A-level Phys notes (w/ some Yr 7 astro)

Particles

- nucleus
- photons
- particle - anti particle
- interactions
- particle zoo / sorting
  - leptons, quarks & antiquarks
  - conservation rules
- ~~EM Radiation~~

- photoelectric effect
  - energy level in atom
  - collision of e's
  - energy level + spectra
  - Wave - particle duality

Waves

- Stationary waves
  - eg: first harmonics
  - double slit
  - TIR, refraction
  - - optical fibre
- diffraction grating
  - d

Mechanics

Materials

- Density, springs
- deformation of solids.
  - stress strain
  - E.

Electricity

- Current & charge, PD, Power, emf, R
- Component & characteristics, Circuit, internal R.
  - potential divider

Thermal Physics

G-field

E-field

Capacitor

B-field

Nuclear physics

Astrophysics

- Optical telescope
- non " "
- distances & magnitude
- Black bodies
- Spectral class
- H-R Diagram
- Stellar evolution
- Doppler effect.
- Quasars
- Exoplanets
- Big Bang Model

~~Ato~~ Atomic structure: chem stuff

Decays:

α-decay: $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$

β-decay: $^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta$

fundamental forces:

increasing strength:

Strong force [for quarks] (gluon) 强 quark 3-4 fm to 0.5 fm (e)(p)

Electromagnetic force [for charges] (photon) E-pho +/−
∞

Weak force [for quarks & leptons] (W⁻, W⁺, Z°) (changing of quark types) 弱 lep p, n, μ, e⁻, τ

gravitational force [for massive stuff] (graviton) (∞) g-m (m)(m)

$\mu \rightarrow \bar{\nu}_e e^- + \nu_\mu$

$n + \nu_e \rightarrow p^+ e^-$

$p + e$

$p + \bar{\nu}_e \rightarrow n + \beta^+$

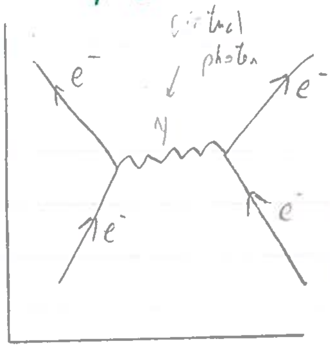
$p + e$

↓

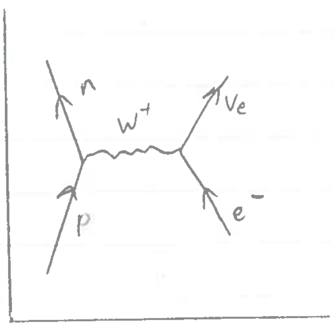
$\mu^+ \rightarrow \bar{\nu}_\mu + \nu_e + \beta^+$

−1 −1 +1 −1

Electron repulsion:



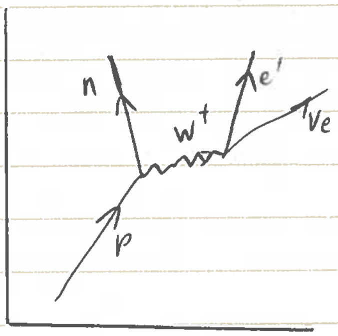
Electron capture / e⁻ + proton 撞



$p^+ e^- \rightarrow n + \nu_e$

pen νe

Beta-plus (β^+) Decay:

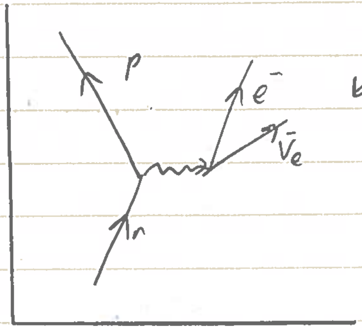


$p \to n + e^+ + \nu_e$

pneve

Beta-minus (β^-) Decay

Weak force
∴ change of quark type



$n \to p + e^- + \bar{\nu}_e$

enpeve

hadrons

strange baryon

n, p, Λ

baryons [3 quarks bound tgt]

mesons (π^0, π^-, π^+) K [quark-antiquark pair]

only strange meson

✪ $p + \bar{\nu}_e \to n + \beta^+$

✪ $n + \nu_e \to p + \beta^-$

✪ proton is the only stable baryon
↳ ∵ it does not decay to other particles

- All baryons decay into protons.

$n \to ddu \quad \beta : +1$

$\bar{n} \to \bar{d}\bar{d}\bar{u} \quad \beta : -1$

$\begin{pmatrix} \pi^+ = u\bar{d} \\ \pi^- = d\bar{u} \end{pmatrix} \begin{pmatrix} K^+ \\ K^- \end{pmatrix}$

Leptons → $e \quad \mu \quad \tau$
$\nu_e \quad \nu_\mu \quad \nu_\tau$

anihillatio

eg. $e^- + e^+$
↓
two photons in opposite directions
∵ conserve momentum

✪ conserve: - charge
- baryon number
- lepton number
- strangeness (except weak interactions) (K)
- momentum ✪
- energy.

Photoelectric effect:

hf $E_{k\,max} = hf - \phi$

y intercept $= \phi$

$E = hf$ 持鳴 全世界

$E_{k\,max}$ against f

Wave particle duality

$hf = \phi + E_{k\,max}$

energy of photon

$E_{k\,max}$ → KE of e^-/s.

ϕ → work function

↳ Energy required for e^-/s to escape

$\lambda = \frac{h}{mv}$

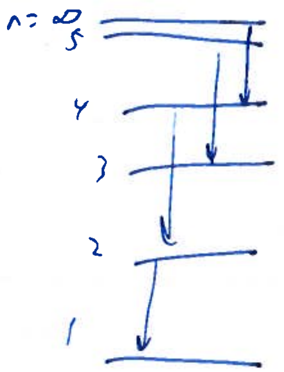
de Broglie wavelength

e^-/s know

d.f fraction

ϕ: work function: min energy for

Threshold frequency: min frequency for photoelectric emission of e^-/s from a metal surface



e^-/s moving down energy levels by emitting a photon

→ frequency & λ determines which part of EM spectrum

Wave: diffraction

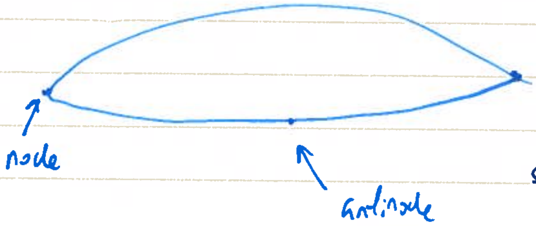
particle: depend on f, not amplitude

Total energy: ~~KE +~~ |KE| − |PE|

Waves $v = f\lambda$ ~~Progressive Wave is reflected off a fixed point~~

~~Reflected Wave undergoes superposition with the incoming wave~~

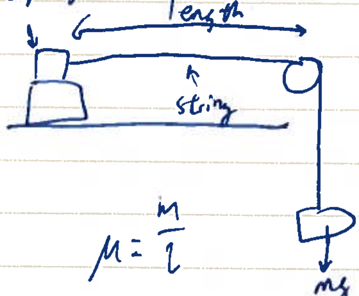
Stationary waves



for 1^{st} harmonic 2nd 3rd

2f 3f

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

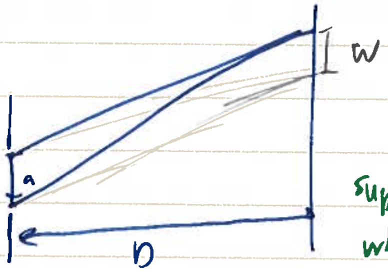


$T = mg$

$\mu = \frac{M}{l}$

mass / length

For Young's double slit

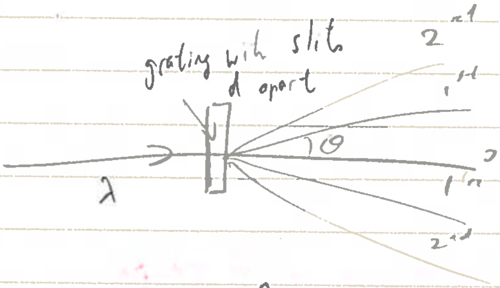


Superposition:

when 2 waves meet, the resultant displacement is the vector sum of them.

$w = \frac{\lambda D}{a}$

For diffraction grating



$d \sin\theta = n\lambda$

max order when

orders $= n$

$1 = \frac{n\lambda}{d}$

$\frac{d}{\lambda} = n$

$d \sin\theta = n\lambda$

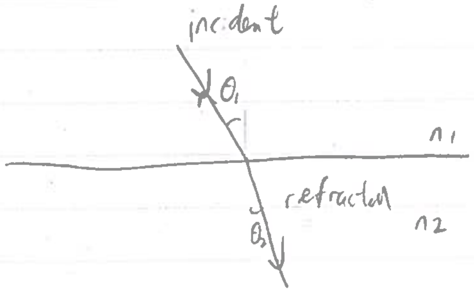
Formation of stationary wave:

- wave reflect → same frequency (coherent)
- interference → undergo superposition
- Constructive interference → antinode → pt of max amplitude
- destructive interference → node → pt of minimum.

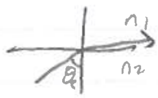
Refractive index:

$$n = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

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



when $\sin = 90°$ | when $\theta >$ Critical ∠ θ_C and $n_2 > n_1$



$$\sin\theta_C = \frac{1}{n_1}$$

OPTICAL FIBRES

refractive index of cladding is smaller than the core

* Total internal reflection.

for EM wave to ~~refract~~ reflect · protects core from scratches → prevent info loss

Signal degradation: $n_2 > n_1$ → TIR · preventing light from escaping

Lose of information by: ↳ ~~one~~ $\theta > \theta_C$

∴ total internal reflection

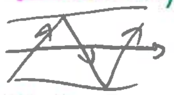
absorption : energy lost through absorption of the material

↳ amplitude reduced → energy reduced

Pulse broadening:

唔同角度入射 : 唔同路径

- modal dispersion → light rays enter the fibre at different ∠s



↳ takes diff. paths

fixed by single mode fibre → only let lights take one path

- Material dispersion → diff. λ of light travel at diff speeds.

$c_{blue} < c_{red}$ 唔色，唔同速

fixed by using a monochromatic light

fixing both by: an optical fibre repeater used to boost and regenerate the signal

Mechanics

Maths & ez shit

eg: when $R(\uparrow) = R(\downarrow)$

$R(\leftarrow) = R(\rightarrow)$

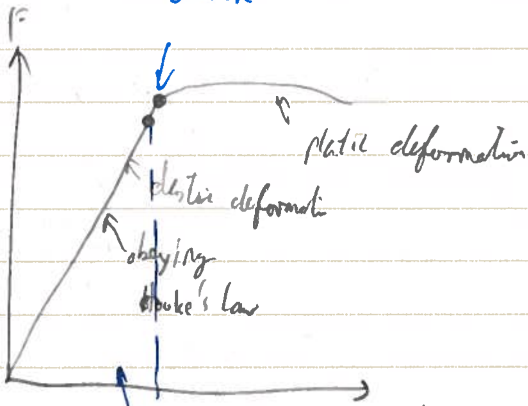
$\circlearrowright = \circlearrowleft$

Centre of gravity : point of an object through which the entire weight of the object may be considered to act.
[average pt of mass]
[torque of weight is zero]

Materials

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

elastic limits



area = elastic energy

ΔK

$E = \frac{1}{2} F \Delta L$

$E = \frac{1}{2} k \Delta L^2$

Hooke's law :

$F \propto \Delta L$

$F = k \Delta L$

spring / stiffness constant

Elastic limit:
→ material permanently stretched → will be longer than the start.
→ no longer ~~to~~ obey Hooke's law

Elastic deformation: (B4 E)
↳ material returns to its original shape & size once forces are removed
有 forces ~~拿回~~ 返回原形
↳ happens as long as elastic ~~def~~ limit is not reached

Plastic deformation (After plastic E)
↳ material permanently stretched

Stress & Strain

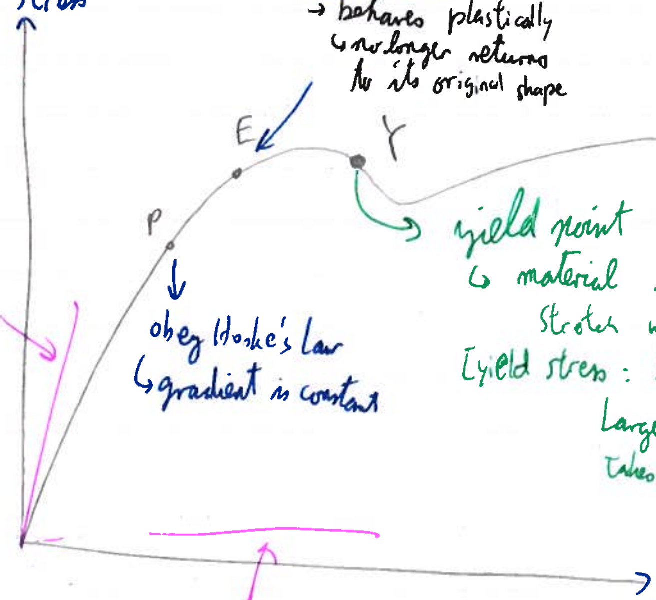
stress $= \frac{F}{A}$ — force exerted per unit cross sectional area

strain $= \frac{\Delta L}{L}$ — extension over original length

~~Young's modulus =~~

Young's modulus $= E = \dfrac{F/A}{\Delta L / L} = \dfrac{FL}{\Delta L A}$ (Nm^{-2})

↓ stiffness



elastic limit
→ behaves plastically
↳ no longer returns to its original shape

obey Hooke's law
↳ gradient is constant

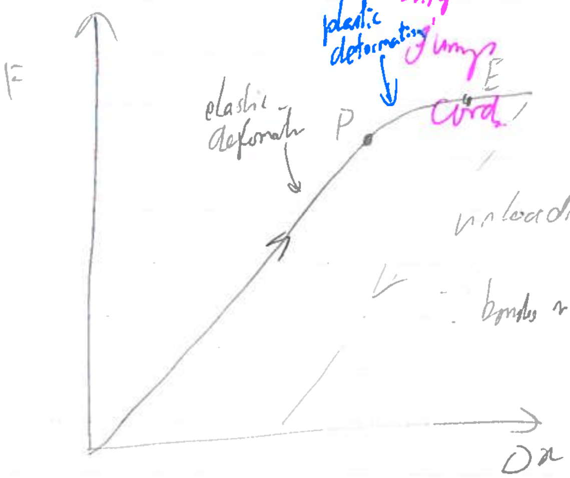
yield point
↳ material suddenly starts to stretch w/o any extra load.
[yield stress : stress at which a large amount of plastic deformation takes place with constant / reduced load.

brittle at

bungee jump cord

show plastic behaviour

能屈能伸



Current

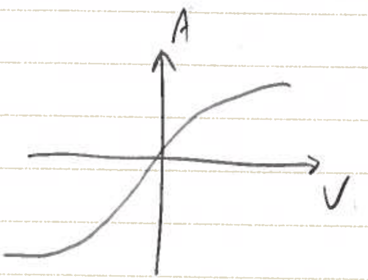
$V = IR$ $Q = It$ $W = VQ$ $P = VI = \frac{V^2}{R} = I^2R$

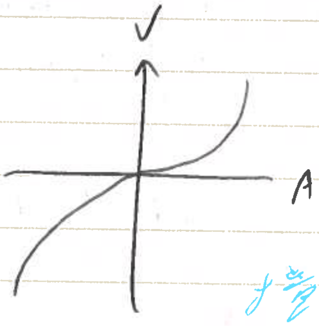
emf: Chemical energy converted to electrical energy when unit charge passes through

✻ Using Kirchoff's Laws.

$\rho = \frac{RA}{l}$

✻ I/V characteristics for a filament lamp





撞嚟撞去,

Current 好難過 ∴ R↑↑

$V = IR$

難高   R↑ → V↑

For: Metals

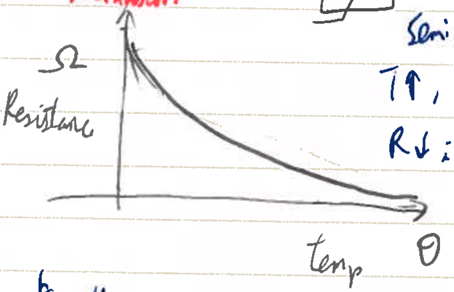
temp ↑ → R ↑ → V ↑

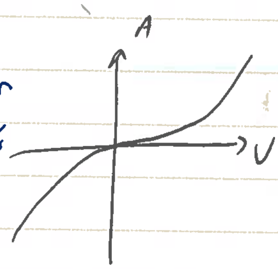
✻ Thermistor

Semi conductor

T↑, free up e⁻s

R↓ ∵ electrons





For thermistors.

temp ↑ → Resistance ↓   temp ↓ → Resistance ↑

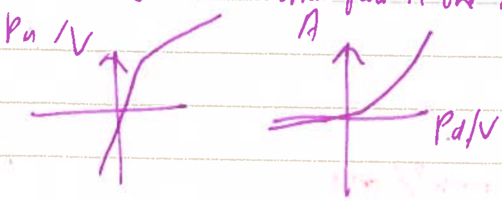
✻ Light-dependent resistor: LDR

↑↑↑ photons 有熱

Resistance ↑ when in dark

Resistance ↓ when in light

✻ Diodes → current flow in one direction



Threshhold voltage >0.6V

∴ Resistance is high

Circular motion

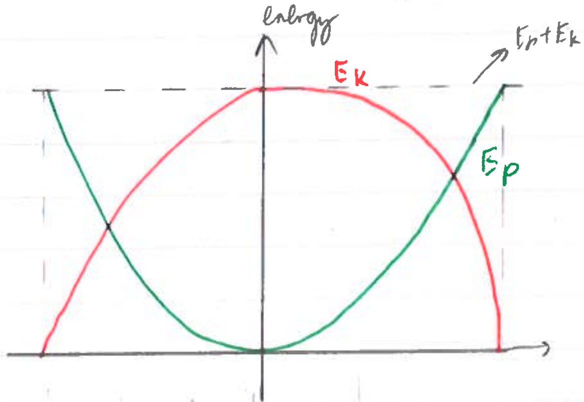
Ex 2.

Simple harmonic motion:

conditions:

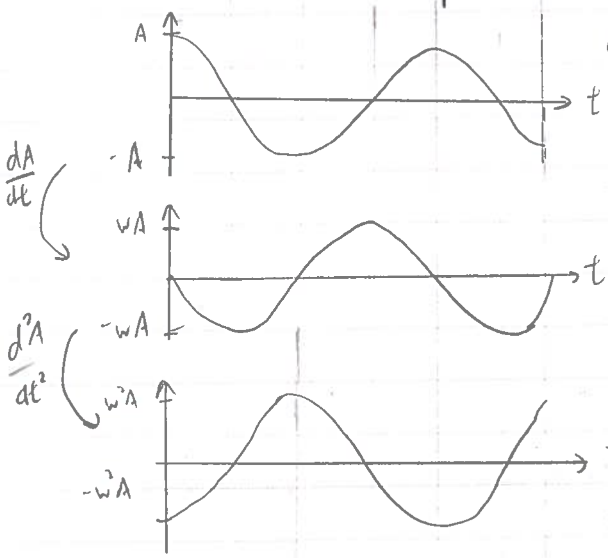
- an oscillation in which the acceleration of an object is directly proportional to its displacement from the mid-pt
  $a \propto -x$

- the acceleration is directed towards the mid-pt.



Sum of E_k and E_p stays constant

E_p provides the restoring force
↳ resultant force acting towards E_q



cos graph s

-sin graph v

-cos graph a

$TE = PE + KE$

$TE = \frac{1}{2}mv^2_{max}$

$\therefore v = wA\cos wt$

$V_{max} = wA$

$TE = \frac{1}{2}mw^2A^2.$

at any time. $KE = \frac{1}{2}mw^2A^2\cos^2 wt$

$PE = TE - KE$

$= \frac{1}{2}mw^2A^2\sin^2 wt$

$T = 2\pi\sqrt{\frac{m}{k}}$ → mass spring

$T = 2\pi\sqrt{\frac{l}{g}}$ → simple pendulum

$a = -w^2x$

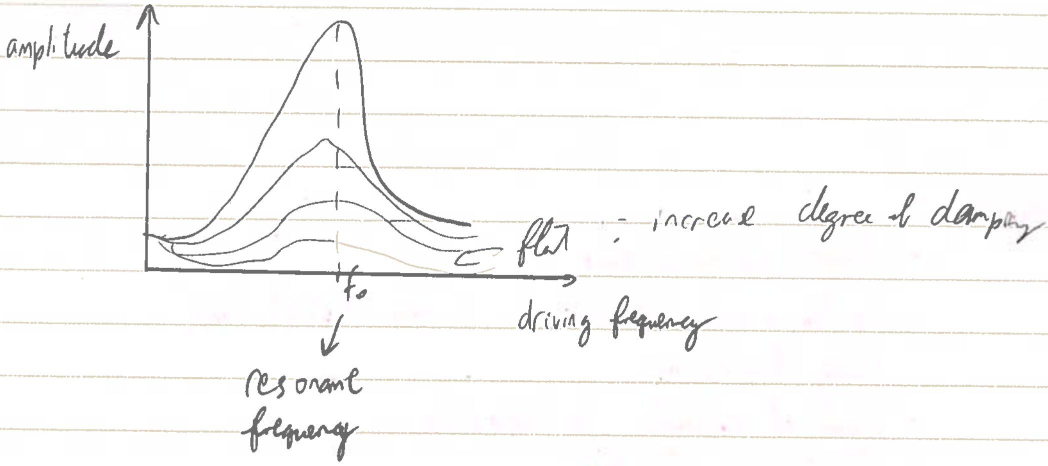
$a_{max} = w^2A$

$v = \pm w\sqrt{A^2 - x^2}$

$V_{max} = wA$

$x = A\cos wt$ $v = -wA\sin wt$ $a = -w^2A\cos wt$

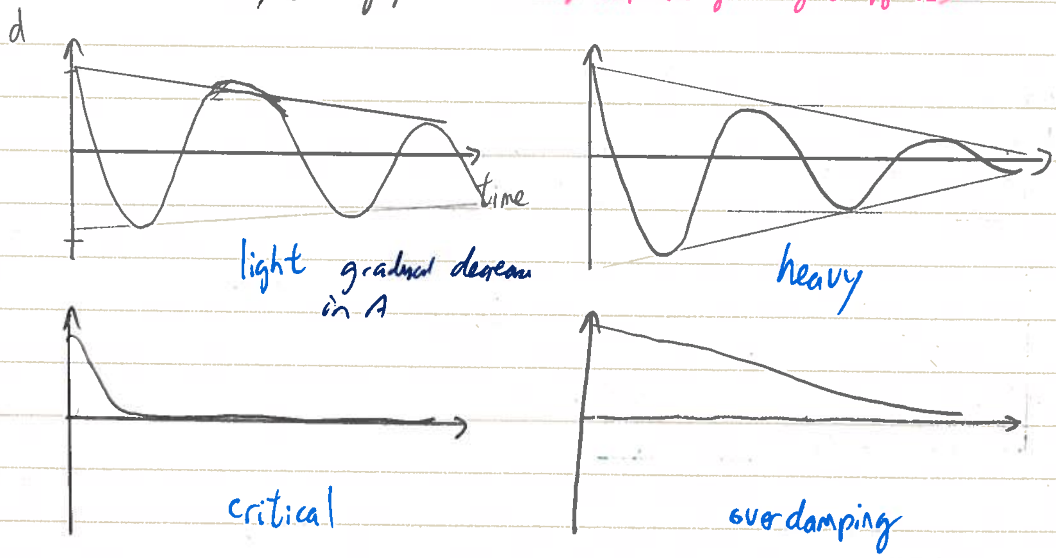
Amplitude changes with driving velocity



free vibrations → no transfer of energy to or from surroundings
↳ resonates at its resonant frequency

forced vibrations → when there is an external driving force
↳ frequency of force produced → driving frequency

DAMPING s/t graphs (diminishing amplitude by making energy loss)



Thermal energy transfe

$E = mc\Delta T$

* Absolute zero: all molecular motion stop at absolute zero

* Latent heat (f or v) energy required to change the state of 1kg of substance w/o a change of temp.

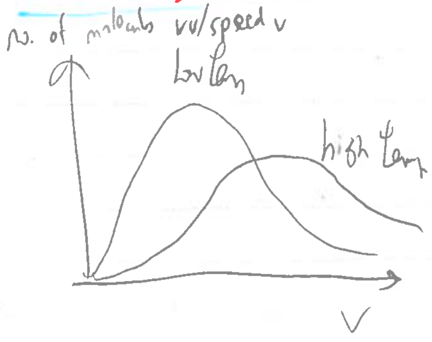
f → solid to liquid v liquid to gas

$E = mL$

Ideal gas laws: @ Pang zhai
@ Kiyan
@ Carson

Assumptions:

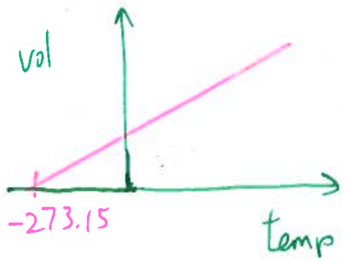
- Perfectly elastic collisions → KE conserved.
- random movement of molecules; obey Newton's laws
- Obey Boyle's law $P_1V_1 = P_2V_2$
- Volume of molecules is neglegible
- No intermolecular forces



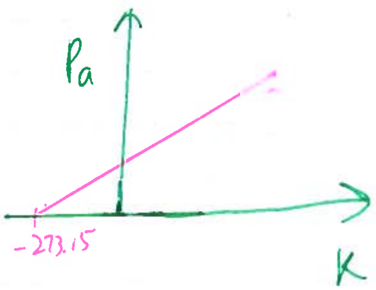
Definitions:

- Isochoric: constant volume 常 V
- Isobaric: constant pressure 常 P
- Isothermal: constant temp 常 T
- Adiabatic: no heat is taken/added into the system $[\Delta U = -\Delta W]$
- Entropy: Measure of disorder of a system $[\Delta S]$ dem btw

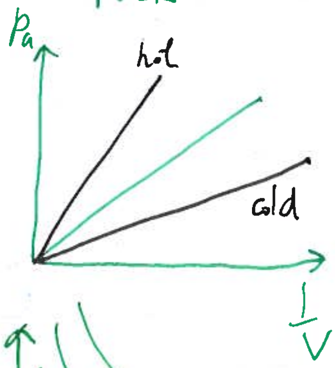
- Charles's law:
~~PV/T=k~~
$V \propto T$ $\frac{V}{T} = k$

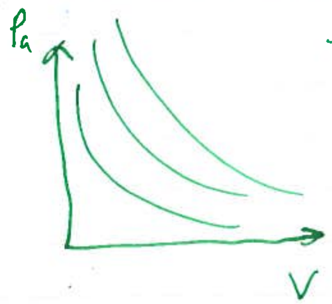


- Gay-lussac
Pressure-temp
$T \propto P$ $\frac{P}{T} = k$



Boyle's law
$P_1V_1 = P_2V_2$
$PV = k$

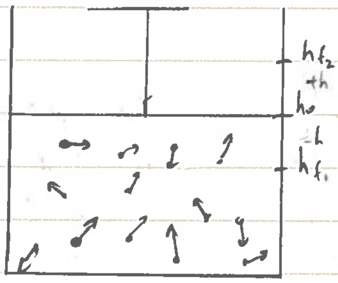




Internal Energy $= \Sigma KE + \Sigma PE$
↑ Temp ↑ latent heat

$E = mc\Delta T$
$E = mL$

Derivations:



from gas perspective

W.D by gas $= -F\Delta x$

when expanding - gas doing work on a system
[gas 俾力] (-ve W.D) $h_i \to h_{f_2}$

when compressing - work done on gas
[俾 gas 力] (+ve W.D.) $h_i \to h_{f_1}$

adding changes in ~~dist~~ distance :

$$W = \int_{h_i}^{h_f} -F\,dx$$

$$= [-Fx]_{h_i}^{h_f}$$

$$= -F(h_f - h_i)$$

Expanding :

$$W = -F(h_{f_2} - h_{f_1})$$
$$= -Fh$$

Compressing

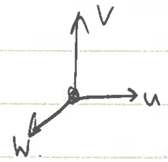
$$W = -F(h_{f_2} - h_{f_1})$$
$$= -F(-h)$$
$$= +Fh$$

By def: $F = PA$

$$W = -F\Delta x$$
$$= -PA\Delta x$$
$$= -P(h_f A - h_i A)$$
$$= -P(V_{f_1} - V_i)$$
$$W = -P\Delta V$$

~~Conservation~~

[illegible]



$\frac{1}{3}$ in u

$\frac{1}{3}$ in V

$\frac{1}{3}$ in W

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

$$= \frac{2mu}{2L/u}$$

$$= \frac{mu^2}{L}$$

$$F = \frac{m\bar{u}^2}{L}$$

force due to all particles:

$$F = \frac{Nm\bar{u}^2}{3L} + \frac{Nm\bar{v}^2}{3L} + \frac{Nm\bar{w}^2}{3L}$$

$$F = \frac{Nm}{3L}\bar{c}^2$$

$$PA = \frac{1}{3}\frac{Nm\bar{c}^2}{L}$$

$$P = \frac{1}{3}\frac{Nm\bar{c}^2}{V}$$

$$PV = \frac{1}{3}Nm\bar{c}^2$$

E_k total

$$= \frac{1}{2}Nm\bar{c}^2 = \frac{3}{2}PV$$

$$\frac{3}{2}NkT = \frac{1}{2}m\bar{c}^2 N$$

$$\frac{3}{2}kT = \frac{1}{2}m\bar{c}^2$$

G-field → always attractive

Total energy : P.E + K.E.

$F = \frac{Gm_1 m_2}{r^2}$

$-\frac{GMm}{R} + \frac{1}{2}mv^2$

$\frac{GMm}{2R^2} = \frac{\frac{1}{2}mv^2}{R}$

$\frac{1}{2}mv^2 = \frac{GMm}{2R}$

$-\frac{GMm}{R} + \frac{GMm}{2R}$

$= -\frac{GMm}{2R}$

by

$mg = \frac{Gm_1 m_2}{r^2}$

$M = \frac{g r_e^2}{G}$

lines of equipotential show all points of equal potential in a field.

geostationary orbit of satellite

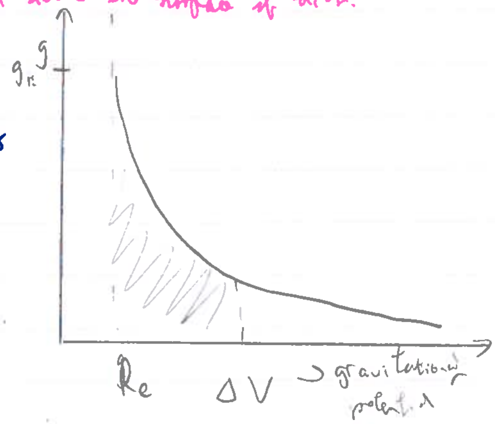
- same period of rotation as earth ($T = 24$hrs)
- appears to be stationary
- ~~over~~ same plane as the equator
- move @ same speed as earth
- 36000 km above the surface of Earth.

field strength : force per unit mass acting on that pt mass

$g = \frac{F}{m}$

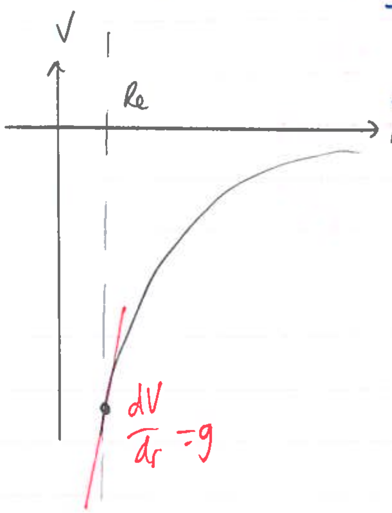
$g = \frac{GM}{r^2}$

$g \propto \frac{1}{r^2}$ inverse square law.



gravitational potential V:

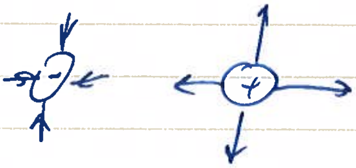
- Work done per unit mass to bring an object from infinity to a point in space
- -ve ∵ -work done is required to bring a point mass from ∞ to a pt in space.
- ∞ is defined to have 0 potential



$V = -\frac{GM}{r}$

$V_{esc} = \sqrt{\frac{Gm}{r}}$

E-field:



正 出
负 入

Coulomb's law:

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{Q_1 Q_2}{r^2}$$

$k = 8.99180 \times 10^9$

$\approx 9 \times 10^9$

field strength: $E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2}$

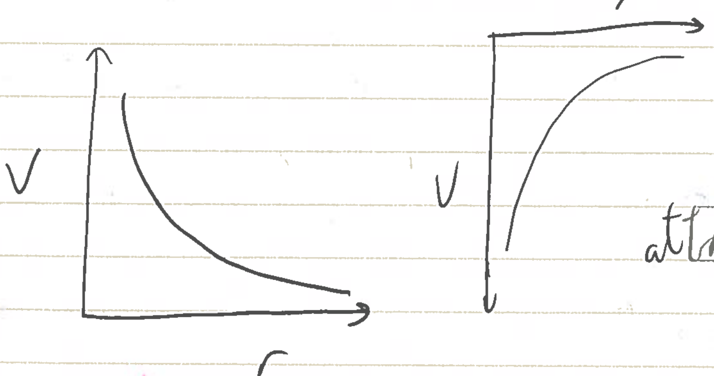
Electric potential: $V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r}$

$= Ed$

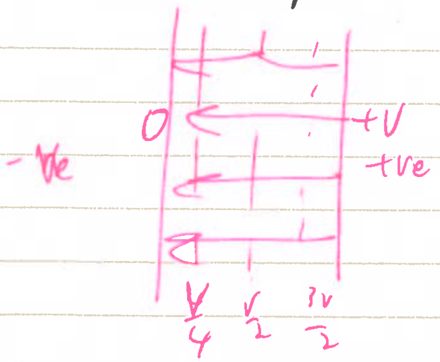
- work done per unit charge to move a +ve test charge from infinity to a pt in space @ infinity where infinity is defined as V=0
- scalar

Overall: $V_1 + V_2 \cdots V_n$

Repulsive



attractive



$E = \frac{V}{d}$

Capacitors.

Building up charges on plates

Eg Capacitance : $C = \frac{Q}{V}$

charge stored per unit voltage

to increase Capacitance
↳ add dielectrics

$C = \frac{A\varepsilon_0 \varepsilon_r}{d}$

→ negative ends of molecules are attracted to the positively charged plate
→ molecules align & rotate 排位
→ molecules now have their own electric fields 有自己 E-field

同 Capacitor E-field 对抗 ↳ alignment now opposes the applied electric field of capacitor
→ reduces the overall electric field E↓
↳ reduce p.d. across plates
↳ by $C = \frac{Q}{V}$ V↓ C↑

$C = \frac{Q}{V}$ V↓ C↑

減小 V, increase C

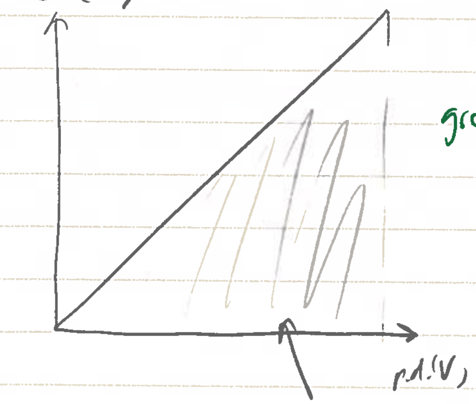
有些 分子 — 產生 E-field

* permittivity: measure of how difficult is to generate an E-field in a certain material

* relative permittivity is the ratio of permittivity of a material to the permittivity of free space.

$\varepsilon_r = \frac{\varepsilon_1}{\varepsilon_0}$ ← material, ← free space

Capacitance graph



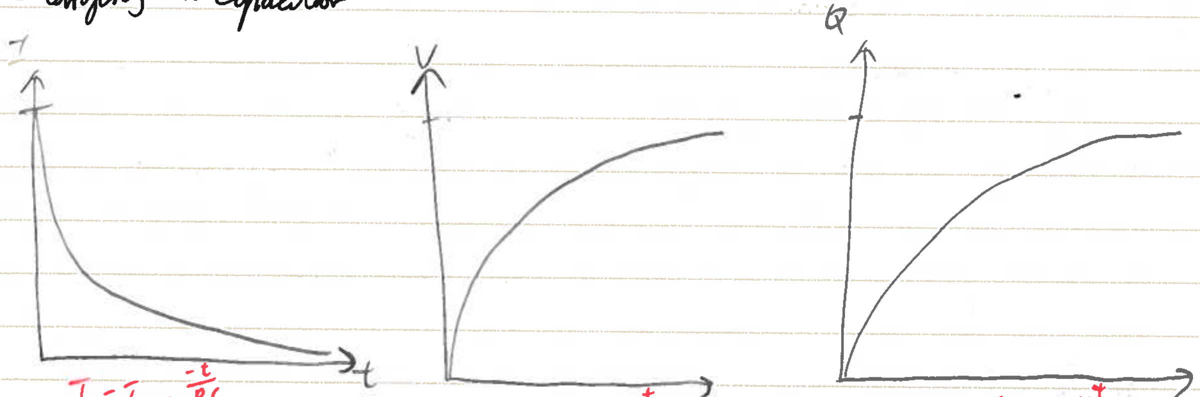
$$\frac{dQ}{dV} = C$$

gradient $= C$: ~~Charge per unit volt~~

Charge stored per unit volt

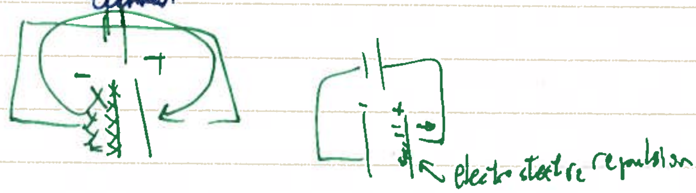
area $= E = \frac{1}{2}QV$
$= \frac{1}{2}CV^2$
$= \frac{1}{2}\frac{Q^2}{C}$

charging a capacitor

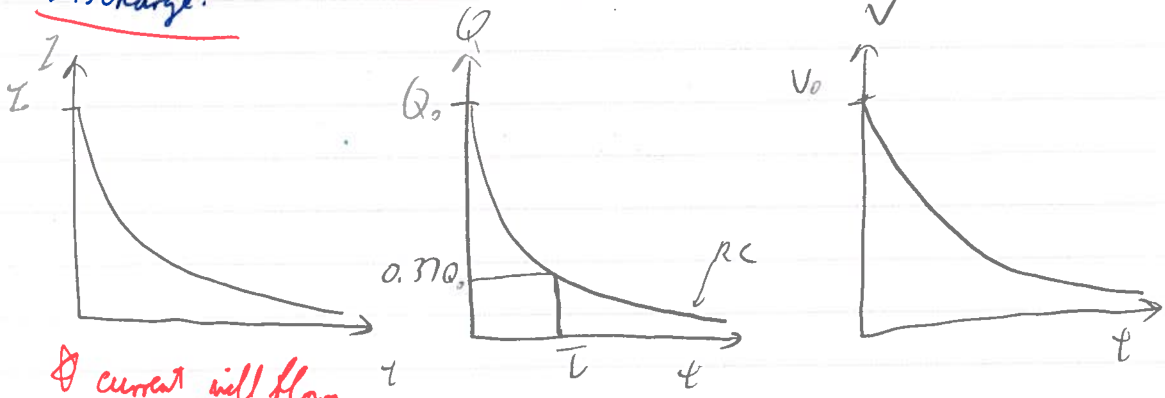


$I = I_0 e^{-\frac{t}{RC}}$ $\quad V = V_0(1 - e^{-\frac{t}{RC}})$ $\quad Q = Q_0(1 - e^{-\frac{t}{RC}})$

when charging:
- e's flow onto the plate connected to the -ve terminal
  ↳ -ve charge builds up -ve 儲[illegible] . 儲 位
→ build up of -ve charge repels e's off the plate connected to the +ve terminal
  ↳ plate will be +ve → e's attracted to +ve terminal
  → charge builds up → electrostatic repulsion makes it harder & harder for more electrons to be deposited
  → when p.d $V_{capacitor} = V_{power\ supply}$
  current $= 0$



Discharge:



∅ current will flow in the opposite direction from the charging current

$I = I_0 e^{-\frac{t}{RC}}$ $Q = Q_0 e^{-\frac{t}{RC}}$ $V = V_0 e^{-\frac{t}{RC}}$

$\tau = RC \rightarrow$ time constant

when $t = RC$

$t =$ $Q = Q_0 e^{-1}$

$\frac{Q}{Q_0} = \frac{1}{e}$

$= \frac{1}{2.718}$

$= 0.37$

τ:
- discharge
  time taken for charge to fall to 37% of its original value
  跌 ~~37%~~ 到 37%
- charging
  time taken for charge to rise to 63% of its original value
  升 63%

time to halve

$T_{1/2} = 0.69RC$

time taken for Q / V / I to reach halve of it value when it was fully charged.

Ec B-field see Main notebook

~~L.H.R.~~ ~~fact~~

$F = BIL\cos\theta$ left hand motor (induce motion)

$F = BQv$ Right hand generator (induced current)

Faraday's Law of EM induction:
- when a conductor when it cuts flux / in a changing B-field },
  a emf is generated
- emf generated is directly proportional to the change of flux

+

Lenz's Law: direction of induced emf / current is always such to oppose the Change That Caused it.

$\cancel{N =}$ $\cancel{\varepsilon = \Delta N}$ $\Delta\Phi$

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$$

Magnetic flux ~~to~~ density : (T)

strength of magnetic flux density which produces a 1N force on 1m of wire with a current of 1A flowing $\perp$ to the B field

Magnetic flux:

product of Magnetic flux density cutting $\perp$ to an Area

$\Phi = BA$ (Wb)

Magnetic flux linkage: $N\Phi = BAN\cos\theta$ (Wb)

change in magnetic flux of 1 Wbs^{-1} will induce 1V of emf in one loop of wire

AC current.

$$V_{rms} = \frac{V_0}{\sqrt{2}} \qquad I_{rms} = \frac{I_0}{\sqrt{2}}$$

Transformers

step up → V↑, I↓, reduce power Loss

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

Nuclear Physics

Rutherford Scattering

↳ showed existence of nucleus

∵ passed straight through foil
∴ atom must be empty space

∵ repel + deflect at large ∠
∴ nucleus +ve

∵ ~~nucleus is small~~

∵ few alpha deflected back
∴ ~~alpha~~ nucleus small

∵ fast alphas are deflected by nucleus
∴ most mass in nucleus

~~A lt~~

nucleus radius ∝ nucleon number^3

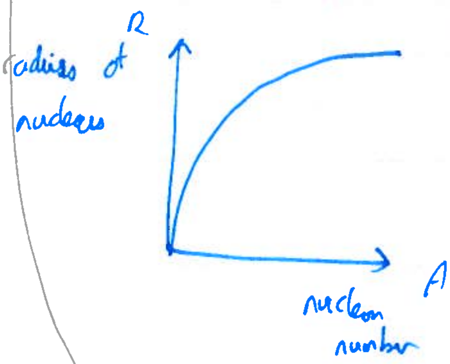
$R = R_0 A^{1/3}$

R_0: 1.2×10^{-15}

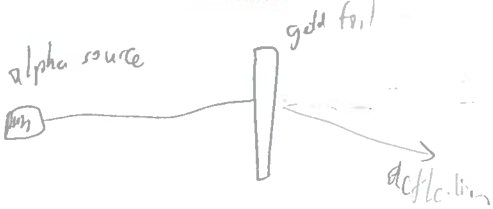
A: nucleon number

~~$A_r =$~~

$R_A = 5\times10^{-11}$ m

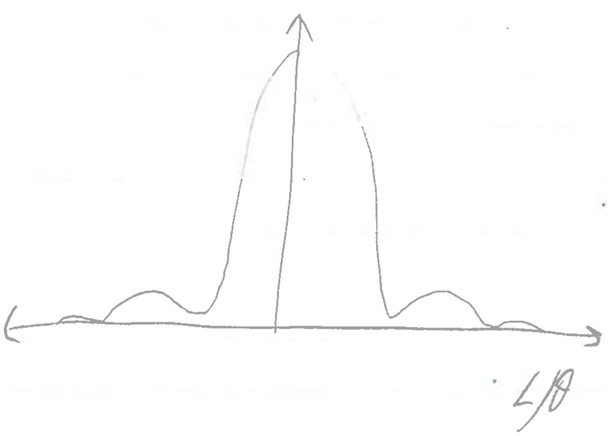


smallest nucleus
↳ ~~1×10^{-13} fm~~
1×10^{-15} m
↳ femtometers



A: Activity:

Number of nuclei of the isotope that decays per second.



Radioactive emissions:

if nucleus is unstable → breaks down to become more stable

unstable ∵ - too many neutrons 太多
- not enough neutrons 太少
- too much energy in nucleus. 太多 en

detaching e/s from molecules → ionising power

distance of range depend on energy

			ionising power		penetrating power:	
alpha (strongly positive)	α	大隻仔	Strong	slow	Absorbed by paper	難 sip
beta	β^- or		Weak	fast	Absorbed by 3mm of aluminium	
beta-plus	β^+		annihilated			
gamma	γ $\left(I = \frac{k}{x^2}\right)$		Very weak	c	absorbed by many layers of lead / concrete	易 sip

increasing ionising power ↑

increasing pen power ↓

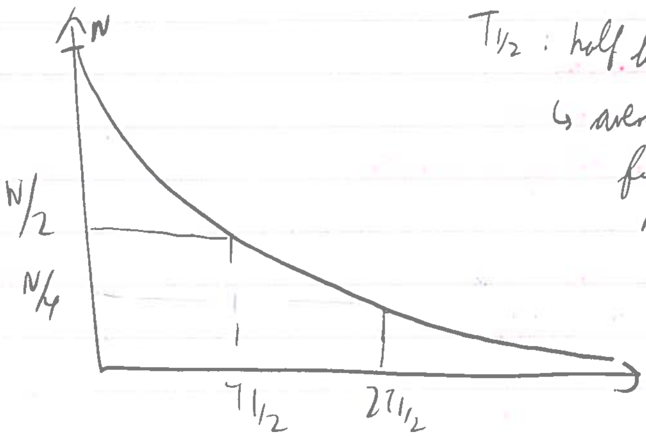
→ PET scanner, damage cancer cells.

radioactive emission:

$I = \frac{k}{x^2}$

Decay:

λ : probability that a radioactive nucleus will decay per unit time



$T_{1/2}$: half life
↳ average time for an isotope for number of unstable nuclei to halve.

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

Using

$$N = N_0 e^{-\lambda t}$$
$$A = N_0 e^{-\lambda t}$$

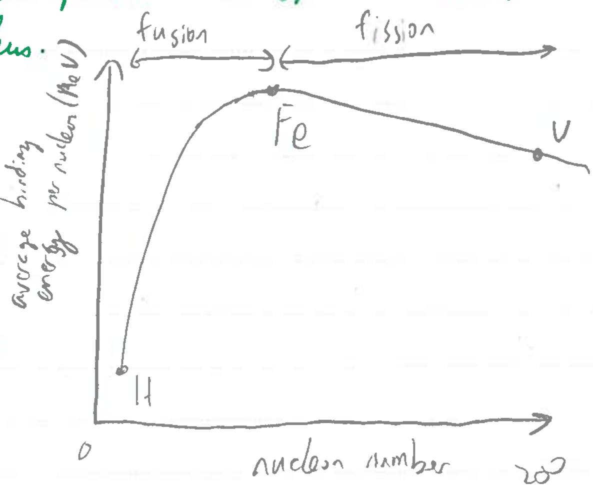
$A = \lambda N \quad (s^{-1})$
↑
decay constant

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

Binding energy → energy needed to seperate all of the nucleons in a nucleus.
= mass defect

↳ using $E = mc^2$

$$\text{MeV} \xleftarrow{\times 931.5} u \xrightarrow{\times 1.66\times10^{-27}} \text{kg}$$
$$u \xrightarrow{\times 1.494\times10^{-10}} \text{J}$$



mass (kg) = u × mass number × 1.66×10^{-27}

heavier nuclei (up to iron, Fe^{56})

binding energy / nucleon ↑↑, energy released

Beyond iron, need to input energy to create heavier nuclei

Nuclear fission   atomic bomb   nuclear reactors

heavy nucleus split into two or more lighter nuclei

$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{236}_{92}U \longrightarrow ^{141}_{56}Be + 3^{1}_{0}n + ^{92}_{36}Kr$

↳ chain reaction

nuclear fusion :   Sun & hydrogen bomb

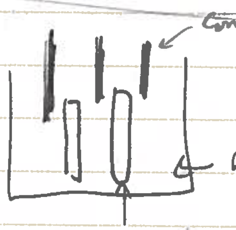
→ light nuclei fuse to form heavier nucleus

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

(Coulomb barrier)

* high KE to overcome the repulsion between nuclei

Nuclear reactors



- rods of Uranium for fuel
  (using supercritical mass of fuel)
- moderator (H_2O) to slow down / absorb neutrons   (slowed down neutrons are called thermal neutrons)
  by elastic collision (K.E. conserved)
  ↳ similar mass to neutron → efficient.
- control rods → control chain reaction by limiting number of neutrons in reaction
  * neutron absorbing (Boron)
  if emergency → control rods released into the reactor to stop the reaction.
- coolant ↳ remove heat → steam → turn turbine
- thicc concrete case for shielding
  ↳ preventing radiation escaping.

Nuclear waste

πc – nuclear waste
↳ from fragments of U-235
or
fuel rods.

treatments:

1. placed in ~~cooling~~ cooling ponds close to the reactor for a number of years. – cool
2. Uranium is seperated to be recycled – 分
3. high level waste is vitrified (made solid into pyrex glass)
↘ made into glass like substance – 玻璃
4. ↳ placed in lead/concrete/steel container ↘ 4. 储存
↳ stored deeply underground. ↘ 埋

Problem + treatment

- Waste: is initially very hot → placed in cooling ponds to cool
- highly radio active → " to absorb radiation
- highly radiactive → constely handled to avoid human contact
- liquid waste may leak → vitrify and barrel in steel.
- radioactive of for thousands of years → Storage has to be stable
↳ container / vitrifly and barrel in stainless steel
↘ needs to be in geologically stable areas / underground
-

~~Binding energy: energy required to~~
Binding energy: work that has to be done to seperate a nucleus into its constituent neutrons and protons.

Mass defect: difference between the mass of the seperated nucleons
Δm
and
mass of the nucleus

$$\Delta m = Zm_p + (A-Z)m_n - M_{nuc}$$

x0

Astro

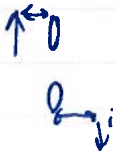
Telescopes:

Optical

~~optical:~~

u_o: d from lens to object

v_i: d from lens to image



lenses: when $u_o < v_i$

↳ real and latterally inverted

→ can be seen by screen

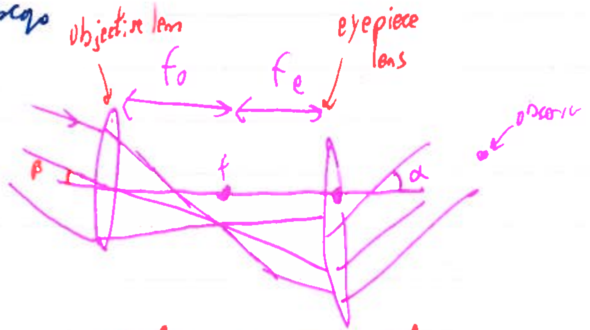
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

when $u_o > v_i$

↳ ~~Large~~ → Magnified + virtual

→ cannot be seen by screen

refracting telescope



angular magnification: $\underline{\underline{M}}$

$M = \frac{\alpha}{\beta}$ or $M = \frac{f_o}{f_e}$ ~~fo over~~ $\frac{\text{Objective}}{\text{eyepiece}}$

or $M = \frac{\angle \text{ got by image at eye}}{\angle \text{ subtended by object at unaided eye}}$

Measuring how big the object appear to be to the unaided eye.

$M = \frac{\theta_i}{\theta_o}$

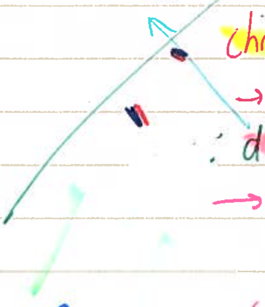
Refractive telescopes

Problems & solutions : chromatic & spherical abberation

blue light diffracts more than red.

X chromatic & spherical abberatio. X heavy, folan, 变化 move quickly

X large magnification required → 大 lens , 长 focal length



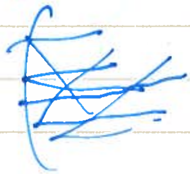
chromatic abberation [coloured fringe effect due to lens focusing colours at diff focal lengths]

→ producing coloured edges to the image 藍外 紅內

∵ diff λ of light diffract at diff ∠s.

→ corrected by → careful design & choice of high quality optical material

小心 設計 → 用品質好的 材料



(large diameter lenses) [blurring : focus not 一致]

spherical abberation

→ light rays in a // beam focused at diff positions

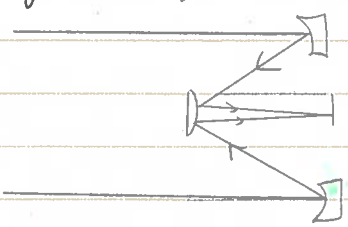
[focus but missed]

↳ minimized by making both surface of the lens contribute equally to ray deviation

Reflecting telescopes ✓

- large single mirrors
  - → light & supportable from behind [易 supp]
- made few nanometres thicc
  - → excellent image properties [jeng shit quality]
- only front surface for reflection [冇 lens 咁 on9]
  - → remove problems from lenses
- X chromatic X spherical abberation
- light mirrors
  - → rapid response to astronomical events [轉 , 快]

Cassegrain arrangement



X Refractive telescope

- difficult to mount
- large diameter lenses are heavy
  - ↳ tend to distort under their own weight

chromatic abberation

↳ diff λs diffract @ diff ∠s

→ coloured fringe

fixed by careful design and use of high quali materials

Spherical abberation

↳ light rays in a // beam focused at diff positions

→ minimized by making both / lens

CCDs (resolution depends on size of pixels and no. of pixels)

efficiency > 80%

Charged couple devices

Quantum efficiency

$$= \frac{\text{number of photons detected}}{\text{number of photons incident}} \times 100\%$$

~~human eye~~ → ≤1%

~~human eye~~ = 1%

→ made up of millions of silicon chips ✓

↳ elec photons hit → electron released → alter charge of chips / pixel

→ measured then create a digital signal

↳ gives brightness / intensity (accurate measurements)

– Info can be stored digitally → transmitted for remote image processing & analysis.

Resolving power: smallest θ

$\theta = \frac{\lambda}{D}$ that you can see through L

$\frac{x}{L} = \frac{\lambda}{D}$

[minimum angular resolution]

Rayleigh criterion: two point objects can be resolved if their angular seperation at least

Collecting power: (LGP)

$P = \frac{1}{4}\pi d^2$ ability to collect EM radiation

collecting power $\propto$ (objective diameter)^2

$P \propto D^2$

Concept?

$1^\circ = \frac{1}{360}$ of circle

1 arcminute $: 1' = \frac{1}{60}$ of a degree

1 arcsecond $: 1'' = \frac{1}{60}$ of an arcminute

1 arcsecond $= \frac{1}{3600}$ of a degree

arcsecond $\xrightarrow{\times 3600}$ degree

degree $\xrightarrow{\div 3600}$ arcsecond

~~NON~~ - DP2

NON-OPTICAL TELESCOPES

- Radio
- infrared
- UV light
- X-RAY
- GAMMA RAY

atmospheric opacity: absorption of EM radiation by the atmosphere

↳ UV, IR, X ray gamma all absorbed (radio wave)

most visible and some IR ~~also~~ can go through

~~Radiowaves can't pass through~~

microwaves ✓✓

- Radio telescope → lower θ
  - ∴ dependence of λ
  - → to resolve objects w/ small angular sizes.
  - ∴ Need large dish → Large diameter aperture
  - away from artificial sources of interference ↳ in isolated areas
  - operate day + night
  - ground based ∴ atmosphere is transparent to large range of radio λ

IR

- infrared telescopes: → make observation of cool region — cool region
  [observe astronomical objects at IR λ]
  (e.g.) interstellar gas, cooler star, active galaxies.
  (0.7 - 450 μm) — space based
  → Earth atmosphere absorb IR radiation: water vapor, O_2
  ↳ space-based observations
  → IR detector is kept cold

- UV telescopes → in space ∵ atmospheric absorption of wavelengths
  (10nm - 400nm) λ
  → Cassegrain mirror system
  - using photoelectric effect to convert UV photons → electrons
  - determine chemical composition and temp of interstellar medium — chem composition
  - determine temp and composition of stars — temp
    - young stars
    - old stars
    - white dwarfs
    - active galaxies
    - quasars
  - reveal hot gaseous halo surrounding our galaxy
  - help understand solar corona — solar corona
    ↓
    aura of plasma that surrounds the Sun

X-ray : - observed from space [space based]

0.01nm - 10nm - X ray from extremely hot gas (10^6 - 10^8 K)

↳ highly energetic process - binary stars
- active galaxies
- galaxy clusters
- supernova remnants
- pulsars
- neutron stars
- black holes

- extremely hot gas from highly energetic process.

skim off w/o penetrating
↳ grazing incidence

- Gamma ray - do not use mirrors

~~0.01nm~~

> 0.01nm

from - solar flares
- pulsars
- quasars
- active galaxies
- supernova remnants

sudden burst last for 0.1s — 1000s

Kirchoff's laws of spectroscopy

(Emmision)

line spectrum : (有色，黑背景)

[Hot tendon gas produces light w/ spectral lines at discrete wavelengths depending on the energy levels of the atoms in the gas]

temp↑↑ → more atomic collisions → e's raised to excited state

→ e's de excite → falls down energy levels, → emitting photon with precise energy

↳ correspond exactly to spacing of energy levels within atoms of gas

→ spectrum recorded : bright light on a dark background

intensity & position of lines → particular electron transition in atoms of gas

Continuous spectrum: (彩虹) [A hot solid object or dense gas produces light with a continuous thermal spectrum]

atoms have KE, undergo multiple collisions, e's at excited states

↳ excited e's fall back into discrete energy levels BUT during this, multiple collisions occured

↳ results in blurring + loss of info about atoms in gas

↳ Continuous spectrum @ photosphere → outer shell of star where light is formed

Absorption spectrum: light passes thru outer layers → source of visible light

↳ which are cooler & mainly H

photons absorbed, electrons raise to excited state

↳ fall down to ground state → photons emitted in random directions

↳ spectrum comprised of dark lines

有[illegible]黑线 seen when light from a continuous spectrum passes ~~through a~~ cooler gas which absorbs at discrete λs depending on the energy levels of the atoms

Emission line spectrum: a hot luminous gas produces light with spectral lines with discrete λs depending on energy levels of atoms in the gas

↳ seen from low density gas clouds according to their temp & composition

e.g. - hot interstellar gas in star-forming regions

- spiral arms of galaxies

· planetary nebulae : evolved stars which have gaseous envelopes

· quasars : emission from gas spiraling into the central massive black hole

Continuous spectrum: hot solid object or gas produces light w/ a continuous thermal spectrum

eg. - spectrum of a light bulb spans all visible λs

- stars : radiation emerging from a stellar interior has a continuous — using SED get T_{eff}

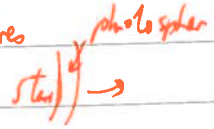
- normal galaxies : spectrum is the combination of all stellar population

- quasars w/ black holes : radiation is non-thermal, but still has continuous spectrum

Absorption line spectrum: seen when light from a continuous spectrum passes through a cooler gas which absorbs at discrete λs depending on energy levels of the atoms

a cloud of intervening cooler gas can absorb the continuum from a background source at specific wavelengths leaving dark absorption lines in the spectrum

eg all classes of stars due to cooler photospheres



Interstellar gas clouds along the sight line

intergalactic gas clouds along the sightline to quasars

Distance & Magnitude:

standard candle
↳ 已知 absolute magnitude (fixed)
   求 apparent magnitude (from earth)
   → 求 d (pc)

Luminosity (brightness) $b = \frac{L}{4\pi r^2}$ (Wm^{-2})

- Amount of energy emitted per second at the surface of the star.
↳ depend on luminosity and distance

Apparent magnitude: → how Bright things Appear on Earth

Using Pogson's Law

$$\underbrace{m_2 - m_1}_{\text{apparent magnitude of } m_2-m_1 \text{ (stars)}} = -2.5 \log_{10}\left(\frac{b_2}{b_1}\right)$$

$\frac{b_2}{b_1}$ → brightness of stars

負數 (-ve) → brighter
正數 (+ve) → dimmer

1pc = distance of which the observed parallax of the star is equal to 1 arcsecond = $\frac{1}{3600}$th of a degree

distances

- 1 AU = 1.5×10^{11} (distance from sun to earth)
- 1 ly = 9.46×10^{15} m (distance EM wave travels through a vacuum in one year)
- 1 parsec = 3.26 ly = 206265 AU = 3.08×10^{16} m
  ↳ distance which the observed parallax of the stars is equal to 1 ~~second~~ arcsecond

Absolute magnitude: its apparent magnitude if it were located at a distance of 10 pc from earth

- based only on the luminosity of the star (standard distance)

Using:

$$\underbrace{m - M}_{\text{distance modulus}} = 5 \log\left(\frac{d}{10}\right)$$

d → distance in pc

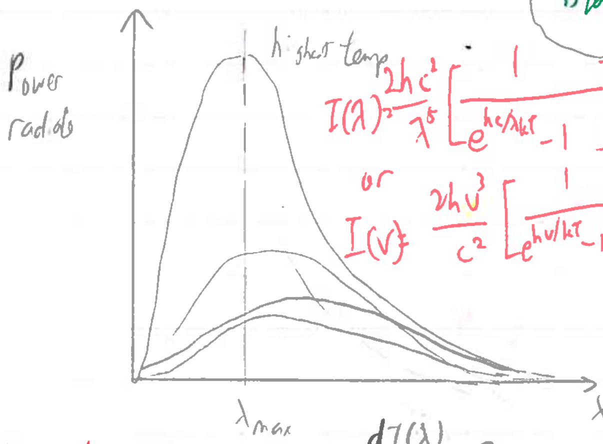
m: apparent magnitude [from earth]
M: absolute magnitude [from 10pc of earth]

determining distances to star cluster / galaxies which cannot be determined by parallax measurements

★ Standard candle:
- objects that you can calculate the luminosity directly

↳ cepheid variable stars:
periodic variation in luminosity has a (constant known relationship) with (max luminosity)
→ measure this → absolute magnitude can be calculated

Stars as Black Bodies [perfect absorber / emitter]



$$I(\lambda) = \frac{2hc^2}{\lambda^5}\left[\frac{1}{e^{hc/\lambda kT}-1}\right]$$

or

$$I(\nu) = \frac{2h\nu^3}{c^2}\left[\frac{1}{e^{h\nu/kT}-1}\right]$$

Black body: idealized body which absorbs all radiation incident upon it

For thermal equilibrium: it must also emit radiation at same rate it absorbs for temp to be maintained

↳ gases inside stars are opaque to all radiation so stellar surfaces approximate a blackbody

– Using Kirchoff's law of thermal radiation

using $L = 4\pi d^2 F$, $F = \sigma T^4$

$$L = 4\pi d^2 \sigma T^4$$

知 $T = T_{eff}$ 同 L ↓ 求 stellar radius

- Find Temp: $\frac{dI(\lambda)}{d\lambda} = 0$

using Wien's displacement law.

$\nu_{max} \approx 10^{11}\,T$

$$\lambda_{max} T = 2.9\times10^{-3}\,mK$$

- Find Power output: (Total flux of a blackbody)

↳ by integration over all λs / fs

[Stefan-

$$F = \sigma A T^4$$

Area; temp; Stefan Boltzmann constant

[Stefan - Boltzmann law

for a black body:

- $P \propto$ surface area
- $P \propto T^4$

Stellar spectroscopy: - analyzing spectrum of stars

- emission line spectrum
- emission continuous spectrum
- absorption spectrum

- Find intensity or flux

Flux: energy flowing through unit area of surface

[inverse square law] $F = I = \frac{L}{4\pi d^2}$

Luminosity: total amount of energy radiated per unit time

~~E~~ E_t

Spectral Class:

		temp T_{eff}		absorption lines
blue	O	50	50000 - ~~25000~~ 30000	He^+, He, H
	B	25	30000 - 11000	He, H
	A	11	11000 - 7500	H, M^+ M^{x+}
white	F	75	7500 - 6000	metal ions → M^{x+}
yellow	G	60	6000 - 5000	M^{x+}
to (vary)	K	50	5000 - 4000	
red	M	35	3400 >	Metal atoms (T:O)
LA	L		2000	(molecular bands.
TA	T		2700	

Strong hydrogen Balmer lines

metal absorption

division into subclasses

See H-R Diagram → 有 Red Supergiants, main sequence stars, white dwarfs

Stellar Evolution

Proto stars
- convective
→ cool $T_{eff} < 4000K$
- Pre MS era last $10^5 - 10^7$ yrs
depending on initial mass

- between interstellar medium:
molecular clouds → cold hydrogen gas (10–50K)
$10^8 - 10^{15}$ molecules per m^3
form a rotating
clump of gas dust → silicates & graphites
through gravitational attraction

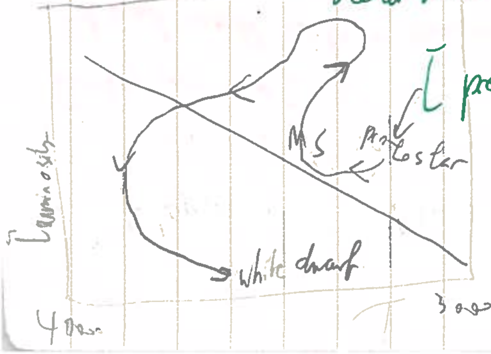
~~movement cathers on HR diagram~~

angular momentum spins the clumped material
with a circumstellar disc

↓

temp in core ↑↑
- thermonuclear reactions begin (fusion)

- stellar wind is produced



[pre main sequence]
- movement continues on HR diagram
until ... zone
- further collapse ↑↑ core temp until
nuclear ignition occurs at which point
star stabilize on the main
sequence.

Main Sequence
H-burning

1). pressure produced by
hydrogen fusion in core
fusion = gravity
balances
gravitational compression
[core hydrogen burning]

2.) depends on mass
more massive stars have hotter cores
high mass high temp → shorter lifetime
low mass low temp → longer lifetime
~10.8 10^9 years.
CNO energy generation rate
is a stronger power of
temperature ($\propto T^{17}$) than
pp rate ($\propto T^4$)

3. 燒到冇 hydrogen

CNO cycle ↑ $> 1.3 M_\odot$
Catalyst
CNO

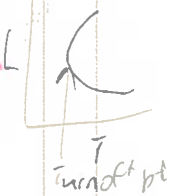
$^{12}C + {}^1H \rightarrow {}^{13}N + \gamma$
$^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$
$^{13}C + {}^1H \rightarrow {}^{14}N + \gamma$
$^{14}N + {}^1H \rightarrow {}^{15}O + \gamma$
$^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$
$^{15}N + {}^1H \rightarrow {}^{12}C + {}^4He$

→ post main sequence

Red Giant : ($1.4 - 3 M_{sun}$)
- appear red
∵ cooling down

critical situation → no nuclear energy → star must collapse

× hydrogen
↳ nuclear fusion stops.
↳ outward pressure stops.
↳ Helium core contracts + heats up
due to the weight of star
↓
outer layers expand and
cool
(Red giant)



- shell hydrogen burning
heat from heating of the helium
core fuse hydrogen

$T_c \approx 10^8 K$ - Core helium burning
→ heat & contraction of helium core
hot & dense enough to fusion Carbon → oxygen
↳ release energy and pushes outer
layer of star

endo
$^4He + {}^4He \rightleftharpoons {}^8Be + \gamma$
$^4He + {}^8Be \rightleftharpoons {}^{12}C^*$
$^{12}C^* \rightarrow {}^{12}C + 2\gamma$

- shell helium burning
× helium → C-O core contracts
↳ heating the shell around it → helium fuse.

OR

→ Redsupergiant (>3M$_{sun}$)

- fusion all the way up to iron ∵ [illegible] pressure [illegible] heat

Mystery for Type I SNe

- Red giant would transfer hydrogen but NO HYDROGEN seen in spectra of Type I SNe
  ↳ Perhaps other companion is ~~star~~ a white dwarf
    ↳ companion white dwarfs are too rare to match the rate of Type I SNe

If Find as Red Giant:

✡ Luminosity & homogeneity of SNe
↳ can be seen to great distances
to chart expansion history of Universe

Chandrasekhar limit

- Explode at some critical mass

Gamma ray burst

- narrow beam of intense radiation
- 10^{48} J
- maybe source of mass extinction

evidence: 1: Remarkably homogeneous in peak luminosity, consistent w/ explosion of a system of fix mass

2: No remnant in Type I events in Milky Way

Neutron star

1 per 100yrs in large galaxies [rare]

Supernova: (rapid, massive increase in brightness)

~~83~~ M > 8M$_{\odot}$

- star that suddenly and very rapidly INCREASES in absolute magnitude ∵ explosion

ejects most of its mass

2 types:

Type I supernova

- star that accrete (draws in) matter from another star in a binary system until it becomes compressed and nuclear reactions are set off, blasting matter into space.
- 10^{44} J of energy released
- roughly same energy output of the Sun over its entire lifetime
- model predict collapse c^2
  → entire white dwarf destroyed in a thermonuclear explosion

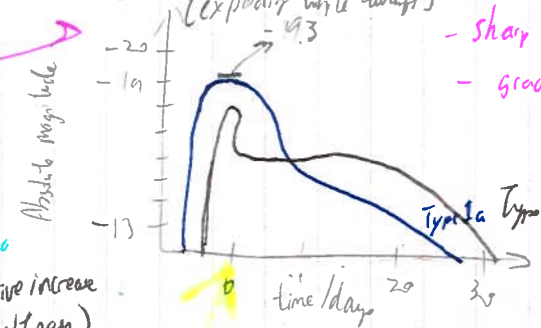
Type II Supernova

- emits bursts of high energy gamma rays [core collapse]
- Star that runs out of nuclear fuel and collapses readily under own gravity
  ↳ ejecting its outer layers (5000-10000 kms^{-1}) w/ enormous energy (10^{46} J)

✡ ~~seve~~ has to be several times more massive than the Sun

完蛋 变 变 neutron star

Type Ia Supernova (Standard candles)
[exploding white dwarfs]



- sharp initial peak
- gradually decreasing curve

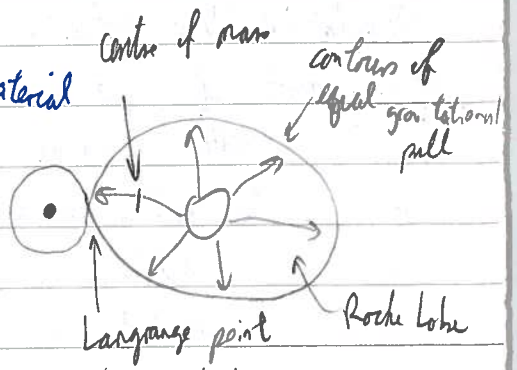
~~Used as~~ - used as a standard candle (known luminosity & distance)

∵ every Type Ia supernova has the same absolute magnitude curve (-19.3)

- bright of ↳ distances up to 1000 Mpc
  ↳ for cosmological distances

Observing Black Hole:

↳ detect its influence via nearby material



↳ pt of balance of G-field

matter falling into black hole loses potential energy

→ thermally or non-thermally radiate

very hot gas → X-ray emission

eg. binary system where more massive stellar companion fills its Roche lobe

↳ leading to accretion onto black hole → accreted material has $\vec{L}$, form an accretion disk around the black hole

[viscosity in the disk can heat up]

accretion disk : flattened band of spinning matter around the event horizon

---

eg. Cygnus X-1 – Black hole in Binary System

→ most luminous X-ray source in the sky

↳ accurate radio position indicated a blue supergiant star which was too cool to emit X-rays

↳ use Doppler 'wobble' of the supergiant star

↳ deduce there was a dark orbiting object w/ mass $\sim 14 M_\odot$

↳ first black hole encounter

X-ray Binaries (XRBs) contain either black hole or neutron star

- Low mass : ~~companion~~ companion fills its Roche lobe
- High mass : stellar wind from hot companion captured
- transient phenomena can be observed

short time or impermanent

↳ associated w/ intermittent hot spots along accretion stream

occurring @ irregular intervals

including nucleosynthetic explosions

Gravitational Wave Astronomy

see ppt for diagram

LIGO

- merger of a pair of neutron stars / black holes
  - creates a major gravitational distortion in waves
    - generating low frequency Gravity wave
      - detected by sensitive interferometer
- time-dependent signal ['strain'] contains key information on masses of 2 merger sources
- can be used to measure mass distribution of black hole & neutron stars

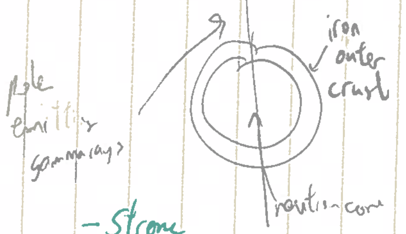
core mass of 1-3 $M_\odot$ → stable degenerate neutron star

→ Neutron stars: $>1.4M$

- great gravitational contraction
  ↳ electrons forced into protons
  ↳ neutrons formed.

collapsed core of neutrons ←

∴ composed entirely of neutrons.



- upper stable mass limit → $M_{neutron} < 3.1 M_\odot$
- similar to e^- degeneracy in white dwarfs
  - rest mass contributes to KE
  - interparticle distance within range of strong force
  - dense at ($4 \times 10^{17}\ kg\ m^{-3}$)
  - small (20km)
  - rotate v. fast (600 times a second)

- Strong gravitational field ($v_{esc} = 0.8c$)

- low intensive luminosity

$p + e^- \rightarrow n + \nu_e$

~~if~~

↳ pulsars

$\vec{L}$ and $\vec{B}$ are conserved

surface of a neutron star has protons and neutrons of which G-field not strong enough to ~~be~~ push them tgt forming neutrons

↳ accelerating towards the magnetic poles of neutron star. [relativistic speeds]

↳ emitting EM waves at poles. e^-'s spiral around B field → creating synchrotron radiation

→ rotate rapidly ($P \sim 10^{-3}$ - 1sec)

→ strong B-field (10^8 Tesla)

lighthouse

— if magnetic & rotation axes to not aligned & rotation axis pt towards Earth → bursts of radiation every rotation period

CNO:

$^{16}_{8}O + ^{1}_{1}H \rightarrow ^{14}_{7}N + ^{4}_{2}He$

↳ $Sirius_B < 8 M_\odot$

white dwarfs: old stars that have (low mass stars)

a high surface temp. but not luminous

- products of fusion how such as H, C, O, N,

blue

$T_{eff} \sim 10 \sim 20,000K$

∴ small, no longer generate energy by fusion

→ dense

↳ ~~eff~~ cooled to a pt of emitting no heat/light (lose energy source)

↳ black dwarfs

less massive stars cannot raise their core temps sufficiently to ignite the next fuel

∴ must collapse to form a stable e^-/degenerate remnant

Black hole: $>3M$ [$M \sim 20$-$50 M_\odot$]

- strong G-field
- no EM wave/particle can escape.

Schwarzschild radius:

$$R_s = \frac{2GM}{c^2}$$

→ for a given mass, how small of an object has for it to trap light around it ∴ appearing black

→ boundary formed ∅ event horizon

laws of phy breaks down

event horizon

↳ region of the black hole of which no matter & ~~radiation~~ radiation can escape unless they have v =

$$R_s = \frac{2(6.67 \times 10^{-11})(?)(1.99 \times 10^{30})}{(3 \times 10^8)^2}$$

=

COSMOLOGY

red shift: observed λ > emitted λ

- expansion of universe
- galaxies moving apart

Doppler shift → change of frequency of light due to motion of observer

observer

$\lambda\downarrow$, $f\uparrow$ $\qquad$ $\lambda\uparrow$, $f\downarrow$

observer – furthest galaxies move furthest.

除[近藍]

除離
↳遠紅

moving closer

Blue shift → 移動埋身

moving further

Red shift ← 離我遠去

~~for v<<c~~ Doppler shift

for $v \ll c$

$z = -\frac{v}{c}$

amount of speed red shift

有幾多紅

doppler shift

$$z = \frac{f_{emitted} - f_{observed}}{f_{emitted}} = \frac{\Delta f}{f} = \frac{v}{c}$$

$$z = -\frac{\lambda_{emitted} - \lambda_{observed}}{\lambda_{emitted}} = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$$\frac{650\,nm - 540\,nm}{650\,nm} = \frac{v}{c}$$

$v = \cancel{50.}\ 51.8 \times 10^{7}\ ms^{-1}$

planet and star orbit around common centre of mass

↳ star moves toward or away from earth

↳ causes shift of wavelength of light received from stars.

observed λ $\qquad$ rest λ $\qquad$ radial velocity of emitter

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

$\lambda\uparrow$ red

$\lambda\downarrow$ blue

$v > 0$, $\lambda > \lambda_0$ → 遠紅 ~~遠紅~~ red shift

$v < 0$, $\lambda < \lambda_0$ → 近藍 blue shift

- Kinematics of stars in galaxies → getting true space velocities of stars
- large scale structures → drawing 3D large scale structure of galaxies of universe
- cosmic Evolution → measure red shift in galaxies allow us to study the universe in periods of cosmic time

Quasars & Exoplanets.

$$\frac{P_{quasar}}{d_{quasar}^2} = \frac{P_{galaxy}}{d_{galaxy}^2}$$

Quasars

Balmer lines of hydrogen shifted enormously

→ extremely luminous objects → shoots out jets of material (active radio sources)

→ high red shifts (most distant)

→ they lie at great distances

↳ suns per year to produce energy observed

[core of distant galaxies, powered by matter falling into a supermassive black hole]

→ produced a continuous spectrum ✗ black body ✗ absorption lines ↳ emission lines

Exoplanets:

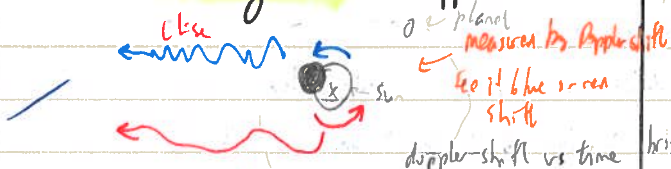
→ planet that orbits a star other than the Sun.

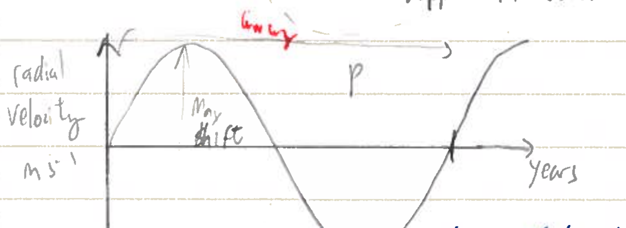
- cannot detect exoplanets in most situations due to limited angular resolution [<<1 arcsecs for all but nearest stars]
- poor brightness contrast w/ parent star

- fainter than the star ∵ only reflect light from the star ∴ difficult to detect / seen directly

TWO METHODS IN FINDING EXOPLANETS

- Radial Velocity Method (Doppler Shift)





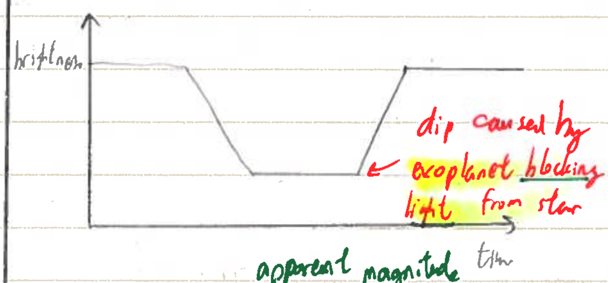
- exoplanets orbiting a star has a small effect on star's orbit
  - ↳ causing tiny variations (wobbles) → orbiting in a common centre of mass
  - ↳ wobbles cause red & blue shifts in star's emissions → detected on earth
- → velocity measurements allow determination of size and shapes of orbits of an exoplanet
- → can calculate minimum mass
- if planet orbits star ⊥ to the line of sight
  - ↳ no detectable shift in the light from the star

exoplanet

[star orbiting in a common centre of mass, doppler shift of the star] [detect wobble due to gravitational pull of nearby planet]

- Transit Method

↳ detecting a dimming in star's brightness



decrease in observed brightness allow radius of exoplanet to be calculated if radius of parent star is known

$$\frac{\pi r_p^2}{\pi r_s^2} = \left(\frac{r_p}{r_s}\right)^2$$

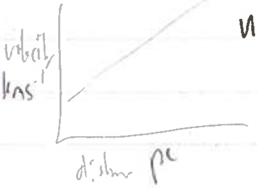
- chances of the planet's path being lined up so that it crosses the line of sight between star & earth v. low → only confirm exoplanets ✗ relevant location

Age of universe (depends on H_0)

$t = \frac{d}{V}$

From Hubble's law

$V = Hd$



$1 = H \frac{d}{V}$

$\frac{1}{H} = \frac{d}{V} = t$

using $H = 67.3\,kms^{-1}Mpc^{-1}$

$1\,Mpc = 3.09 \times 10^{22}\,m$

$H = \frac{67.3 \times 1000}{3.09 \times 10^{22}}$

$= 2.18 \times 10^{-18}\,s^{-1}$

$t = \frac{1}{H}$

$= \frac{1}{2.18 \times 10^{-18}\,s}$

$t = 4.59 \times 10^{17}\,s$

$= 4.59 \times 10^{17} \div (365 \times 24 \times 3600)$

$= 14.5 \times 10^{9}$ years

→ 14.5 billion years

Universe is same in every direction

By **cosmological principle**:

on a large scale: → every part is same as the other part

universe is homogeneous

and

isotropic → every thing looks the same in every direction

∴ No centre no axis

(eg vizu)

EXPANDING UNIVERSE → (galaxies receding → $v \propto d$)

→ Spectra from galaxies all show red shift

↳ ∴ giving recessional velocity (v)

$V \propto d$ ← found by standard candles

$V = H_0 d$ ← Mpc

kms^{-1} ↑ Hubble's constant

→ Big Bang model

universe is expanding & cooling down

↳ going back in time → smaller & hotter

H_0 = hubble's constant

- ratio of the speed of recession of a galaxy due to expansion of the universe to its distance from the observer
- does not depend on direction

using balloon analogy → no centre of expansion

More on later parts

- isotropic → everything looks the same in every direction → no centre
- homogeneous → every part is the same as the other part

Big Bang model - Expansion of the Universe

- Cosmic Microwave Background Radiation (CMBR) - ~~Blue shifts~~] Evidence
- Amount of Helium in Universe H : He - evolution of galaxies
  - ↳ abundances of light elements 3 : 1

[nucleosynthesis in first 3 min]

[CMBR]:

$T_{uni} > 3000\,K$	$T_{uni} < 3000\,K$
photons continually scattered, absorbed & re-emitted by fog of free e⁻/s	no more free e⁻/s, photons able to travel freely thru the Universe

HBB (Hot Big Bang) predicts EM radiation was produced in early universe

↳ radiation should still be observed today

↳ ∵ expansion of universe → background radiation have been stretched and in the microwave region (red shifted)

high energy gamma radiation ($t \approx 300000$ years)

coming from all directions (Penzias & Wilson in 1960s)

↳ intensity is coming from all directions — isotropic & homogeneous

1992

from Satellite → Cosmic Background Explorer. redshifted $z \sim 1100$ & $T \sim 3000/1100$

COBE

peak λ → T = ~~2.73~~ 2.725 K

- confirm peak λ (λ_{max}) corresponds to black body temperature of 2.725K
  - ↳ expected if radiation is emitted after Big Bang when universe is small & hot

measured by angular power spectrum → measure how much structure there is in background on various scales

- fluctuation in temperature of the microwave background ($\delta T/T \sim 10^{-6}$)
  - originate from quantum effects?
  - ∵ tiny energy-density variations in the early Universe ; density cannot be completely uniform @ times

T & P ∝

needed for initial 'seeding' of galaxy formation by gravitational forces

- showing a ~~ok~~ Doppler shift: → Earth's motion through space

Andromeda shows blue shift

redshifted $z \sim 1100$

↳ Earth approaching Andromeda ∵ gravitational attraction

@ a million miles an hour

further planets stars have more redshifts

early universe fully ionized → photons were unable to travel far w/o being scattered by e⁻/s

↳ 380000 yrs after Big Bang, Temp dropped below $T \sim 3000\,K$

↳ H atom could form enabling photons to travel freely

↳ We see this thermal glow [last scattering surface]

Primordial Nucleosynthesis [PN]

For fixed density of baryonic matter
↳ all observed abundances for these light elements can be reproduced

Hydrogen & Helium abundances:

universe expands from the Big Bang → $n + p + \gamma$ plasm cools

Universe: - 25% Helium
- 73% Hydrogen
- 2% others

↳ PN occurs in first 3 min

↳ consistent with HBB model of ~~hydrogen formation~~ and fusion of hydrogen into Helium

which is primordial nucleosynthesis — forming 1H and fusing 2H to He

lightest elements such as H and He are formed: (170s after Big Bang)

↳ ∵ immense / high temp & helium

↳ H → He (for 3 min)

∴ H : He
3 : 1

high temp → fusion
H : He
3 : 1

elements are produced by fusion and dispersed across interstella medium by supernovae

↳ ∵ rapid expansion of Universe

↳ temp ↓↓ below those required to sustain fusion

- ∵ rapid expansion
↳ cools down → no fusion
No heavier elements
↳ formed

No heavier elements than Lithium are produced

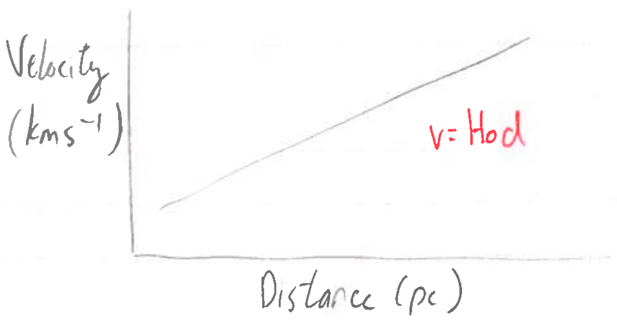
elements produced thru fusion in supernova
↳ spread by the fusion explosion

Expansion of the Universe

receding Doppler Shifts in 25 galaxies [by Slipher]

Made Hubble Diagram [1929 by Hubble]

1927 Lemaître
→ General Relativity permitted cosmic expansion and the linear relation



Again on Hubble's Law

H_0: → measures the rate of cosmic expansion

for more accurate measure

→ ~~exneeds~~ extend the velocity-distance relation as far as possible

because:

- Cannot resolve Cephied stars beyond 20Mpc
  ↳ ∵ become too faint for accurate period measurements
- galaxies have their own peculiar velocities [$w \sim 200\ kms^{-1}$]
  ↳ adds scatter to the Hubble diagram
  ~~Exce~~ EXCEPT @ Large distances where cosmic expansion velocity dominates

W adds more noise to the relation when $w \sim v$ at low d

@ large d, $v >> w$

Solution → using cosmic distance ladder:

- use Cephoids to get distances to $d \sim 20Mpc$
  & use them to calibrate luminosities of type I Supernovae
  ↳ seen to $d \sim 200\ MPc$

Results & Implication ...

$$\boxed{H_0 = 68\text{-}72\ kms^{-1}\ MPc^{-1}}$$

↳ for each extra MPc^{-1}, galaxies are receding $\sim 70\ kms^{-1}$ faster

Age of universe $T \sim 1/H_0$ (units of time)

☆ Assuming expansion is constant w/time [k's 全錯 ga]

$1MPc = 3.1 \times 10^{19}\ kms^{-1}$

$T \sim 4.4 \times 10^{17} s \sim 14\ Gyr$

☆ Expansion is isotropic

↳ everything Looks the same in every direction

↳ ☆ Value of H_0 does not depend on direction

every galaxy sees all the galaxies receding from it

∴ No centre of expansion

First Peak → Curvature:

* sound is relativistic in the dense plasma

↳ represents the sound horizon @ the last scattering surface

↳ close to 380000 light year in scale

↳ testing the overall geometry of the Universe

↳ SPACE is FLAT

curvature of space: constrains energy density of the Universe

- $\Omega_0 < 1$: Empty universe [open] → ~~+ve~~ -ve curved → hyperbolic
- $\Omega_0 = 1$: Critical density universe [closed] → flat space → flat
- $\Omega_0 > 1$: Overdense universe → +ve curved → spherical

---

Overall for CMBR

- confirm existence of Big Bang → evolutionary Universe
- detected level of density fluctuations → structures of stars galaxies
- determined a spatially-flat Universe → provide independent measures of other cosmological parameters

puzzles : - homogeneity & isotropy over the sky

↳ defies causality ∵ horizon scale is smaller

- why flat space? 'fine tuned'

∵ any departure from flatness would increase with time

- origin of density fluctuations

* proposing cosmological inflation [hypothesis]

↳ universe underwent rapid Inflationary period [$t \sim 10^{-36} - 10^{-32}$ sec]

↳ expand exponentially by $\times 10^{26}$

- explains :
  - homogeneity & isotropy → area of contact much larger than the horizon
  - space flat → enormous expansion
  - density fluctuations → smooths out naturally occuring quantum-scale fluctuations to ones we detect in EM CMBR