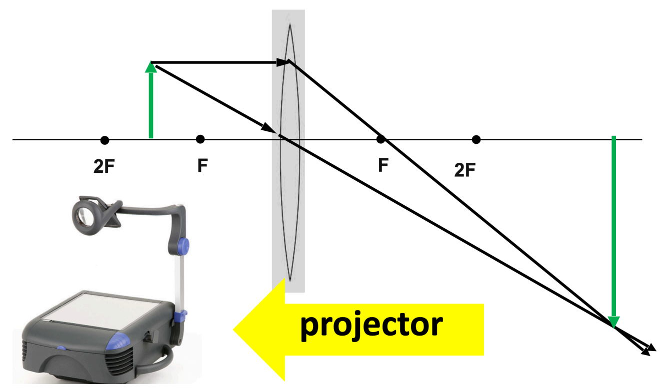
3. focal ray: through the focus and then parallel to the axis

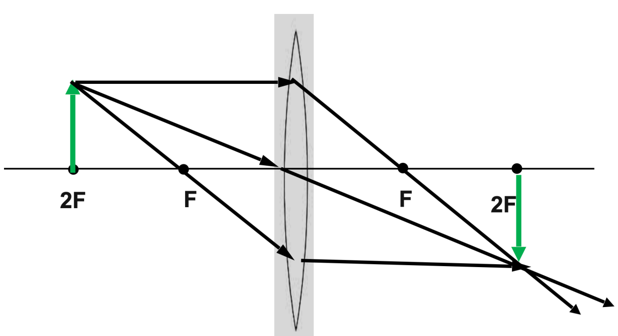


Examples

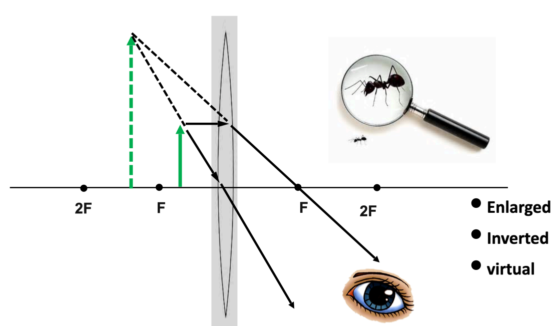
POSITION OF OBJECT : When the object is placed beyond 2F



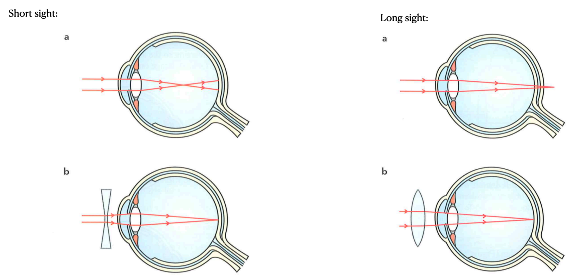




When the object is placed within F

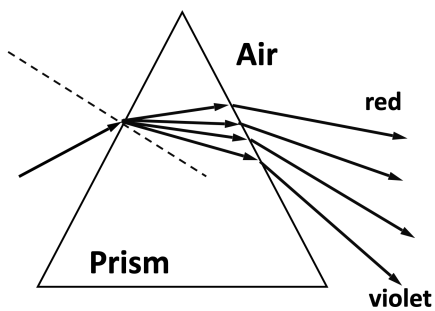


Using lenses to correct eyesight



13.5. Dispersion

Monochromatic: light of a single frequency
Explanation of dispersion: In a medium (not vacuum), light with higher the frequency travels slower.



Chapter 14. Properties of waves

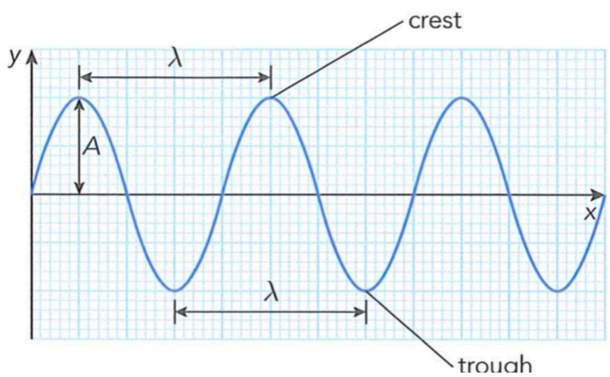
Wave transfers energy not matter/wave is moving not matter

1. Displacement-distance graph(波形图)

Wavelength λ: the distance from one **crest** to the next/ btw any two points which are in step; unit: m

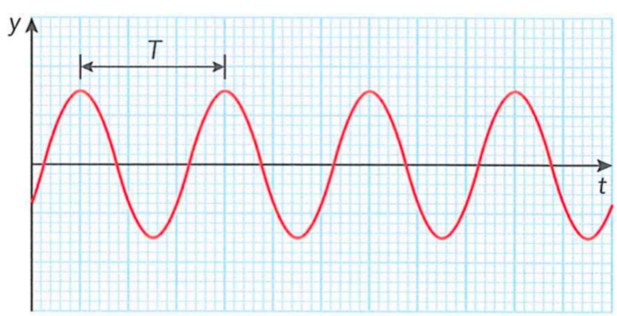
Amplitude A: the height of the crest/the depth of a trough; unit: m

Wavefront: the set of all points having the same *phase*/moving for the same time -> e.g. **all crests**



Wave at a particular time moves up and downs at different **positions**

2. displacement- time graph（振动图）



Wave at **a particular point** moves up and down as time

Frequency f: number of waves send out per second; unit: Hz

Period T: the time taken for one complete wave to pass a point; $T = \frac{1}{f}$

Wave speed: the rate at which the crest of a wave travels; Waves travel in different materials will have different speed, but frequency unchanged:.

$$v = \lambda f$$

Transverse wave vs longitudinal wave:

1. Transverse wave: the particles vibrate **perpendicular** to the direction of propagation/travel of the wave.

Longitudinal wave:the particles vibrate **parallel** to the direction of propagation/travel of the wave.

2. Transverse wave have **crests and troughs**; longitudinal wave have **compressions and rarefactions**

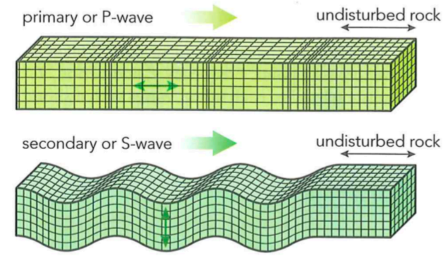
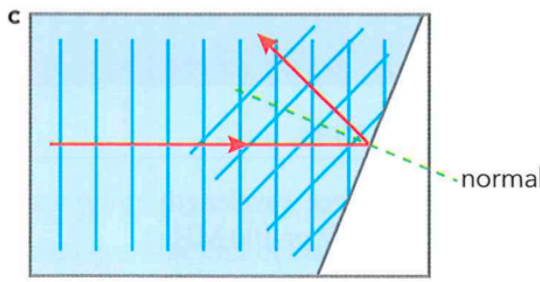


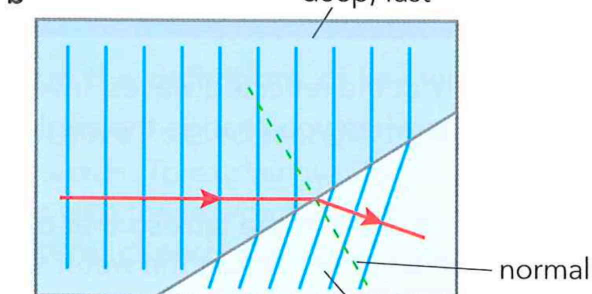
Figure 14.8: Primary and secondary seismic waves.

Wave phenomena:

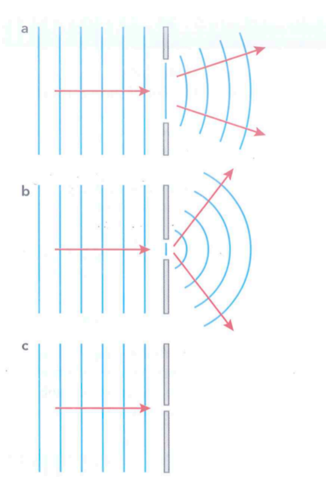
reflection

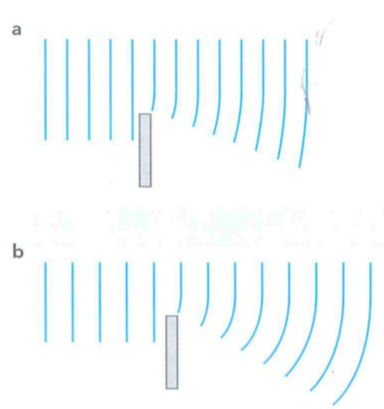


refraction: Wave travel at different speed in different medium



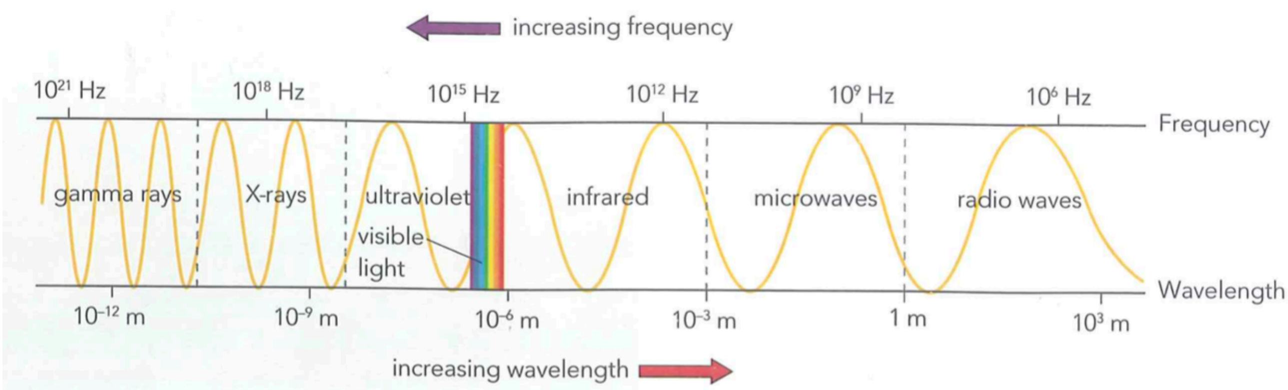
diffraction: Diffraction effect is **greatest** when the **size of the gap or the object** equals to the **wavelength.**





Chapter 15. The electromagnetic spectrum

1. Electromagnetic spectrum



2. Different wave and their uses

(a) radio waves; radio and television transmissions, astronomy, radio frequency identification (RFID)

(b) microwaves; satellite television, mobile phones (cell phones), microwave ovens

(c) infrared; electric grills, short range communications such as remote controllers for televisions, intruder alarms, thermal imaging, optical fibres

(d) visible light; vision, photography, illumination

(e) ultraviolet; security marking, detecting fake bank notes, sterilising water

(f) X-rays; medical scanning, security scanners

(g) gamma rays; sterilising food and medical equipment, detection of cancer and its treatment

3. Electromagnetic hazards

(a) microwaves; internal heating of body cells

(b) infrared; skin burns

(c) ultraviolet; damage to surface cells and eyes, leading to skin cancer and eye conditions

(d) X-rays and gamma rays; mutation or damage to cells in the body

4. Artificial Satellite: microwave

(a) some satellite phones use low orbit artificial satellites

(b) some satellite phones and direct broadcast satellite television use geostationary satellites

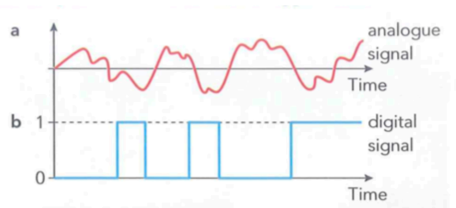
5. EM wave used in communication systems

Mobile phone/wireless internet: microwave

Bluetooth: radiowave

Optical fibre: optical/infrared => carry more data

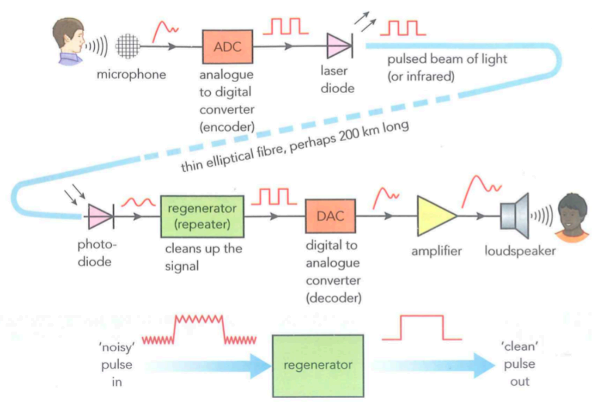
6. Analogue and digital signals



Varies continuously

Contains a series of pulses

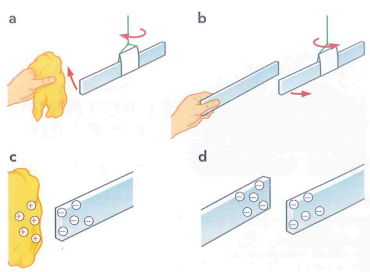
Making a digital phone call



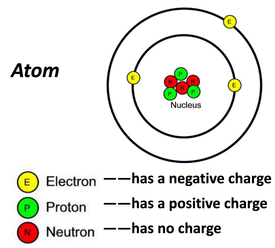
Benefits of digital signaling
fast data transmission rate
Signals can be regenerated=> increased range
Can communicate directly with computers

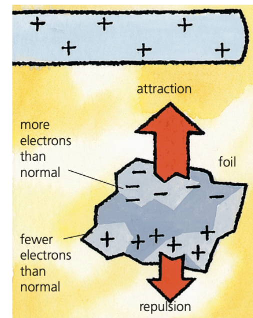
Chapter 17. Static electricity

1. Charging and explanation
Two types of charge: Positive & negative
Charge: Q unit: coulomb
Like charge repels;Unlike charge attracts



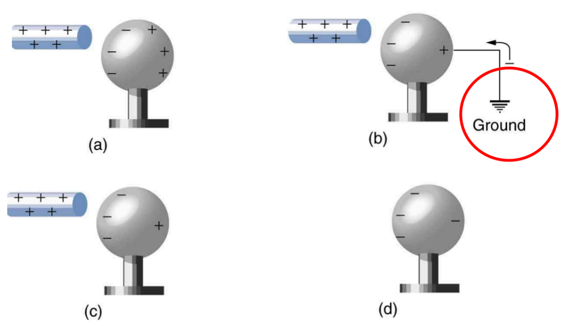
2.





Charge by friction: electrons are rubbed off one object(will be positively charged) and **move** to the other object(will be negatively charged)
Conductor vs insulators
Conductors: a substance that allows flow of electrons<= contains **free electrons**
Insulators: a substance that inhibits flow of electrons <= electrons are tightly bonded

3. **Grounding/earthing:** being connected to the ground by a conducting material so that the unwanted charge flows away (because grounding will balance charge).

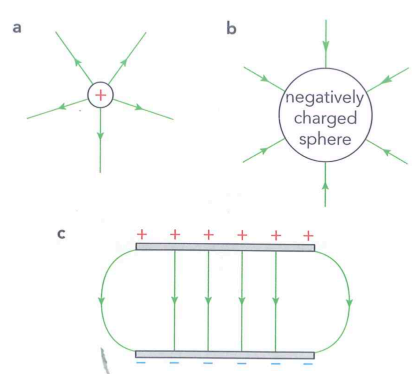


How to make a conductor sphere uniformly charged using a charged rod?
1. Put rod close to the sphere but not touching it
2. Earth the sphere with a metal wire/touch sphere with hand
3. Remove wire/hand and then remove rod

3. Electrical field

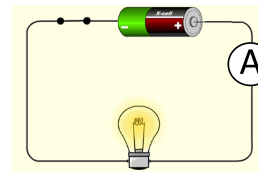
Electrical field: A region of a space in which an electric charge will experience a force

Direction of a field line is the direction of electrical field & the direction of the force a positive charge will experience



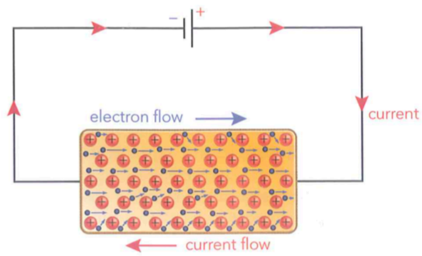
Chapter 18. Static electricity

18.1 Electrical Current: $I = \frac{Q}{t}$**;** the rate at which charge flows

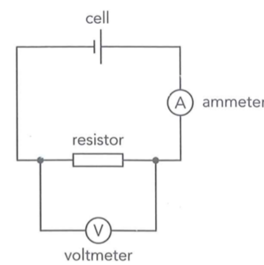


Unit: A (amps)
Measuring tool: **<u>ammeter</u>** in series

Conventional current



18.2 Electrical Voltage/p.d.: $V = \frac{W}{Q}$; work done per unit charge

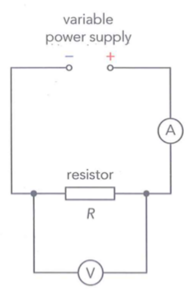


Unit: V (volts)
Measuring tool: **<u>voltmeter</u>** in parallel

e.m.f(p.d. across battery)**: work done per unit charge by battery**

18.3 Electrical resistance: $R = \frac{V}{I}$

Unit: R (ohms)
Measuring method:

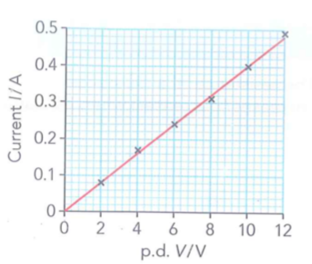


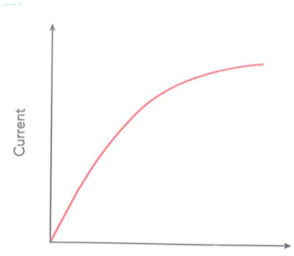
Resistance and thickness & length:

$$\boxed{\begin{array}{l} R \propto L \\ R \propto \frac{1}{A} \end{array}}$$

R is directly proportional to length;
inversely proportional to cross-sectional

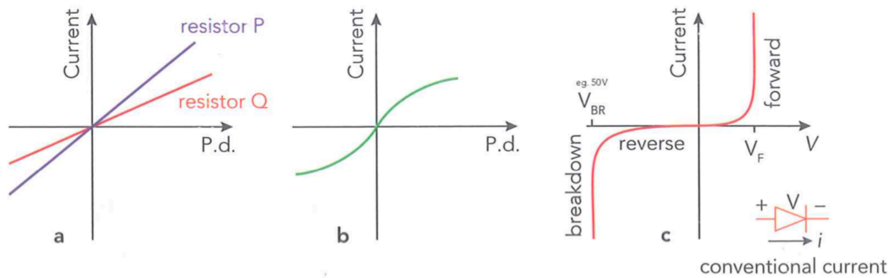
current-voltage characteristics:
Ohmic resistor: constant resistance; otherwise: non-ohmic





<u>slope = 1/R</u>

Typical current-voltage characteristics:



. **a:** For two ohmic resistors. **b:** For a filament lamp. **c:** For a diode.

For filament lamp: T increase => R increase

Electrical power: $P = VI = I^2R = \dfrac{V^2}{R}$

Electrical energy: $E = Pt = VIt = QV$

Unit of electrical energy: $1\,kWh = 3.6 \times 10^6 J$