Physical Foundations of Biological Systems

1. Measurement and mathematical background

(a) Systems of units

- MCAT uses SI
- Other systems cgs, imperial
- There are base units & derived units

ex.

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

$$[G] = \frac{[F][r^2]}{[m^2]} = \frac{M L L^2}{T^2 M^2}$$

$$[G] = \frac{L^3}{M^2 T^2}$$

(b) dimensions

	Unit	abbrev	quantity/dimension	abbrev
base	meter	m	length	L
	kilogram	kg	mass	M
	second	s	time	T
	ampere	A	electric current	I
	candela	cd	luminous intensity	C
	mole	mol	amount of material	N
derived	meter/sec	m/s	velocity	L/T
	Newton	N	force	ML/T^2

(c) scientific notation

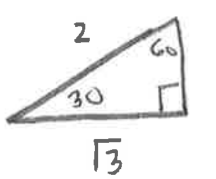
ex1 $5 \times 10^2 = 500$

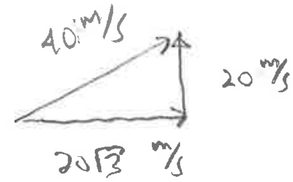
ex2 $(5\times10^2)(3\times10^4)(1\times10^{-1}) = 15\times10^5$
$= 1.5\times10^6$

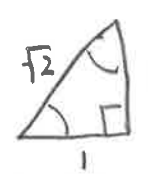
(d) scientific prefixes

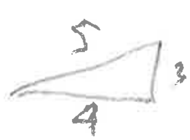
kilo	10^3
centi	10^{-2}
milli	10^{-3}
micro	10^{-6}
nano	10^{-9}

(e) trigonometry

ex1




ex2


ex3


(f) logarithms

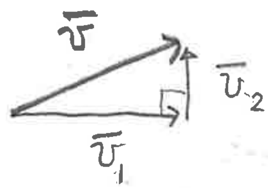
$10^0 = 1$
$10^1 = 10$
$10^2 = 100$

$\log_{10} 1 = 0 \quad (10^0 = 1)$
$\log_{10} 10 = 1 \quad (10^1 = 10)$
$\log_{10} 0.1 = -1 \quad (10^{-1} = 0.1)$

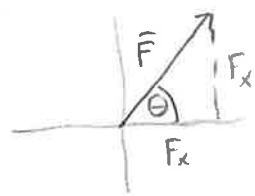
(g) vectors and scalars

mag & direction

mag.



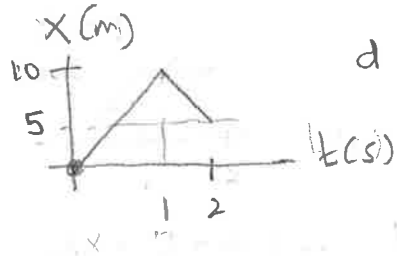
$\bar{V} = \bar{V}_1 + \bar{V}_2$



$F_x = F\cos\theta$
$F_y = F\sin\theta$

2. Motion (kinematics)

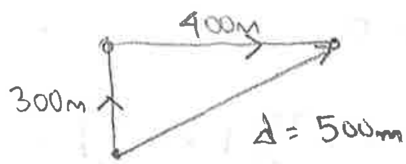
(a) displacement



$d = 5$ meters

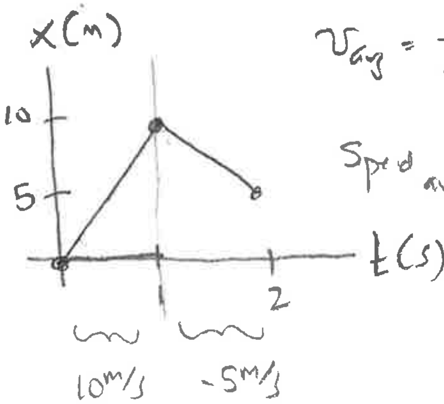
1D) d = final pos − init pos

2D)



(b) velocity

$$v_{avg} = \frac{\text{displacement}}{\text{time}} = \frac{\Delta x}{\Delta t}$$



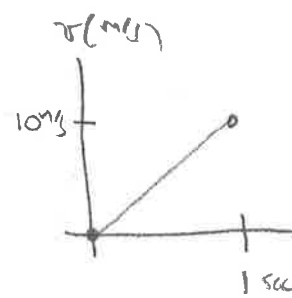
$v_{avg} = \frac{5\,m}{2\,s}$

$\text{Speed}_{avg} = \frac{15}{2} \frac{m}{s}$

speed is magnitude of velocity
it is never negative.

(c) acceleration

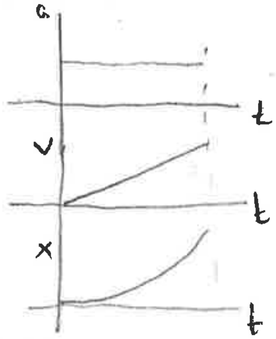
$$a_{avg} = \frac{\text{change in velocity}}{\text{time}} = \frac{\Delta v}{\Delta t}$$



t (s)

$a_{avg} = \frac{10\,m/s}{1\,sec} = 10\,m/s^2$

(d) constant acceleration



$a = \text{const}$

mean speed theorem } $x = \frac{1}{2}(v_{avg})t$

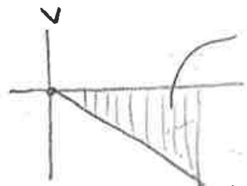
$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

} $v^2 = v_0^2 + 2ax$

(e) free fall motion

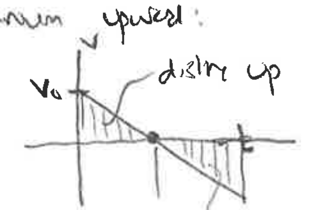
(ex1)



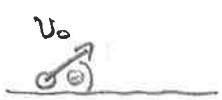
x = distance fallen = area of this triangle

$v = (-g)t$

(ex2) ball thrown upward:



(f) projectile motion



horiz	vert
$x = v_{ox}t$	$y = y_0 + v_{oy}t + \frac{1}{2}(-g)t^2$
$v_x = v_{ox}$	$v_y = v_{oy} + (-g)t$
$a_x = 0$	$a_y = -g$

Do free study problems Chap 2.1, 2.2, 2.3, 2.7

3. Newton's laws of motion (dynamics)

(a) definitions: mass, momentum, force

$p = mv$

force changes momentum

(b) Newtons' first law: the principle of inertia

If $F_{net} = 0$ then $\bar{p} = \text{const}$ and $\bar{v} = \text{const}$

(ex1) object falls in fluid has drag

term vel., $\Sigma F = 0$

Skip

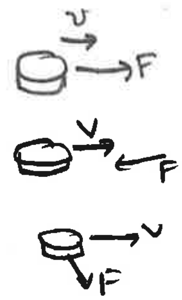
(c) Newton's second law: F=ma

$F_{net} = ma$

ex1 accelerates

ex2 decelerates

ex3 changes direction



(d) Newton's third laws: action/reaction pairs

$F_{1 on 2} = -F_{2 on 1}$

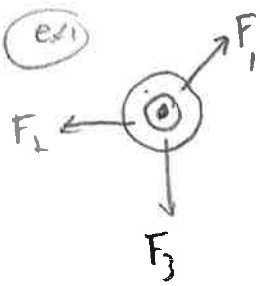
ex1

ex2

(e) Free body diagrams

$F_{net} = ma$

ex1



x) $F_{1x} + F_{2x} + F_{3x} = ma_x$

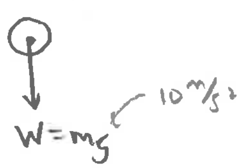
y) $F_{1y} + F_{2y} + F_{3y} = ma_y$

Once you find all forces, can find acceleration, velocity, position

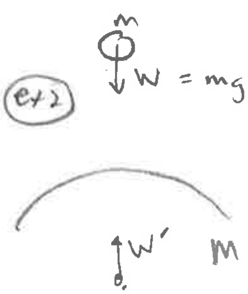
types of forces

(f) Force of gravity (weight)

ex1

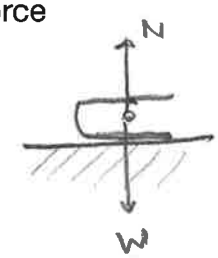


ex2 $W = mg = G\frac{mM}{r^2}$ g

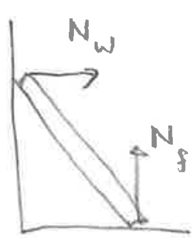


(g) Normal force

ex1



ex2



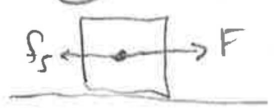
(h) Friction force

- friction force acts in opposite direction of movement

ex 1: as F increases, f_s increases while stationary

ex 2: while moving

$0 < f_s < \mu_s N$

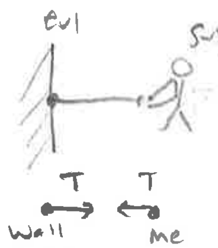


$f_k = \mu_k N$

(i) Tension force

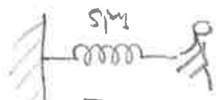
- force with which rope/cord/string pulls on what it's attached to

ex 1



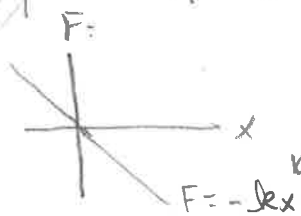
suppose I pull on rope.

(j) Spring force



suppose I pull on spring

- force exerted by spring on what it's attached to.

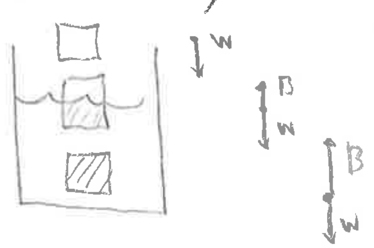


$F = -kx$

amount stretched (or compressed)

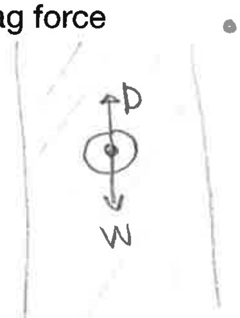
(k) Buoyant force

- force exerted by medium on submerged object



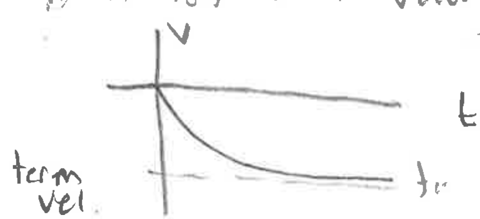
B = weight of fluid displaced (arch. principle)

(l) Drag force



- drag is exerted by fluid on moving object

- it increases with velocity



(m) Centripetal force

- force directed toward a point or toward a center

(n) Centripetal acceleration

- acceleration of object moving in a circle

$a_c = m\frac{v^2}{r}$

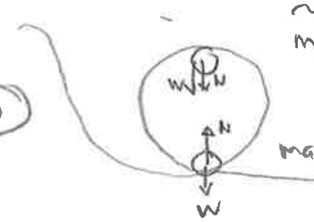
ex1

centrip force

$T = ma_c$

centrip accel

ex2



centrip accel force

$ma_c = N + W$

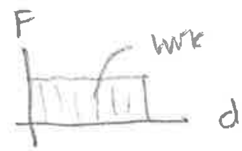
$ma_c = N - W$

Do Chap 3.1, 3.3, 3.4, 3.5, 4.4, 4.7 if time

4. Work and energy

(a) work done by a constant force

W = force × displacement



① use component of force in direction of disp

② if force is not const, find area

(b) work done by a non-constant force

- work done in compressing spring

$F = kx$ (Hooke's law)

$W = \frac{1}{2}(\text{base})(\text{height})$

$W = \frac{1}{2}(d)(kd) = \frac{1}{2}kd^2$

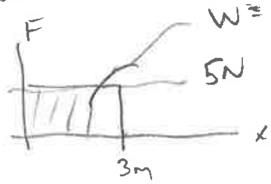
- the spring stores work as spring potential energy

(c) work-kinetic energy theorem

$KE = \frac{1}{2}mv^2$ = energy of motion

$W = KE_{final} - KE_{initial}$

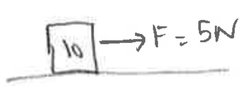
ex1



$W = 15\ N\cdot m = 15$ Joules

$15\ J = \frac{1}{2}m v_f^2 - 0$

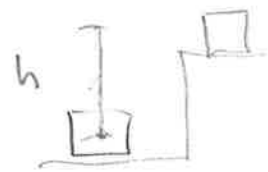
$3 = v_f^2$



$v_f = \sqrt{3}$ m/s

(d) work and potential energy

Doing work on something increases its KE or PE (or both)

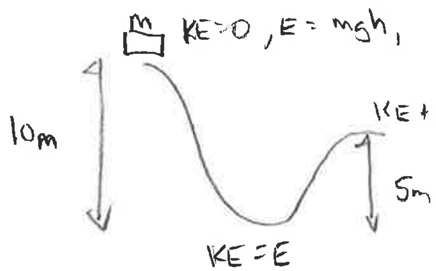


$W = F \times \text{displacement}$
$= mg \cdot h$

$\Delta PE = W = mgh$
$PE_{top} - \cancel{PE_{bot}}^{\,0} = mgh$

(e) conservation of energy

$E = \underbrace{KE + PE}_{\text{mechanical energy}} + (\text{other forms of energy})$



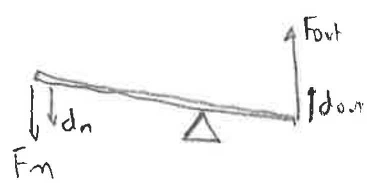
Do: Ex 5.5 later

(f) power

$\text{power} = \frac{\text{work}}{\text{time}}$: $\left(1\,\frac{\text{Joules}}{\text{second}} = 1\,\text{watts}\right)$

(g) machines and mechanical advantage

$\text{Work}_{in} = \text{Work}_{out}$



$F_{in}\, d_{in} = F_{out}\, d_{out}$

$F_{out} = F_{in}\left(\frac{d_{in}}{d_{out}}\right)$ ← mech advantage

Exercises 5.5

5. Linear momentum and collisions

(a) conservation of momentum

If there are no net external forces on a system of objects, then the total momentum of the system remains constant.

$P_{tot} = P_1 + P_2 + P_3 + \ldots = \text{constant}$

(b) elastic and inelastic collisions

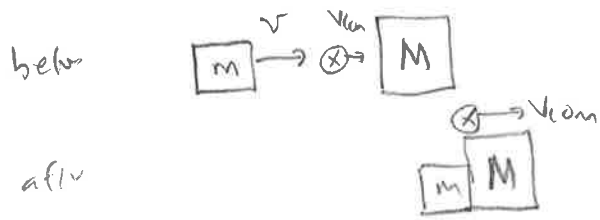
elastic: KE is conserved, p too

inelastic: KE is not conserved

(c) center of mass calculation

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$

(d) center of mass motion

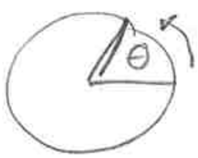


center of mass velocity does not change due to collision

Do Ex 5.6 (careful of units)

6. Rotational motion

(a) angular displacement



(b) angular velocity

$$\omega_{avg} = \frac{\Delta\theta}{\Delta t}$$

(c) angular acceleration

$$\alpha_{avg} = \frac{\Delta\omega}{\Delta t}$$

linear	angular
x	θ
v	ω
a	α
m	I
$p = mv$	$L = I\omega$
$F = ma$	$\tau = I\alpha$
$KE = \frac{1}{2}mv^2$	$KE_{rot} = \frac{1}{2}I\omega^2$

(d) rotational inertia

$$I = \beta M R^2$$

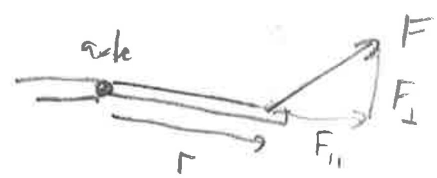
(e) angular momentum

$$L = I\omega$$

(f) torque

$$\tau = (\text{Force})_{\perp}(\text{lever arm})$$

perp. to lever arm



(g) rotational kinetic energy

$$KE_{rot} = \frac{1}{2}I\omega^2$$

(h) conservation of angular momentum

If net torque on a system is zero the angular momentum is conserved $L_{init} = L_{final}$

$L_1 = L_2$

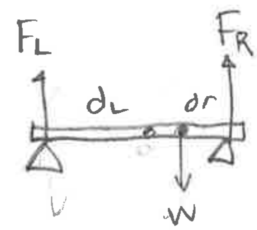
$I_1\omega_1 = I_2\omega_2$

7. Static equilibrium

(a) translational equilibrium

If $F_{net} = 0$ then $a = 0$

(b) rotational equilibrium



If $\tau_{net} = 0$ then $\alpha = 0$

$F_L + F_R = W$ ($F_{net} = 0$)

$F_L d_L = F_R d_R$ ($\tau_{net} = 0$)

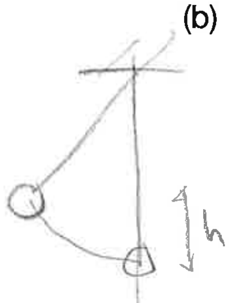
8. Oscillatory (periodic) motion

(a) angular frequency, frequency, and period of oscillation

T = period of 1 oscillation (sec)

$f = \frac{1}{T}$ ($\frac{1}{sec}$ or Hz), $\omega = 2\pi f$ ($\frac{rad}{sec}$)

(b) pendulum motion



$\omega = \sqrt{\frac{g}{L}}$, $f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$, $T = 2\pi\sqrt{\frac{L}{g}}$

$mgh = \frac{1}{2}mv^2$

(c) mass on a spring

$\omega = \sqrt{\frac{k}{m}}$, $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$

$\underbrace{\frac{1}{2}kd^2}_{\text{distant}} = \underbrace{\frac{1}{2}mv^2}_{\text{center}}$

★ Ex 9.1

9. Planetary motion and universal gravitation

(a) Kepler's first law

(b) Kepler's second law

(c) Kepler's third law

$\frac{T_1}{T_2} = \left(\frac{a_1}{a_2}\right)^{3/2}$

(d) Newton's universal law of gravitation

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

10. Fluids

(a) pressure measurement

$$P = \frac{\text{Force} \perp}{\text{area}}$$

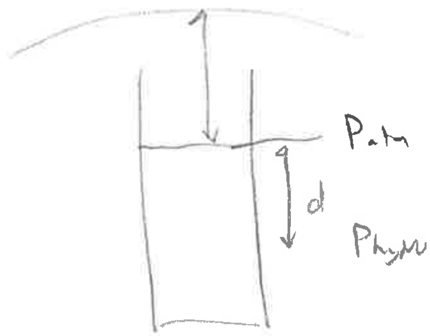
$$[P] = \frac{N}{m^2} = \text{Pascals}$$

$$1 \text{ Pascal} \approx 1 \times 10^5 \frac{N}{m^2}$$

Gauge pressure vs absolute pressure

(b) hydrostatic pressure

$$P_{abs} = P_{atm} + P_{hyd} = \rho g d$$



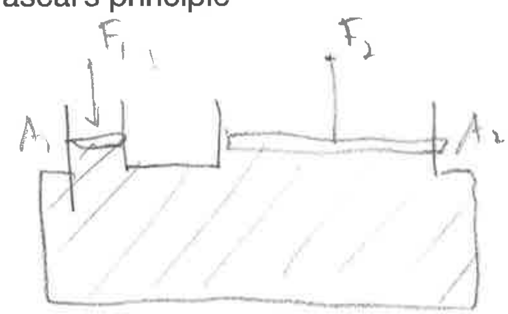
(c) Archimedes' principle

$$B = w_{disp}$$

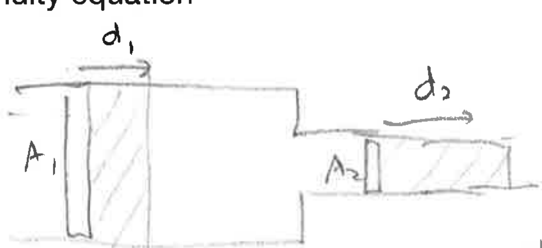
$$= m_{disp} g$$

$$= (\rho_f V_{disp}) g$$

(d) Pascal's principle



(e) continuity equation



$$\frac{A_1 d_1}{\Delta t} = \frac{A_2 d_2}{\Delta t}$$

$$\underbrace{A_1 v_1}_{} = A_2 v_2$$

volume flow rate is same!

(f) viscosity

tendency of fluids to cohere

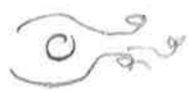
laminar drag $D = 6\pi\mu r v$ (for sphere moving thru fluid)

└ dynamic viscosity (Pascal-seconds)

(g) laminar flow, turbulent flow, and Reynolds number

not time dep.

streamlines don't cross

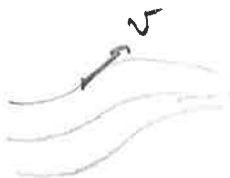


time dep.

$$R_e = \frac{\rho v L}{\mu} = \frac{\rho v L}{\nu}$$

└ kinematic viscosity

(h) Streamlines

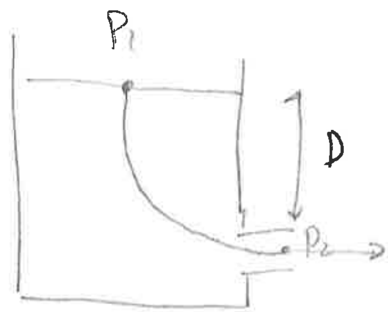


tangent to streamline indicates direction of fluid flow

(i) Bernoulli's equation

for ideal fluid
- incompressible
- negligible viscosity
- laminar, steady

$$\rho g y_1 = \frac{1}{2}\rho v_2^2 + \rho g y_2$$



$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = \text{const}$$

Torricelli's law $v_2 = \sqrt{2gD}$

(j) elastic solids: young's modulus, shear modulus, bulk modulus

$$Y = \frac{(F/A)}{(\Delta L/L)} \quad \frac{\text{stress}}{\text{strain}}$$

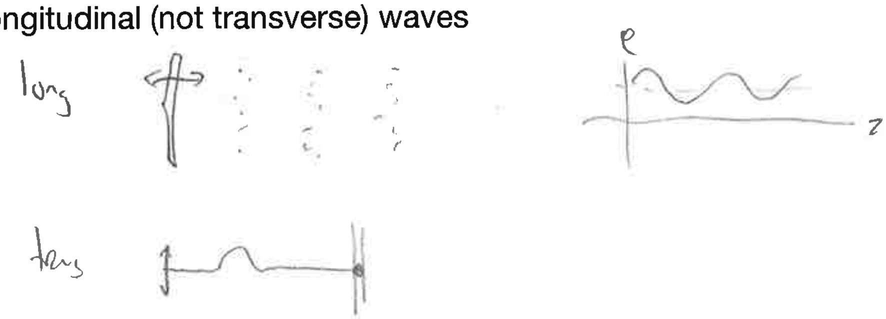
$$B = \frac{(F/A)}{(\Delta V/V)}$$

$$S = \frac{(F/A)}{(x/h)}$$

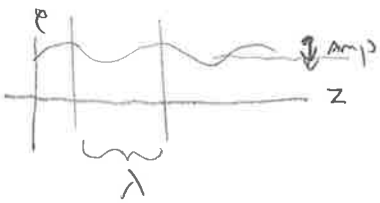
* PS Ex 6.3, 6.4, 6.5

11. Sound

(a) longitudinal (not transverse) waves



(b) amplitude and volume



330 m/s

$v = \lambda f$

(c) frequency and pitch

(d) wavelength, frequency, and speed

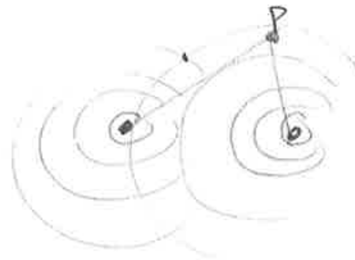
(e) intensity of sound and the decibel scale

$\text{Intensity} = \frac{\text{power delivered}}{\text{area}} \quad \left(\frac{\text{Watts}}{m^2}\right)$

[If $I = 100 I_0$ then 20dB]

sound level $\beta(dB) = 10 \log_{10}\left(\frac{I}{I_0}\right)$, I_0 = hearing threshold $= 1\times10^{-12} \frac{W}{m^2}$

(f) superposition principle



Const int.

dest. int.

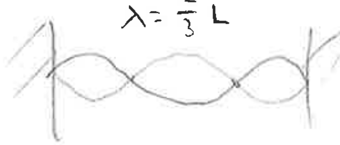
(g) traveling waves vs standing waves

$\lambda = L$

$\lambda =$

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

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



(h) doppler effect

$$f' = f\left[\frac{V \pm V_{DET}}{V \pm V_{SOURCE}}\right]$$

perceived freq

frequency of source

V_{DET} = speed of detector wrt medium

V_{SOURCE} = " " source wrt medium

EX 10.4, 10.6 Doppler

12. Thermodynamics

(a) temperature scales

$T_C = T_K - 273$

$T_F = \frac{9}{5} T_C + 32$

	K	C	F
abs zero	0	-273	-460
water freeze	273	0	32
water boil	373	100	212

(b) thermal expansion

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

coeff of lin. expansion

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

coeff of volume exp

(c) heat capacity

$$C = \frac{\Delta Q}{\Delta T}$$

$$\Delta Q = m \underset{\text{sp. heat cap}}{c} \Delta T$$

(d) conduction, convection and radiation of heat

cond: direct transfer of heat thru contact

conv: transfer of heat via motion of material

rad: transfer of heat via em waves

(e) latent heat

L = latent heat of transformation

fusion (liq $\leftrightarrow$ sol)

vaporization (gas $\leftrightarrow$ liq)

(f) heat, work and the first law of thermodynamics

$$\underbrace{\Delta U}_{\text{change in internal energy of system}} = \underbrace{Q}_{\text{heat delivered to system}} - \underbrace{W}_{\text{work done by system}}$$

(g) adiabatic process

$$Q = 0 \Rightarrow \Delta U = -W$$

(h) isothermal process

$\Delta T = 0$

(i) isochoric process

$\Delta V = 0$

(j) isobaric process

$\Delta P = 0$

(k) closed cycle process

$\Delta U = 0 \Rightarrow Q = W$

(l) ideal gas equation of state

$PV = nRT$ # moles

$PV = NkT$

atm

(m) real gas/van der wals equation of state

(n) partial pressure

$$P = P_1 + P_2 + \dots$$

(o) entropy and the second law of thermodynamics

$$\underbrace{\Delta S}_{\text{change in entropy of system}} = \frac{Q}{T}$$

Q ← heat added to system

T ← temperature of system as heat is added

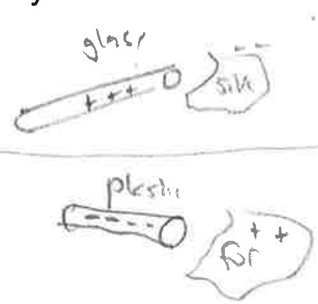
(p) heat engines and efficiency

$$\eta = \frac{\text{work done}}{\text{heat transferred}}$$

13. Electrostatics

(a) positive and negative electricity

⊕ vitreous



proton $+1.6 \times 10^{-19}$ Coulomb

⊖ resinous

electron -1.6×10^{-19} Coulomb

(b) triboelectricity and charge separation

See above

triboelectricity ⟹ separation of charge by friction

(c) conservation of electric charge

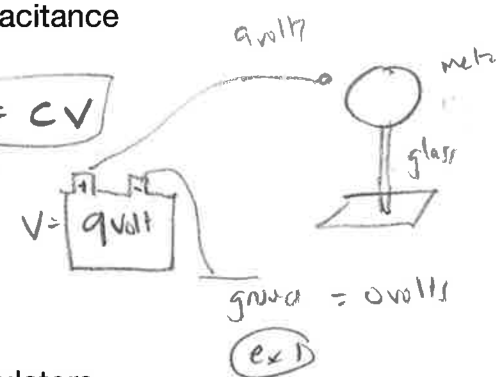
See above

(d) storing charge: capacitance

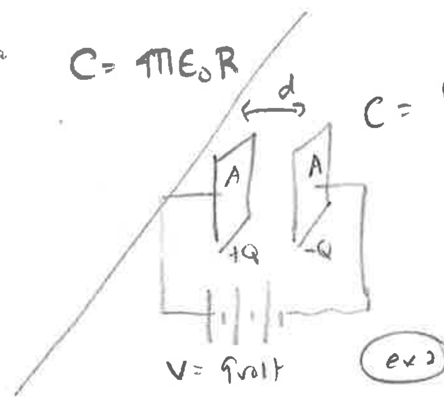
$[C] = \text{Farads}$

$\boxed{Q = CV}$

$1 \text{ pico Farad} = 1 \times 10^{-12} \text{ F}$

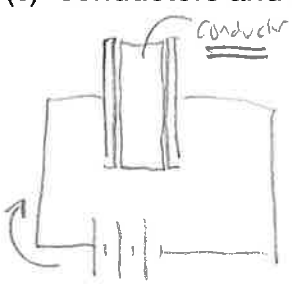


$C = 4\pi\epsilon_0 R$



$C = \frac{\epsilon A}{d}$

(e) conductors and insulators



conductor allow elect current to flow (with some resistance)

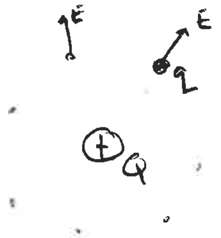
insulator prevents electrical current from flowing up until breakdown voltage.

gets polarized

(f) coulomb's law

$$F = k\frac{q_1 q_2}{r^2}, \quad k = \frac{1}{4\pi\epsilon_0}, \quad = 9\times10^{9}\ \frac{Nm^2}{Coul^2}$$

(g) electric fields



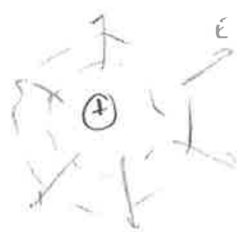
$$\boxed{E_Q = \frac{F_{Qq}}{q}} = \frac{k\frac{Qq}{r^2}}{q} = \frac{kQ}{r^2} \quad \left(\frac{\text{Newt}}{\text{Coul.}}\right)$$

$$\boxed{F_{Q\,\text{on}\,q} = E_Q\, q} \quad (\text{Newtons})$$

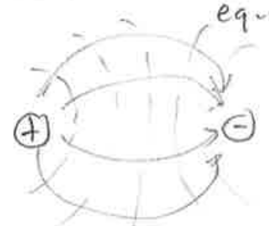
(h) electric potential

Potential of point

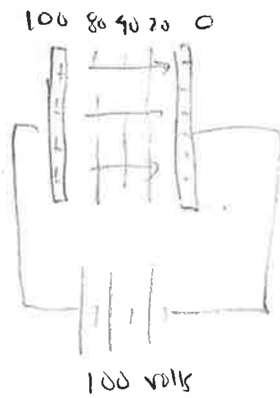
$$\boxed{V_Q = \frac{kQ}{r}}$$



equipotentials of dipole



units are $[V] = \frac{\text{Joules}}{\text{Coulomb}}$



(i) electric potential energy

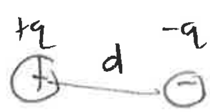
$$\boxed{\Delta U = q\,\Delta V}$$

change in elect pot. energy

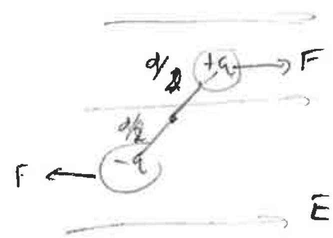
move charge through

difference in voltage

(j) electric dipole moment



$$p = qd$$



$$\tau_{total} = \tau_1 + \tau_2$$

Ex 7.1, 7.3, 7.4, 7.5, 7.6, 7.7

14. Electronic circuits

(a) electric current

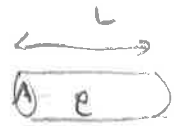
$$i = \frac{\Delta q}{\Delta t}$$

the direction of flow of ⊕ charge

(b) resistance and resistivity

$$R = \frac{\rho L}{A}$$

resistance (Ohms)



$\rho =$ resistivity $\left(\frac{\text{Ohms}}{\text{meter}}\right)$

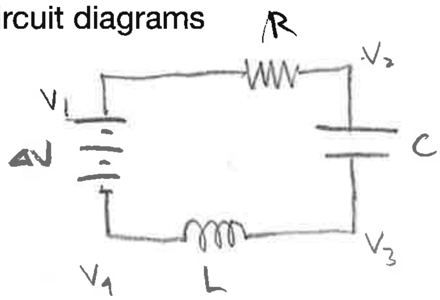
$\rho = \rho(T)$

metals $T\uparrow$ $\rho\uparrow$

semi $T\uparrow$ $\rho\downarrow$

(c) insulators, conductors, semiconductors, superconductors

(d) circuit diagrams



(e) voltmeters and ammeters

voltmeters measure difference in voltage

ammeters measure electrical current

(f) ohm's law

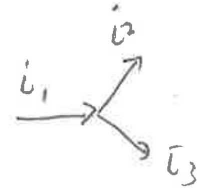
$$\Delta V = IR$$

(g) Kirchoff's circuit rules

electric potential (voltage) sign valued

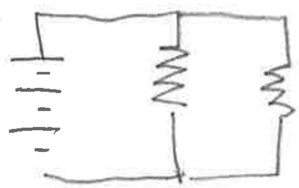
1) $\sum_i (\Delta V)_i = 0$

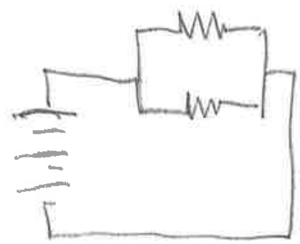
2) at junction $i_{in} = i_{out}$



$i_1 = i_2 + i_3$

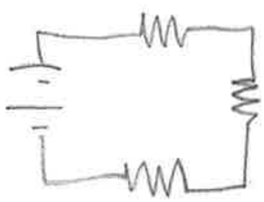
(h) resistors in parallel





$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

(i) resistors in series



$$R_{eq} = R_1 + R_2 + R_3$$

(j) joule heating of a resistor

$$P = IV$$

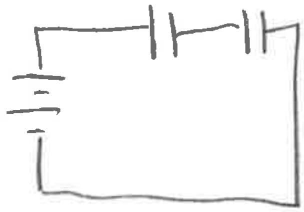
$$= I\,IR = I^2 R$$

$$= \frac{V}{R} V = V^2/R$$

(k) capacitors in parallel

$$C_{eq} = C_1 + C_2$$

(l) capacitors in series



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

(m) energy stored in a capacitor

$$U = \frac{1}{2} C V^2$$

(n) capacitors with dielectrics

$$\epsilon = \epsilon_0 K$$

$$C' = KC$$

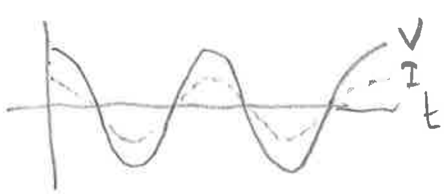
K – dielectric constant , ceramic $K = 2$

$$C = \frac{\epsilon A}{d}$$

$$C' = \frac{\epsilon A}{d}$$

$$C' = KC$$

(o) alternating current and rms voltage

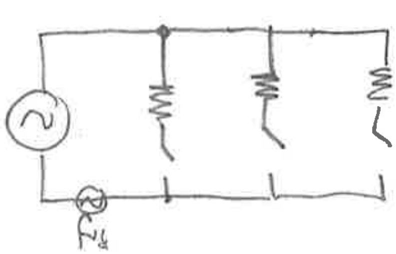


60Hz

$$V_{RMS} = \frac{V_{max}}{\sqrt{2}}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

(p) household wiring



EX 8.3, 8.4, 8.5

15. Magnetism

(a) terrestrial magnetism and magnetic poles

$[B]$ = Tesla $\quad 1T = 1 \frac{N \cdot s}{mC} = 10^4$ gauss

(b) diamagnetic materials

materials with no unpaired electrons

so no net B field

wood, plastic, glass • weakly Repelled by perm magnets due to induced currents in atoms

(c) ferromagnetism, paramagnetism, Curie temperature

- have unpaired electrons.
- possess net magnetic dipole moment
- randomly oriented ordinarily

Al, Cu, Au • paramagnetic (align with external field). Attracted toward magnets! weakly

Fe • ferromagnetic (spontaneously aligned. Strongly attracted to magnets.

(d) hard (hight coercivity) magnets and soft (low coercivity) magnets

ceramics

SmCo

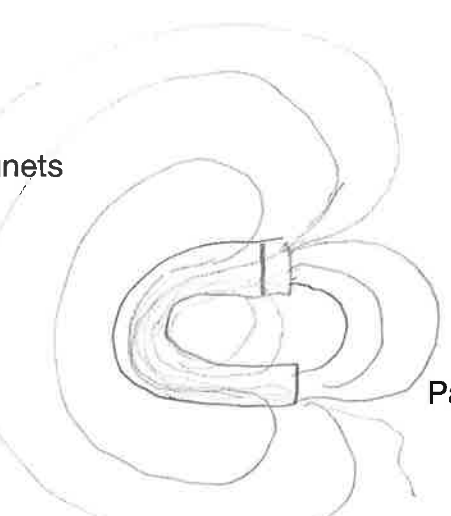
Nd

Fe

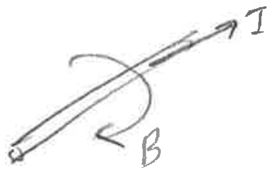
Ferromagnets are paramagnets above Curie temperature (1043K for Fe)

(e) magnetic fields near permanent magnets

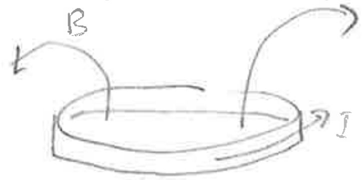
loops

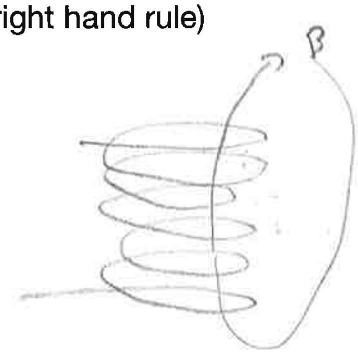


(f) magnetic fields near wires, loops and helices (1st right hand rule)



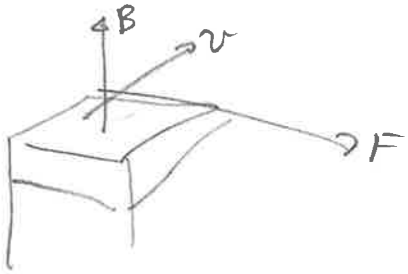
$$B = \frac{\mu_0 I}{2\pi r}$$





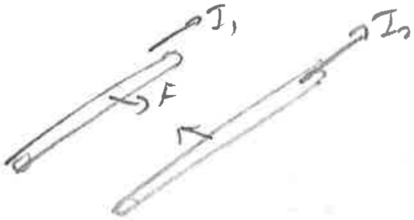
$$B = \mu I\left(\frac{N}{L}\right)$$

(g) magnetic (lorentz) force on moving charges (second right hand rule)



$$F = qv(B \sin\theta)$$

(h) magnetic force on current-carrying wires



$$\frac{F}{L} = IB$$

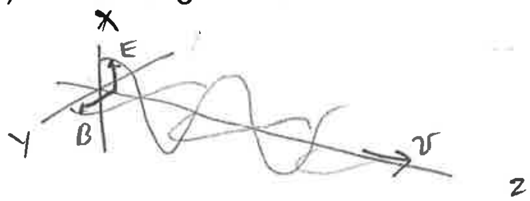
(i) the discovery of the electron

(j) mass spectroscopy

EX 8.1, 8.2

16. Light

(a) electromagnetic waves



gamma 0.01 nm

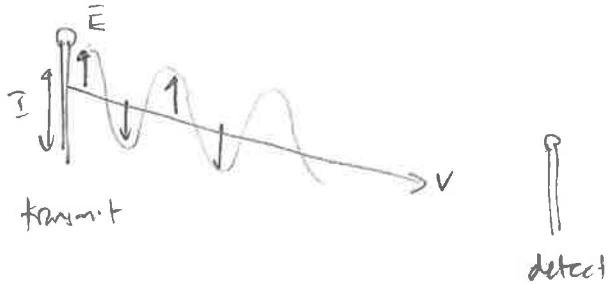
x-ray 0.1 nm

vis 400-700 nm

IR 10 μm

μwave 0.1 cm

(b) producing and detecting electromagnetic waves: antennae and atoms



(c) speed of light and refractive index

$c = \lambda f$

$v = \frac{c}{n}$ ← ref. index of material

$n = 1$ in vac

$n \gtrsim 1$ in air

$n \approx 1.3$ in ice

$n \approx 1.5$ in glass

(d) frequency, color and the visible spectrum

frequency ⇒ color

(e) geometric optics: the ray approximation

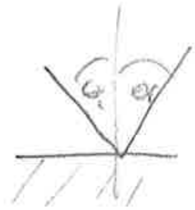
treat waves like rays.

Ignore they are waves.

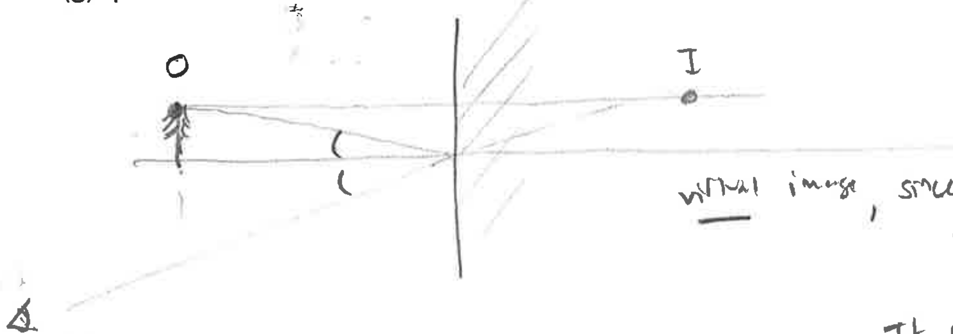
Good for much of optics

(f) law of reflection

$\theta_i = \theta_r$



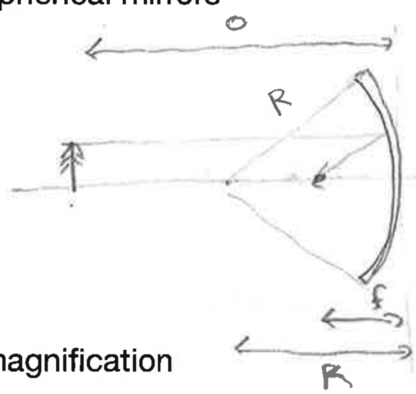
(g) plane mirrors



virtual image, since no light actually comes from location of image.

It only appears to.

(h) spherical mirrors



$f = \frac{1}{2} R$

$$\boxed{\frac{1}{o} + \frac{1}{i} = \frac{1}{f}} = \frac{2}{R}$$

{Concave mirrors are converging (r +)
Convex mirrors are diverging (r −)

{Can use this eqn to compute image distance for lenses & mirrors!}

i	image	location
+	real	in front of mirror
−	virtual	behind mirror

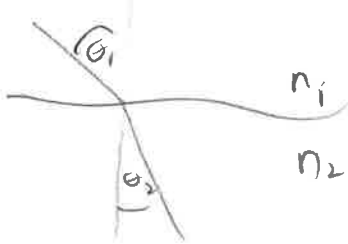
(i) magnification

$m \equiv \frac{-i}{o}$

$\lvert m \rvert$	image
< 1	reduced
> 1	enlarged

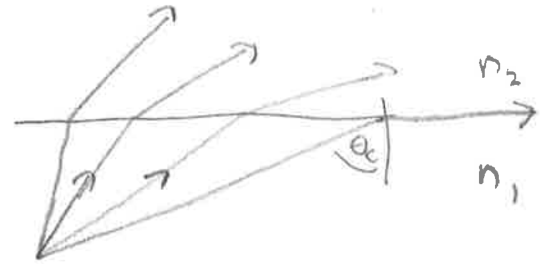
(j) law of refraction

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

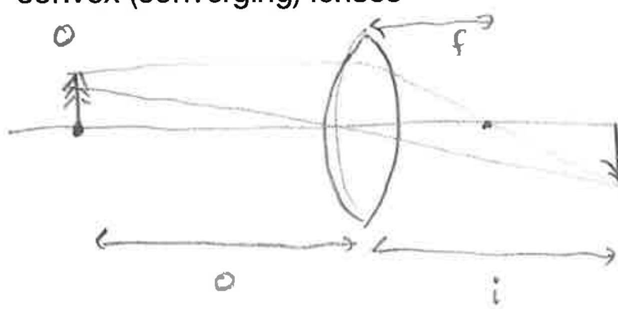


(k) total internal reflection

If $\theta_2 = 90°$
then total int. ref.



(l) convex (converging) lenses



$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$m = \frac{-i}{o}$$

(m) concave (diverging) lenses

Symbol	positive	negative
o	object on side of lens light coming from (V)	object on side of lens light going to
i	image on side of lens light going to	image on side of lens light coming from
f	converging lens	diverging lens
m	image erect	image inverted
r	when on R side (convex as seen from side light coming from)	when on V side (concave when seen from side light coming from

(n) thin lens equation

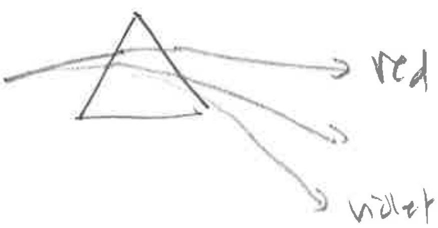
(o) human eyes

nearsighted (need diverging corrective lens)

farsighted (need converging corrective lens)

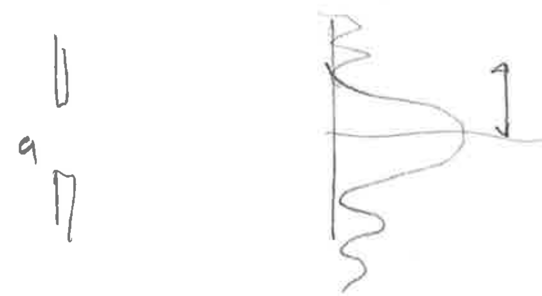
(p) telescopes

(q) dispersion of light (prisms and rainbows)



$n = n(\lambda)$

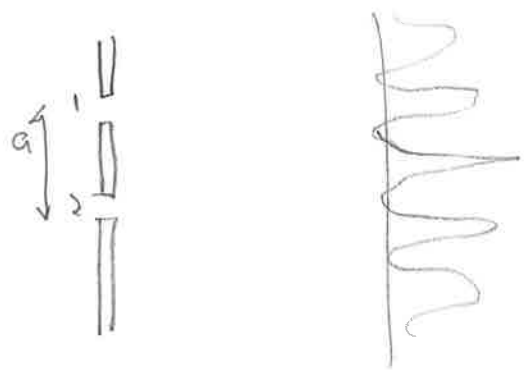
(r) diffraction of light



minima at

$a \sin\theta_n = n\lambda$

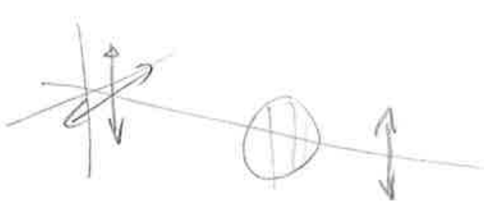
(s) interference of light



maxima at

$a \sin\theta_n = n\lambda$

(t) polarization of light



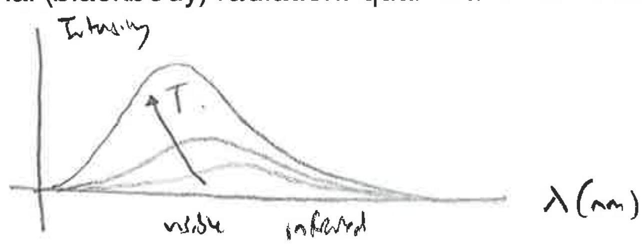
(u) scattering of light

Ex 11.2, 11.3, 11.5

17. atomic phenomena

(a) atomic emission and absorption spectra

(b) thermal (blackbody) radiation: quantization of energy



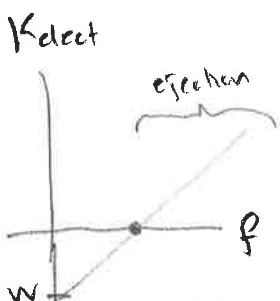
heated solids emit light

Stefan Boltzmann Law

Intensity $= \sigma T^4$

Wien's displacement law $\lambda_{peak} T = \text{const}$

(c) photoelectric effect: quantization of light



$h = 6.63 \times 10^{-34}$ J·s

$E_\gamma = hf = h\frac{c}{\lambda}$

$K_{electron\ max} = hf - W$

work function

(d) Davisson-Germer experiment: wave particle duality

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

ptcl momentum

ptcl wavelength

If waves act like ptcls, ptcls act like waves, too!

(e) Bohr model of the atom: quantization of energy levels

ionized

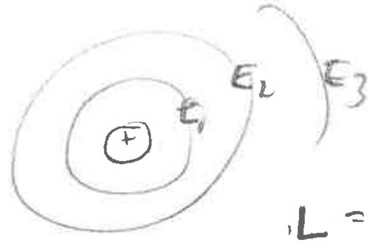
$$E_n = \frac{-13.6\,eV}{n^2}$$

$E_\infty = 0$

E_3

E_2

$E_1 = -13.6eV$



$L = n\hbar = n\frac{h}{2\pi}$

(f) emission and absorption of light from atoms

E_3

E_2

$E_\gamma = hf = E_3 - E_2$

(g) electron spin and the pauli exclusion principle

(h) the building-up principle and the periodic table

No 2 electrons can have same 4 quantum #s

n = princ. quant # $(n \geq 1)$

l = azimuthal quant # (up to $n-1$)

m_l = mag. quant # $(-l, \ldots 0 \ldots +l)$

m_s = spin quant # $(\pm\frac{1}{2})$

18. nuclear phenomena

(a) atomic number and mass number

Atomic number Z = # protons in nucleus

Mass number A = total # nucleons

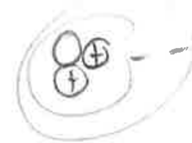
$^{4}_{2}He$

$A = \underbrace{Z}_{protons} + \underbrace{N}_{neutrons}$ $\qquad ^{A}_{Z}X$

(b) isotopes

$^{4}_{2}He$ He-4 isotope

$^{3}_{2}He$ He-3 isotope (rare)



(c) atomic mass units

$1 \text{ amu} = \frac{1}{12}$ mass of $^{12}_{6}C$ atom

$1 \text{ amu} \approx 1.66 \times 10^{-24}$ grams

$m_{elec} \approx \frac{1}{2000} m_{proton}$

$^{1}_{1}H$ proton hydrogen

$^{2}_{1}H$ deuterium

$^{3}_{1}H$ tritium

(d) binding energy and mass defect

- every atomic nucleus has a smaller mass than the sum of its constituent parts
- difference is called <u>mass defect</u>

$E = mc^2$

mass defect

energy released upon forming nucleus of atom

(e) nuclear reactions: fusion

$^{2}_{1}D + ^{3}_{1}T \rightarrow ^{4}_{2}He + ^{1}_{0}n$

$^{4}_{2}He$ constituents have $m = 4.03390$ amu

$^{4}_{2}He$ has mass $m = 4.00260$ amu

$\Delta m = 0.02930$ amu

$\Downarrow$

binding energy 27.3 MeV

(f) nuclear reactions: fission

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U$

$\rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2\,^{1}_{0}n$

(g) alpha decay helium emission

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + \alpha$$

α = ${}^{4}_{2}He$

(h) beta decay electron or positron emission

$${}^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + \beta$$

β = e^-

neutron → proton + electron

or

proton → neutron + positron

(i) gamma decay high-energy γ-ray emission

$${}^{A}_{Z}X' \rightarrow {}^{A}_{Z}X + \gamma$$

X' = excited state

(j) radioactive decay half life

$T_{1/2}$ = time it takes for $\frac{1}{2}$ of nuclei to undergo radioactivity decay

Ex) If half life is 1 years then in 4 years there will be $(\frac{1}{2})(\frac{1}{2})(\frac{1}{2}) = \frac{1}{8}$ left.

(k) exponential decay

$$\underbrace{\frac{\Delta n}{\Delta t}}_{\text{decay rate}} = -\lambda \underbrace{n(t)}_{\text{number at time } t}$$

λ = decay constant

$$n(t) = n_0 e^{-\lambda t}$$

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