PHYSICS

physics

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TEXTBOOKS QUESTION DIFFICULTY
easy → hard

WACE
textbook
STAWA

do 10 questions then assess if you understand, then move on

EQUATIONS

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

$s = ut + \frac{1}{2}at^2$ ← don't try to solve unless $u = 0$

$v = u + at$

$v^2 = u^2 + 2as$ ← only one without t

UNITS

work = Joules
power = watts
mass = kg
force = N
impulse = N·S
momentum = $kgms^{-1}$

$PE = mgh$
$KE = \frac{1}{2}mv^2$
$F = ma$
conservation of momentum = $m_1u_1 + m_2u_2 \ldots = m_1v_1 + m_2v_2 \ldots$

impulse, time, Force:
$\Delta p = F\Delta t$

mass, momentum, velocity:
$p = mv$

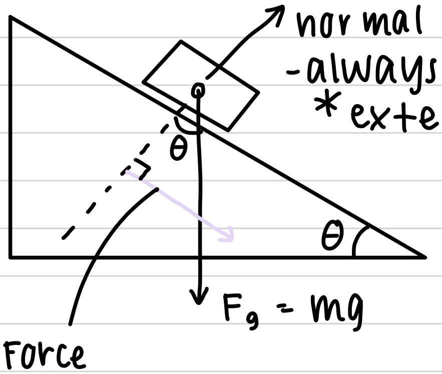
work, force, displacement:
$W = Fs$
or
$W = Fs\cos\theta$ (incline)

power, work, time:
$P = \frac{W}{t} = \frac{\text{change in energy}}{\text{time}}$
or
power, Force, velocity:
$P = Fv$

elevators

$N = ma$ ← (F)
$W = mg$
$F_{net} = W - N$

inclined planes



normal force/reaction force
-always ⊥ to the surface
*extend down/backwards

BEAT FREQUENCY

$f_B = f_2 - f_1$

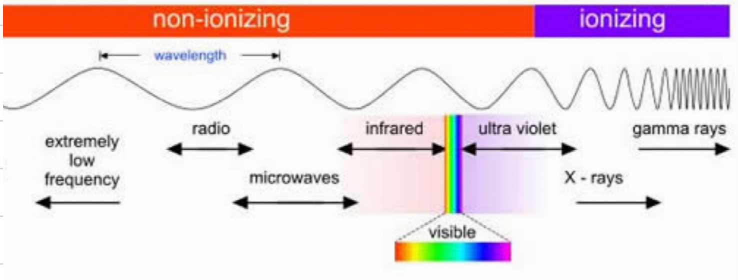
NUCLEAR

RADIATION - WHAT IS IT?

- the emission of energy as electromagnetic waves or as moving subatomic particles

non-ionizing radiation is low energy electromagnetic radiation

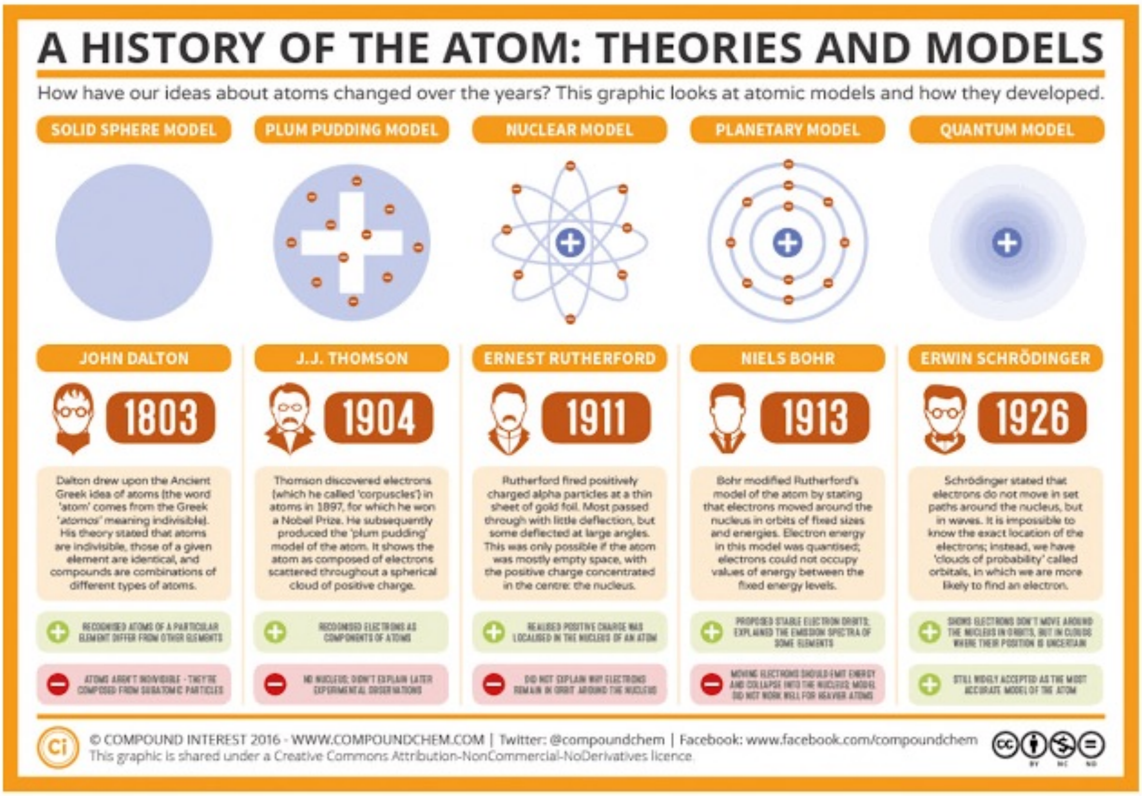
ionizing radiation is high energy radiation that can affect the electrons surrounding an atom so that a charged ion is formed



THE 2 KINDS OF BACKGROUND RADIATION

- terrestrial radiation
- cosmic radiation

ATOMIC THEORY



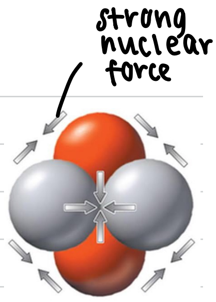
WHAT HOLDS A NUCLIDE TOGETHER?

there are 4 fundamental forces

strong | weak | electrostatic | gravitational

strong: acts to hold nucleons together against the force of electrostatic repulsion

STABILITY OF NUCLIDES



- protons and neutrons are tightly packed into the nucleus
- the positive charges should repel each other, but they don't
- nuclear force keeps protons and neutrons stuck together in the nucleus
- it is 100 times stronger than the repulsive electric force between the protons
  - ↳ the nuclear force is a short range force (only acts over a short distance)
- the larger the nucleus, the less tightly the protons and neutrons are held together (because distance between them has increased)
- when the nuclear force is sufficiently strong, the nuclide is stable
  - ↳ otherwise the nuclide is unstable and will emit radiation

Unstable atoms are radioactive and an individual radioactive isotope is known as a radioisotope

WORKSHEET: ALPHA, BETA AND GAMMA RADIATION

ALPHA, BETA AND GAMMA RADIATION

BACKGROUND INFORMATION

mass # / charge symbol

	Symbol
Proton	(lowercase) $^{1}_{1}p$
Neutron	$^{1}_{0}n$
Electron/ positron	electron $^{0}_{-1}e$ / positron $^{0}_{1}e$

mass (nucleon) number

$$^{A}_{Z}X$$

element symbol

Atomic (proton) number

An unstable isotope - a radioisotope - may spontaneously decay, emitting a particle from the nucleus. During this process of radioactive decay, three different forms of nuclear radiation may be released. These are alpha (α), beta (β) or gamma (γ) radiation.

→ chuck something out of the nucleus

Alpha Decay $^{4}_{2}\alpha$

- ☐ Positively charged chunk of matter consisting of 2 protons and 2 neutrons ejected from the nucleus of a radioactive atom.

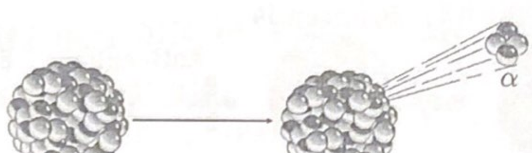
- ☐ Is identical to a helium nucleus and can be written as:

alpha symbol

$^{4}_{2}He^{2+}$, α^{2+}, $^{4}_{2}\alpha$ or simply α

Example of alpha decay:

A common source of alpha radiation is Uranium – 238



Uranium - 238
92 protons
146 neutrons

Thorium - 234
90 protons
144 neutrons

alpha = $^{4}_{2}\alpha$
beta^{-} = $^{0}_{-1}\beta$
beta^{+} = $^{0}_{1}\beta$
gamma = $^{0}_{0}\gamma$

$^{1}_{1}x$ proton $^{1}_{0}y$ neutron $^{0}_{-1}z$ electron $^{0}_{+1}w$ positron

WORKSHEET: ALPHA, BETA AND GAMMA RADIATION

In this process Uranium changes to a new element Thorium-234. We can represent this alpha decay by the following equations:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha + \text{energy}$$

or

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

In any radioactive decay charge is conserved (seen as a conservation of atomic number). For example $92 = 90 + 2$. The number of nucleons is also conserved. For example $238 = 234 + 4$.

Beta Decay ${}^{0}_{-1}\beta$

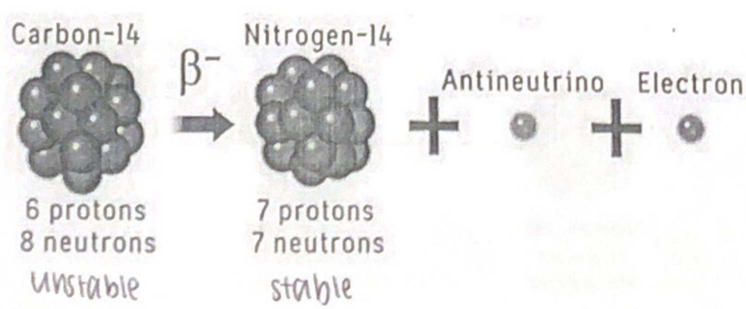
- ☐ Beta particles are electrons that have originated from the nucleus of a radioactive atom, **NOT from the electron cloud.** A beta particle can be written as: ${}^{0}_{-1}e$, β, β^{-1} or ${}^{0}_{-1}\beta$
- ☐ The atomic number of -1 indicated that it is a single negative charge, and a mass number of zero indicates that its mass is insignificant in comparison to the mass of a neutron or proton.
- ☐ Beta decay occurs in the nuclei where there is an imbalance of neutrons to protons. Typically, if a light nucleus has too many neutrons to be stable, a neutron will spontaneously change into a proton, and an electron and an uncharged massless particle called an antineutrino (v) are ejected to restore the nucleus to a more stable state.

symbol = $\bar{\nu}$ → = anti

${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$

neutron → proton + elec

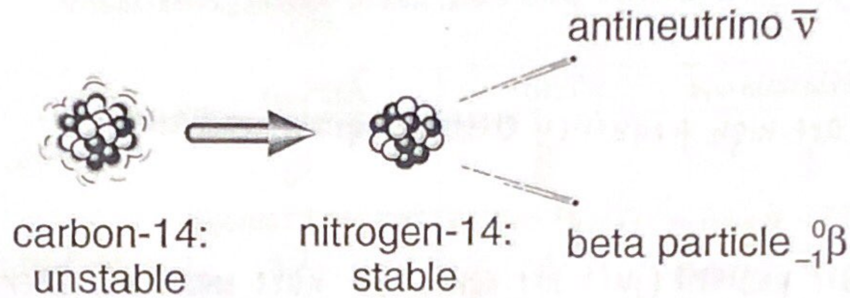
creat to balan



WORKSHEET: ALPHA, BETA AND GAMMA RADIATION

Example of beta decay:

A common source of beta radiation is Carbon – 14.



The nucleus of Carbon - 14 is unstable. In order to achieve stability, one ___neutron___ transforms into one ___proton___, and an ___electron and antineutrino___ are emitted in the process. The emitted electron is the ___beta particle___ and it travels near the speed to light.

The nuclear equation for this decay is:

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + \bar{\nu} + \text{energy}$$

The transformation taking place in the nucleus is:

$$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \bar{\nu}$$

Atomic and Mass number are still conserved

BETA ~~positive~~ DECAY

- beta particles may also be positrons (anti-electrons) e^+
- results when an unstable isotope has too few neutrons compared to their number of protons

EXAMPLE:

$$^{23}_{12}Mg \longrightarrow {}^{23}_{11}Na + {}^{0}_{+1}e + {}^{0}_{0}\nu$$

neutrino
*not an anti-neutrino hence no 'hat' $\bar{\nu}$

WORKSHEET : ALPHA, BETA AND GAMMA RADIATION

Gamma Decay γ

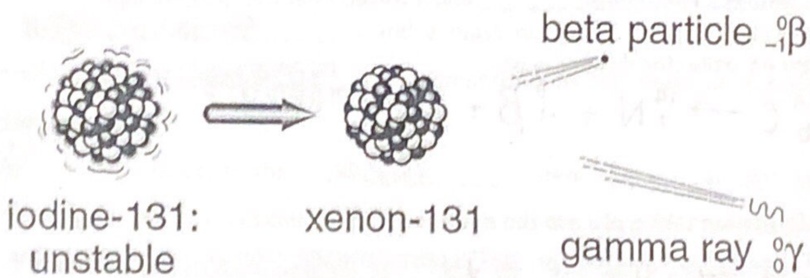
When a nuclide undergoes either an alpha or beta decay it is often left with an excess of energy. The nucleus achieves a normal energy state by releasing gamma radiation.

Gamma radiation rays:

- ☐ are high frequency electromagnetic radiation
- ☐ are photons (just like light) and have no mass or charge
- ☐ ~~There~~ Their symbol is: ${}^{0}_{0}\gamma$

Example of a gamma ray emitter:

A common source of gamma radiation is Iodine – 131



The equation for this decay is:

$${}^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e + \gamma$$

beta particle

gamma radiation

* will have an anti-neutr

or

$${}^{131}_{53}I \xrightarrow{\beta\gamma} {}^{131}_{54}Xe$$

means it is unstable (is a gamma emitter)

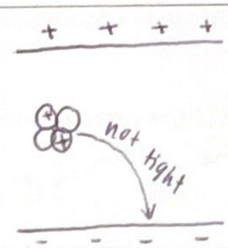
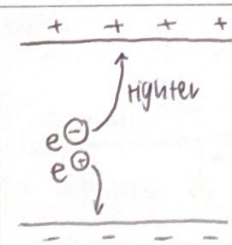
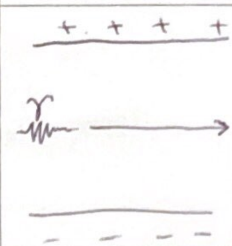
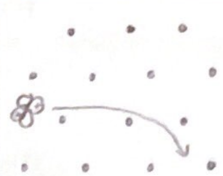
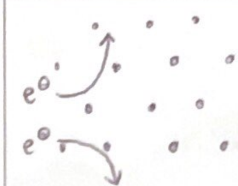
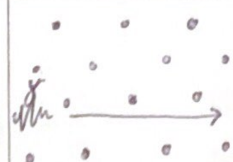
$${}^{99m}_{43}Tc \longrightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

or

$${}^{99*}_{43}Tc \longrightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

WORKSHEET: ALPHA, BETA AND GAMMA RADIATION

PROPERTIES OF ALPHA, BETA AND GAMMA RADIATION

	ALPHA	BETA	GAMMA
SYMBOL	α	β	γ
CHARGE	2 protons, 2 neutrons +2	electron (β negative) -1	electromagnetic radiation 0
MASS	4	0	0
PENETRATING POWER	low stopped by paper	moderate stopped by aluminium	high stopped by lead
IONISING POWER	high	moderate	low
PATH THROUGH AN ELECTRIC FIELD			
PATH THROUGH A MAGNETIC FIELD			
WHAT IS IT?	helium nucleus	electron	electromagnetic radiation

ability to gain/lose electrons

the power to make atoms ions

(opposites attract)

HALF-LIFE

HALF-LIFE $t_{1/2}$

- the decay rate of a radioisotope is measured in terms of its half-life
- the half-life of a radioisotope is the time it takes for half of the nuclei of the sample to spontaneously decay

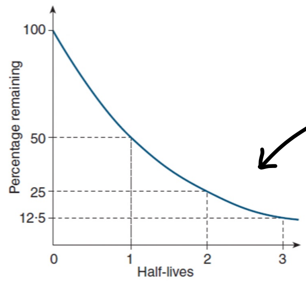


Figure 5.19
The amount of the original isotope halves as each half-life passes. This is an exponential relationship.

a half-life diagram is exponential (it never reaches 0)

in general, for a sample of N_0 particles, the number, N, remaining after n half lives is given by the equation: (the half-life equation)

original no. of nuclei

$$\boxed{N = N_0 \left(\tfrac{1}{2}\right)^n \quad \text{where} \quad n = \frac{t}{t_{1/2}}}$$

number of particles remaining after half-life

EXAMPLE QUESTION 1 (USING NO. OF NUCLEI)

A sample of the radioisotope thorium-234 contains 8.0×10^{12} nuclei. The half-life of ^{234}Th is 24 days. How many thorium-234 atoms will remain in the sample after:

a) 24 days?

$N = N_0 \left(\frac{1}{2}\right)^n$

$N = 8.0 \times 10^{12}$

$n = \frac{24}{24} = 1$

$\therefore 8.0 \times 10^{12} \left(\frac{1}{2}\right)^1$

$N = 4 \times 10^{12}$

b) 48 days?

bruh

c) 96 days?

bruh

RADIO ACTIVITY

- the number of radioactive decays occurring in a sample each second

measured in becquerels (Bq)

$$\boxed{\text{Activity } (A) = \frac{\Delta N}{t}}$$

ΔN — change in the number of nuclei present (or decays or counts)

t — time

1Bq = 1 disintegration per second

*note : over one half-life, the activity of a sample will be reduced by half

EXAMPLE QUESTION 2 (USING ACTIVITY)

In 2 hours, the activity of a sample of a radioactive element falls from 240 Bq to 30 Bq. What is the half life of this element?

$240 \rightarrow 120 \rightarrow 60 \rightarrow 30$

count the arrows = 3 half-lives

3 half-lives in 2 hours (120mins)

$\therefore t_{1/2} = \frac{120}{3} = 40$ mins

activity

(notes from after the test)

$$\text{Activity} = \frac{\Delta N}{t}$$

ΔN — number of decays

t — in this period of time

activity $= \frac{\text{decays}}{\text{seconds}}$

= Bq

THE EFFECT OF RADIATION ON HUMANS

ABSORBED DOSE

the energy cells absorb from radiation is called absorbed dose

- radiation damage depends on 2 factors:
  - ↳ the energy the cell absorbs
  - ↳ the time over which the cell absorbs the energy

unit = Gray (Gy)

1 Gy = 1 joule per kg ($J \cdot kg^{-1}$)

$$\boxed{\text{Absorbed dose} = \frac{\text{energy absorbed}}{\text{mass of body part}}}$$

measured in Joules per kg of tissue

DOSE EQUIVALENT

unit = sievert (Sv)

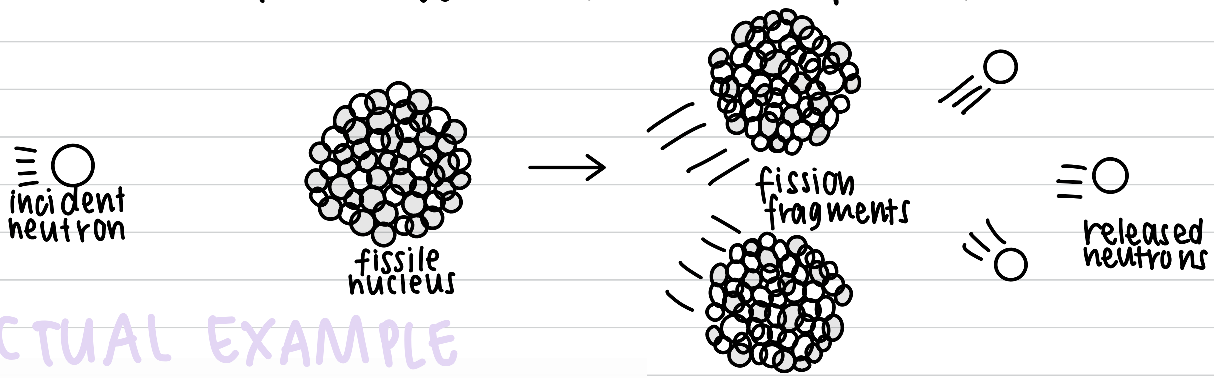
1 Sv = 1 joule per kg ($J \cdot kg^{-1}$)

$$\boxed{\text{dose equivalent} = \text{absorbed dose} \times \text{quality factor}}$$

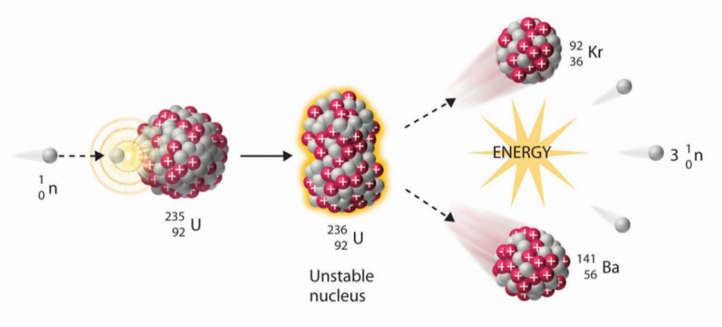
NUCLEAR FISSION + FUSION

FISSION

- occurs when an atom splits into 2 or more pieces
  - ↳ this is often triggered by the absorption of a neutron



ACTUAL EXAMPLE



- elements capable of undergoing nuclear fission are known as fissile materials
  - ↳ only a handful of isotopes have this property including U-235 and PU-239

ENERGY RELEASED

- in any fission reaction, the combined mass of the incident neutron and the target nucleus is always greater than the combined mass of the fission fragments and the released neutrons

*(the decrease in mass is referred to as the total binding energy of the nucleus. It represents the amount of energy that is needed to hold the nuclide together)

this decrease in mass* is equivalent to the energy released during each fission and can be determined by using:

$$\boxed{E = \Delta m c^2}$$

energy released (joules) — E; mass decrease (kg) — Δm; speed of light^2 $(3\times10^8\,ms^{-1})$ — c^2

THE ELECTRON-VOLT (eV)

- one electron-volt (eV) is an energy unit
- it is equivalent to the energy that an electron gains when it is exposed to a one volt potential difference
- thus, 1 electron-volt is equivalent to 1.602×10^{-19} J

$$\boxed{1\,\text{eV} \underset{\div}{\overset{\times}{\rightleftarrows}} 1.6\times10^{-19}\,\text{J}}$$

the atomic mass unit, u, is defined as 1/12 the mass of a carbon-12 atom $= 1.6606 \times 10^{-27}$ kg

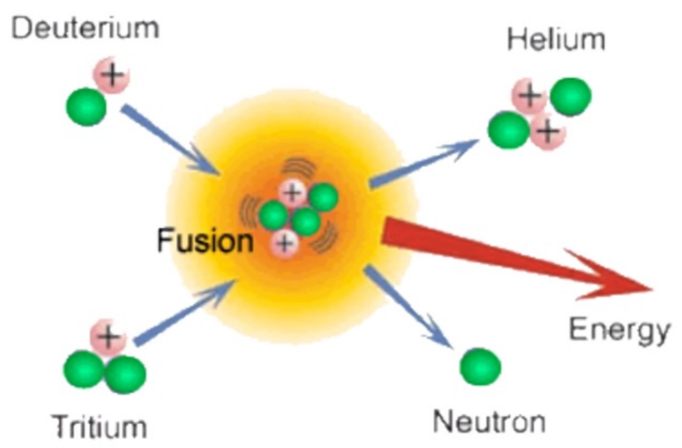
the energy equivalent of this mass ($E = 1.6606 \times 10^{-27} \times c^2$) is:

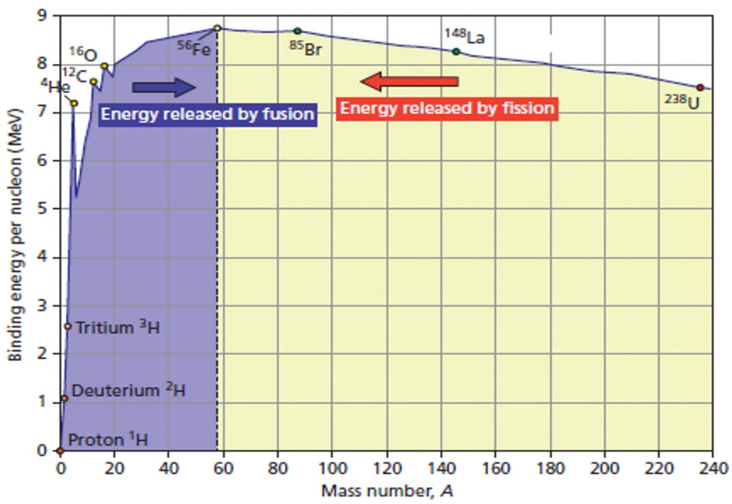
unified mass units

$\boxed{1u = 931 MeV}$

FUSION

- occurs in the sun and stars and is how heavier elements are formed from light nuclei such as hydrogen & helium
- involves joining 2 small nuclei to form a large one
- when this happens, energy is released and there is a mass defect
  - ↳ binding energy of reactants > BE of products





NUCLEAR REACTORS

U-235, U-238 & PU-239

Uranium-235 is most likely to undergo fission when struck by a slow moving or thermal neutron

Uranium-238 is only slightly fissile. It requires a neutron with a large amount of energy to cause fission
- ↳ generally captures a neutron and decays into Plutonium-239 which is a fissile material
- ↳ ∴ U-238 is known as a fertile material

Plutonium-239 is fissile when struck by a fast moving neutron

CHAIN REACTIONS

- when Uranium-235 undergoes fission, it releases 2 or 3 neutrons each time
- each of these neutrons is then able to cause fission in another Uranium-235 nucleus, which in turn will also release 2 or 3 neutrons, and so on

CRITICAL MASS

the minimum amount of enriched fissile material in the shape of a sphere that leads to a sustained chain reaction is known as critical mass

NUCLEAR POWER STATIONS

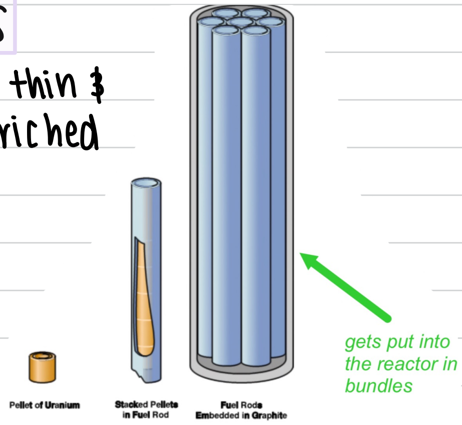
military ← nuclear reactors → electricity

research ← nuclear reactors → medical

THE MAJOR COMPONENTS OF THERMAL NUCLEAR REACTORS

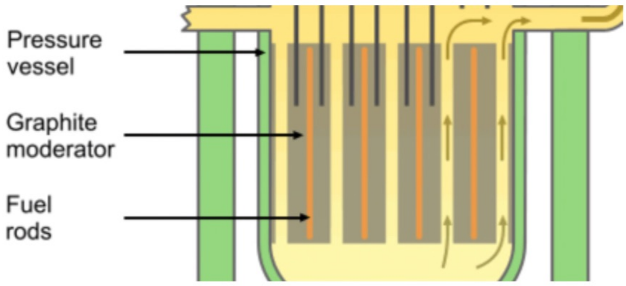
FUEL RODS

- long and thin & contain enriched Uranium



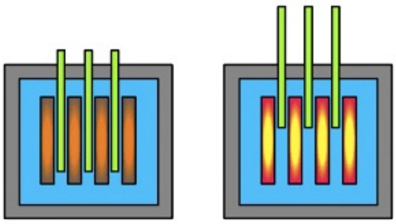
MODERATOR

- used to slow the neutrons



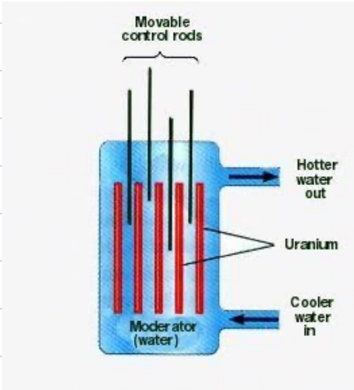
CONTROL RODS

- used to absorb neutrons and maintain a steady chain reaction



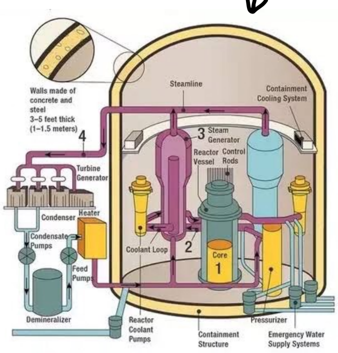
COOLANT

- a liquid which absorbs the heat energy produced by nuclear fission



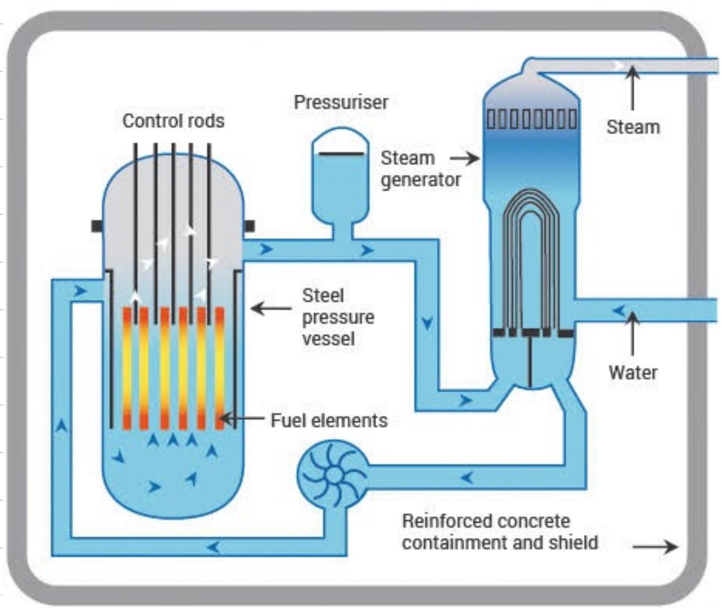
RADIATION SHIELD

- thick concrete wall which prevents the neutrons escaping from the reactor



PUTTING IT ALL TOGETHER →

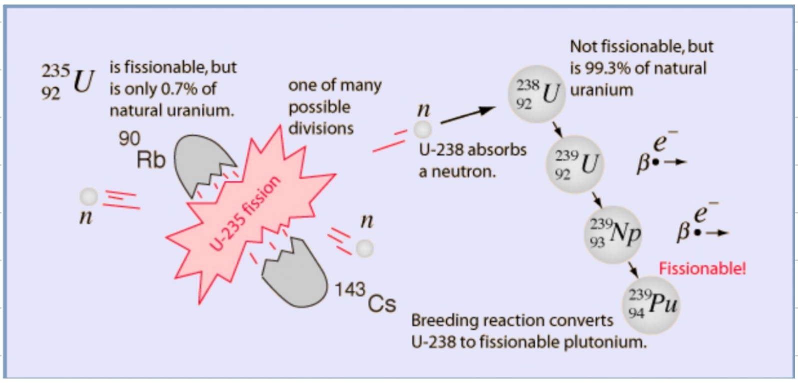
A Pressurized Water Reactor (PWR)

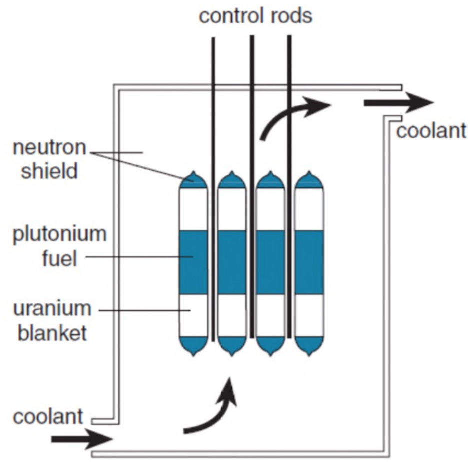


FAST BREEDER REACTORS

- makes use of the abundant U-238 isotope, it absorbs neutrons and transmutes into Plutonium-239

U-238 → U239 → Np239 → Pu239





thermal vs fast breeder reactors

SIMILARITIES	DIFFERENCES
- both use control rods - a coolant flows through the core-removing heat - energy is used to produce steam that drives the turbines & generates electricity	- does not require a moderator since fast moving neutrons are required - contains a core of plutonium which is surrounded by a blanket of Uranium-238

WAVE PROPERTIES

WAVES: WHAT ARE THEY?

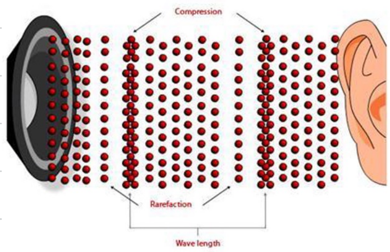
a wave is a travelling disturbance
- it involves energy being transferred from one place to another without the net transfer of matter

2 major categories:
- those which rely on an elastic medium to carry them (mechanical waves)
- those which require no medium

THE 2 TYPES OF WAVES

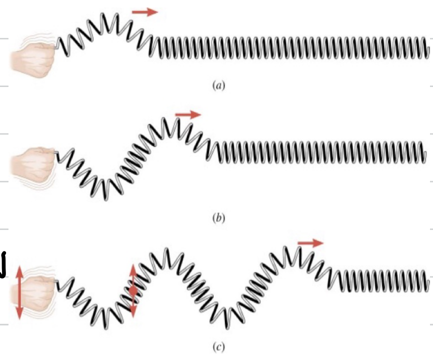
transverse

longitudinal



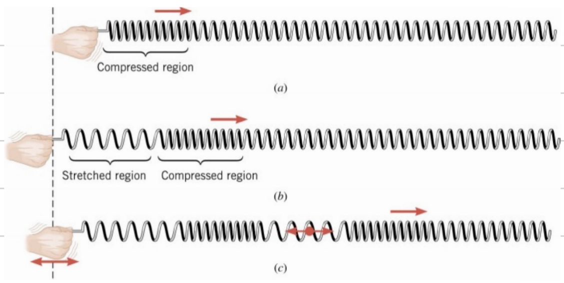
TRANSVERSE WAVES

a transverse wave is one in which the displacement of the particles occurs perpendicular to the direction of travel of the wave
- radio waves, light waves & microwaves are transverse waves
- transverse waves also travel on the strings of instruments such as guitars and banjos



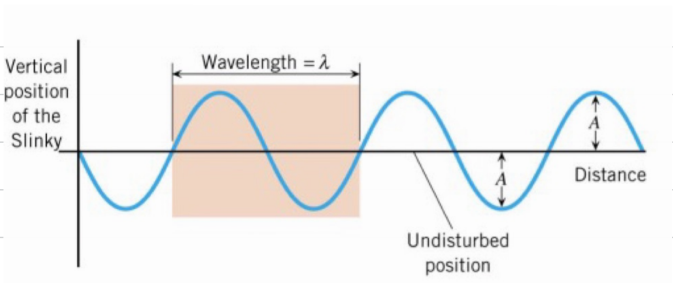
LONGITUDINAL WAVES

- a longitudinal wave is one in which the displacement of the particles is parallel to the line of travel of the wave
- a sound wave is a longitudinal wave

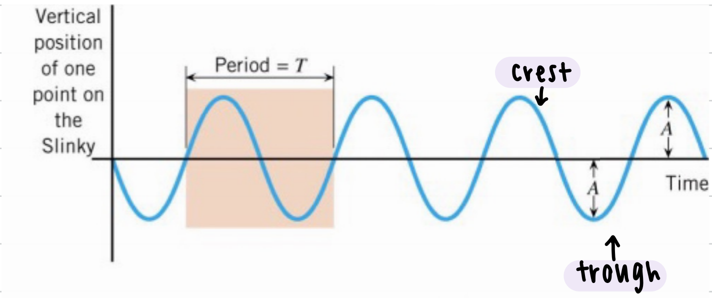


PERIODIC WAVES

- if the source of the disturbance produces it repeatedly, at equal time intervals, the resulting wave is called periodic
- many periodic waves in nature are sinusoidal waves, represented by sine and cosine graphs
- like anything else periodic, these waves are characterized by: an amplitude, a wavelength, a period and a frequency



(a) At a particular time



(b) At a particular location

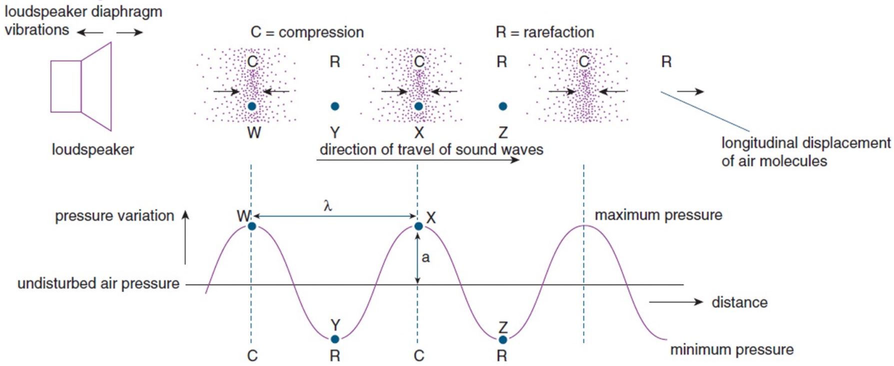
AMPLITUDE A

is the maximum displacement from the particle's undisturbed position

WAVELENGTH

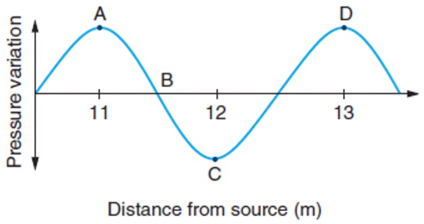
is the horizontal length of one wave cycle (or the distance a wave travels during 1 period)

LONGITUDINAL WAVES REPRESENTED PICTORIALLY AS A TRANSVERSE WAVE



EXAMPLE 1

A note sung by a school choir is transmitted through air as a longitudinal wave. The graph below represents the pressure variation of the sound wave at a particular instant in time.



a What is the wavelength of the sound wave?
b Which of the points A–D represent compressions?

THE RELATIONSHIP BETWEEN T AND f

Period (T): time required for one complete cycle

Frequency (f): number of cycles per second of time

$$f = \frac{1}{T}$$

where T is the time taken for one cycle to be completed in seconds (s) and f is the frequency of the wave in hertz (Hz) or cycles per second (s^{-1}).

THE WAVE EQUATION

THE WAVE EQUATION is given by:

$$v = \frac{\lambda}{T} \quad \text{and} \quad T = \frac{1}{f}$$

$$\therefore v = f\lambda$$

where v is the velocity of the wave (m s^{-1}), f is the frequency (Hz) and λ is the wavelength (m).

EXAMPLE 2: THE WAVELENGTHS OF RADIO WAVES

AM and FM radio waves are transverse waves that consist of electric and magnetic disturbances. These waves travel at a speed of 3.00×10^8 m/s. A station broadcasts an AM radio wave whose frequency is 1230×10^3 Hz (1230 kHz on the dial) and an FM radio wave whose frequency is 91.9×10^6 Hz (91.9 MHz on the dial). Find the distance between adjacent crests in each wave.

EXAMPLE 3

Waves are created on the surface of the water in a wave pool by a device that dips up and down 20.0 times per minute. The velocity of the resultant wave is 3.00 m s^{-1}.

a) State the frequency, period and wavelength of the observed wave.

b) What happens to the value of the wavelength if the frequency of the source is doubled?

a) $f = \frac{20}{60} = 0.33\overline{3}$ Hz

$T = \frac{1}{f} = \frac{1}{0.333} = 3$ s

$\lambda = T \times v = 3 \times 3 = 9$ m

$v = \lambda f$ or $v = \frac{\lambda}{T}$

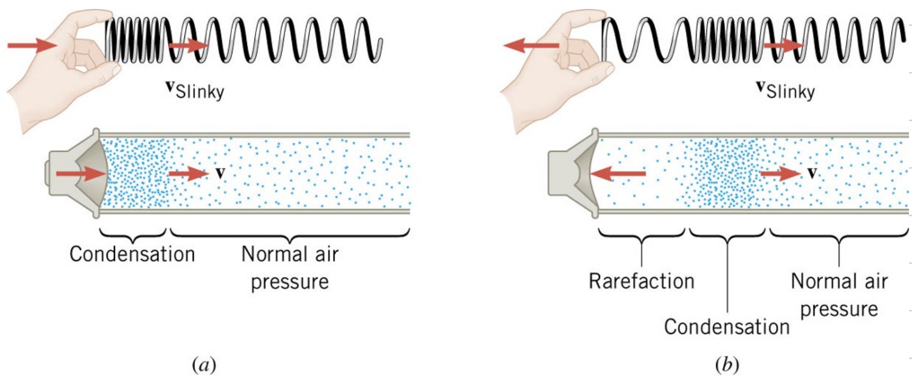
b) $f = 0.6\overline{66}$ using $\overset{\text{constant}}{v} = \lambda f$

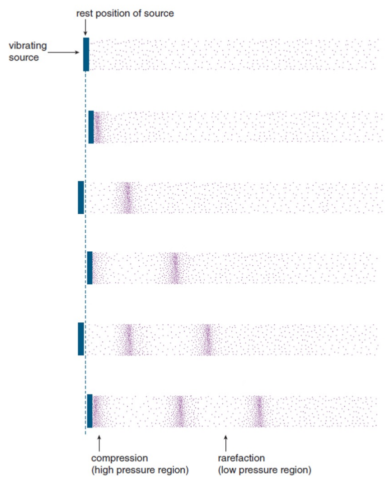
$\lambda = \frac{v}{f} = \frac{3}{0.666}$

$= 4.5$

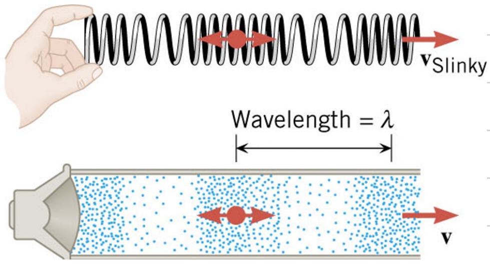
SOUND

sound is a longitudinal wave in which the disturbance is a change in the pressure in the air (or other medium)

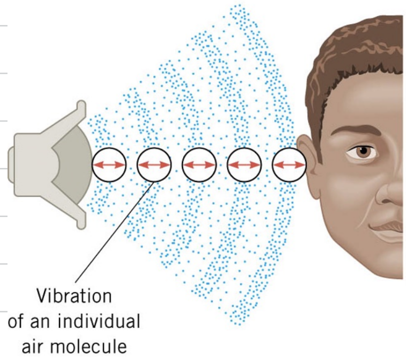




like any wave, sound is characterized by a velocity and a wavelength

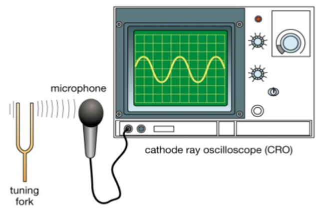


as with any wave, the disturbance travels, and energy travels but the material (air) 'sloshes back and forth' mostly in one place

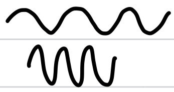


HOW AMPLITUDE AND FREQUENCY CHANGE WITH PITCH AND LOUDNESS

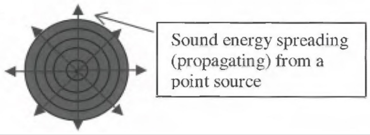
a source that vibrates rapidly produces sound of a higher pitch (or frequency)



Summary: higher pitch = higher frequency
louder sound = larger amplitude

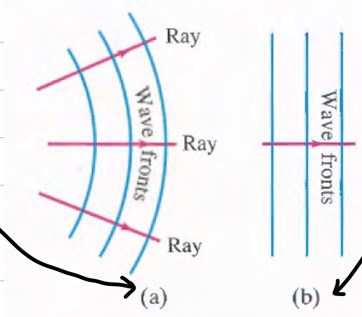


REPRESENTING WAVES



wave fronts - points along the wave which form the wave crest
rays signify the direction of wave motion, are always perpendicular to wave fronts

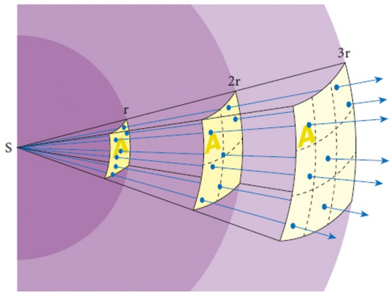
(a) circular or spherical waves near the source



(b) far from the source, the wave fronts are nearly straight or flat. called plane waves

THE INTENSITY OF WAVES

- waves from a point source will spread out uniformly into the surrounding space, likewise, the energy at the source becomes spread out over larger and larger areas as the light travels away from the source



proportional

$$\boxed{I \propto \frac{1}{r^2}}$$

MATHEMATICAL PROOF OF INVERSE SQUARE RELATIONSHIP FOR WAVE INTENSITY

The energy is spread over the area of a sphere of radius r:

$$A = 4\pi r^2$$

If the source strength, S, is the energy per second being emitted, then the intensity, I, at distance, r, from the source, is the energy per second per area:

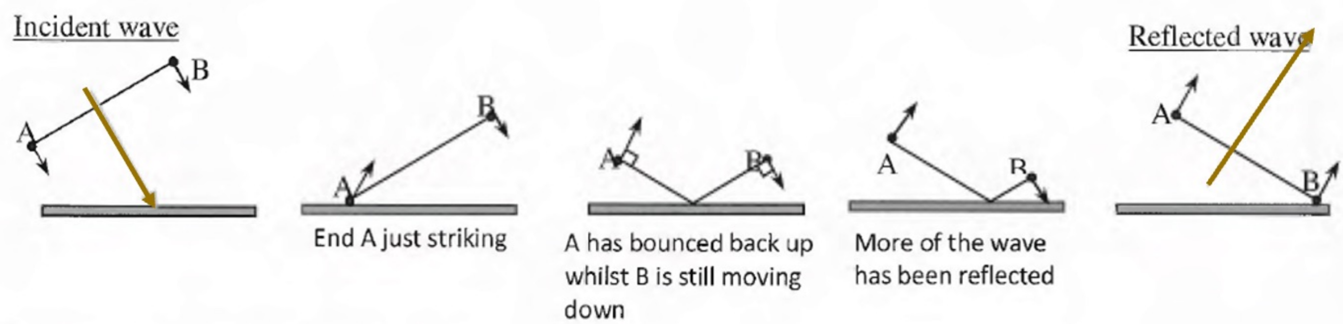
$$I = \frac{S}{4\pi r^2}$$

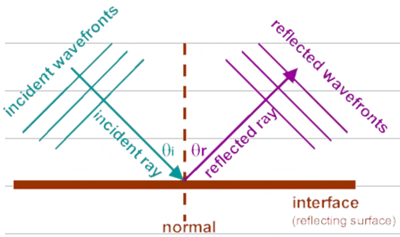
$$\Rightarrow I = \frac{1}{4\pi}\left(\frac{S}{r^2}\right)$$

Thus, the intensity at any point is proportional to the source strength, $I \propto S$, but inversely proportional to the square of the distance from the source, $I \propto \frac{1}{r^2}$.

The constant, $\frac{1}{4\pi}$, tells us that a sphere is involved in the calculations.

LAW OF REFLECTION

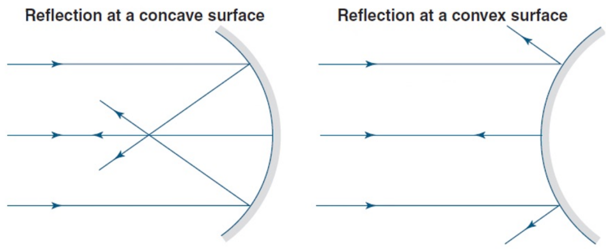


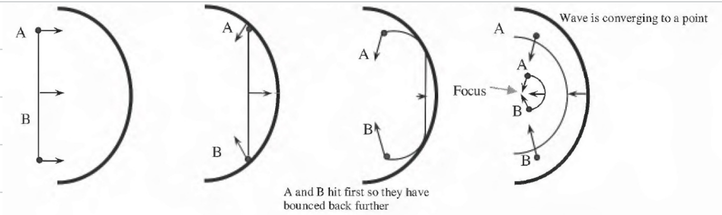


Law of reflection: angle of incidence = angle of reflection

note: when sound is reflected in the same medium, there is no change in frequency, speed or wavelength

REFLECTING OFF A CURVED SURFACE





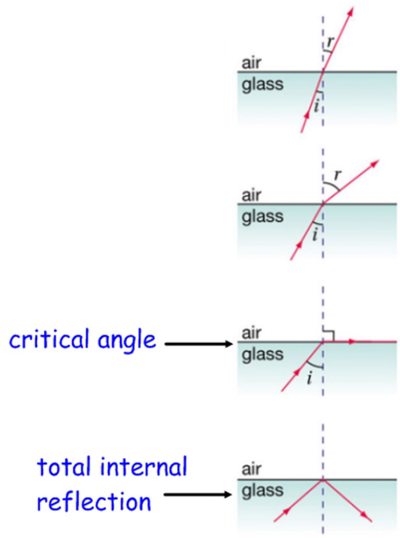
- if the reflecting surfaces are curved, then sound waves will converge or diverge, like light

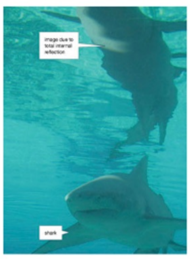
WAVES MEETING BARRIERS

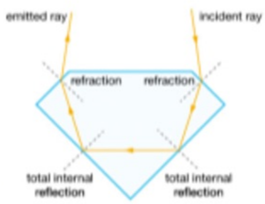
- at the boundary of the medium, the energy that was being carried by the wave may undergo different processes - some may be absorbed by or transmitted into a new medium, and some energy may be reflected
- the extent to which these processes occur depends on the properties of the boundary

TOTAL INTERNAL REFLECTION

- can occur when $v_1 < v_2$
- minimum angle at which total internal reflection occurs = critical angle (at this point, the angle of reflection = 90°)







✓ Worked Example 5.2B

At what minimum incident angle would sound need to strike water from air if it is to reflect completely? The speed of sound in air is 344 m s⁻¹ and in water it is 1500 m s⁻¹.

Solution

In this example, the critical angle needs to be calculated using Snell's law:

$r = 90.0°$

$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

$v_{water} = 1500 \text{ m s}^{-1}$

$\sin i = \frac{v_1 \sin r}{v_2} = \frac{344 \sin 90.0°}{1500}$

$v_{air} = 344 \text{ m s}^{-1}$

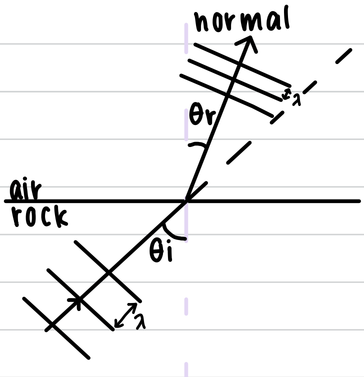
$\sin r = 0.0229$

$r = 13.3°$

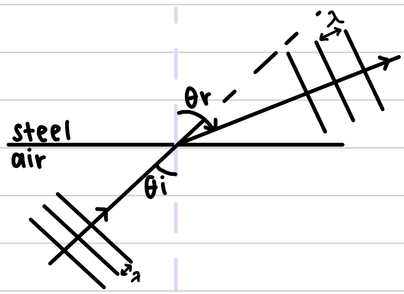
WAVE REFRACTION

- refraction = bending of waves
- occurs when the wave changes from one medium to another

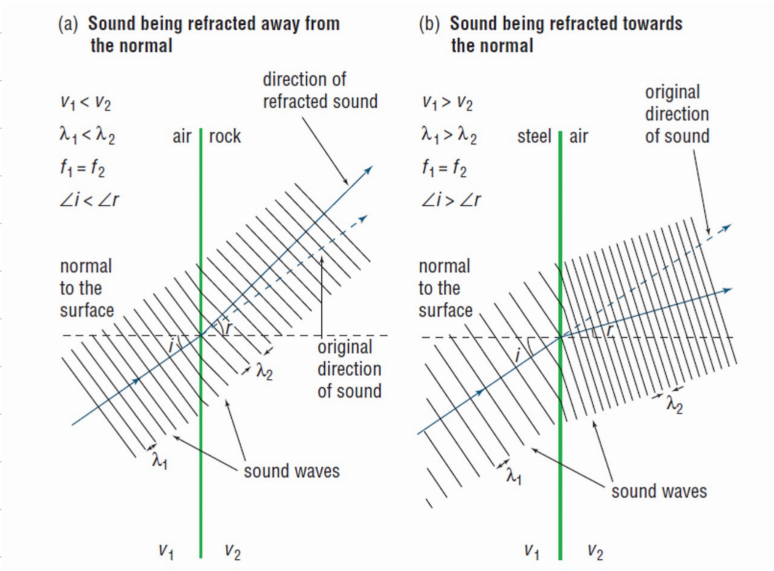
REFRACTION DIAGRAMS



more → less
bend towards
the normal



less → more
bend away



WAVE REFRACTION AND SNELL'S LAW

incident angle — speed of sound in medium 1

$$\boxed{\frac{\sin i}{\sin r} = \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}}$$

refracted angle — wavelength of 2

SNELL'S LAW is:

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

where i and r are the incident angle and the refracted angle, v_1 and v_2 are the speeds of sound in the first and the second medium and λ_1 and λ_2 are the wavelengths in the first and the second medium.

EXAMPLE: REFRACTION OF AN EARTHQUAKE WAVE

An earthquake P wave (a longitudinal wave) passes across a boundary in rock where its velocity increases from 6.5 km/s to 8.0 km/s. If it strikes this boundary at 30°, what is the angle of reflection?

APPROACH: Apply Snell's Law

SOLUTION:

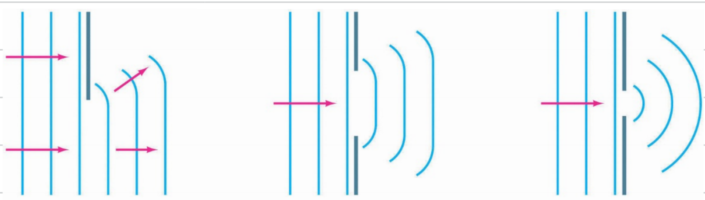
$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

$$\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$$

$$\sin\theta_2 = \frac{8.0}{6.5}\sin 30 = 0.62$$

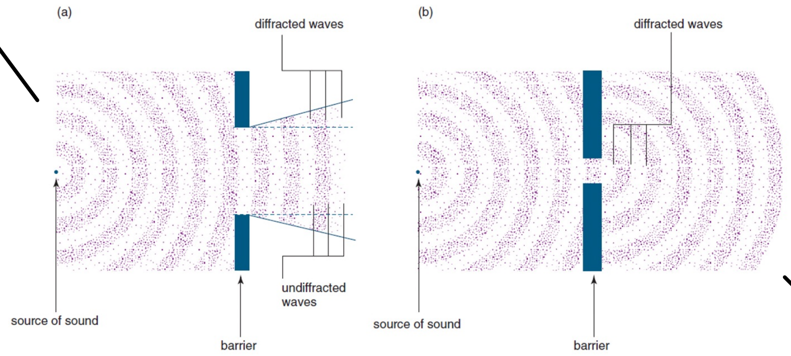
DIFFRACTION OF SOUND

- diffraction: the bending of waves as they pass the edge/s of an obstacle or pass through an aperture (hole / slit)



(a) (b) (c)

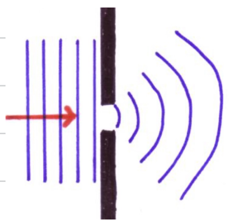
(a) waves passing through an aperture or past an obstacle that $> \lambda$ will not be significantly diffracted - leaves 'sound shadows'



(b) apertures or obstacles that are comparable (same order of magnitude) to λ or smaller will cause significant diffraction

significant diffraction occurs when $\frac{\lambda}{\text{width}} \approx 1$ or more

DIFFRACTION OF SOUND - SUMMARY



$\lambda > d$ reflects
$\lambda = d$ sphere shaped diffraction
$\lambda < d$ limited diffraction

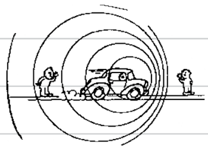
ULTRASOUNDS PG 383-384

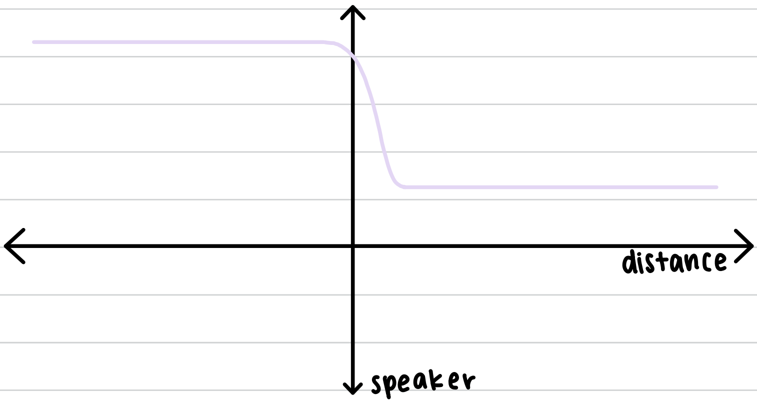
- ultrasounds are used for diagnosis and treatment
- during ultrasound procedures, vibrations are created in the cells of the body
  - ↳ at low intensities, the vibrations aren't very energetic
  - ↳ at high intensities, they can heat regions deep inside the body and damage or destroy cells
- for heat treatments, intensity must be $30{,}000\ \text{Wm}^{-2}$ to avoid tissue damage
- it is believed that heat treatment increases metabolism in the treated site and accelerates healing
- if the intensity of sound waves sent into the body is high enough, they can destroy certain cells

SOUND WAVES – WAVE INTERACTIONS

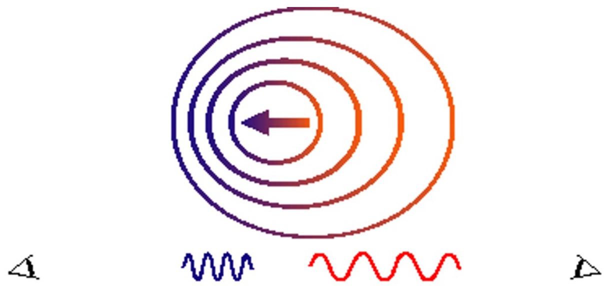
DOPPLER EFFECT

- frequency (f) of a wave can also vary due to the movement of the source of the wave or the receiver of the wave
- if the source or receiver of a wave are moving together, the wave will decrease its λ and increase its f
- if the source or reciever are moving apart, the λ will be longer and the f will be lower





DOPPLER EFFECT AND RED SHIFT



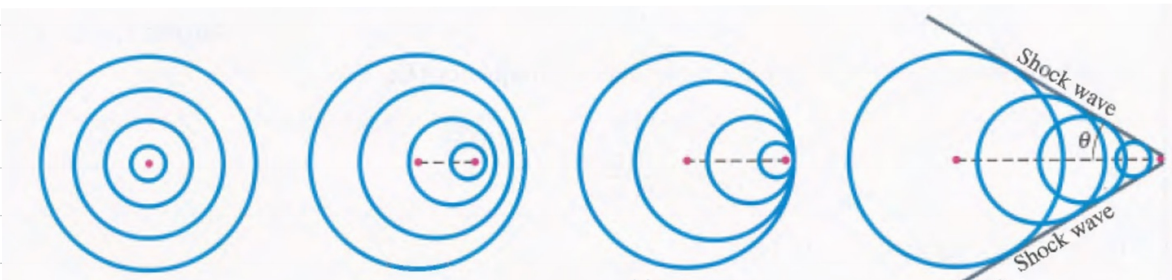
Source moving TOWARD observer
Wavelength decreasing,
Frequency increasing,
Observer experiencing BLUE shift.

Source moving AWAY from observer
Wavelength increasing,
Frequency decreasing,
Observer experiencing RED shift.

SONIC BOOMS

an intense pressure front builds up on the cone and is the cause of the shock wave known as a sonic boom

the shock wave advances at the speed of sound v, and since it is built up from all of the combined wave fronts, the sound heard by an observer will be quite intense



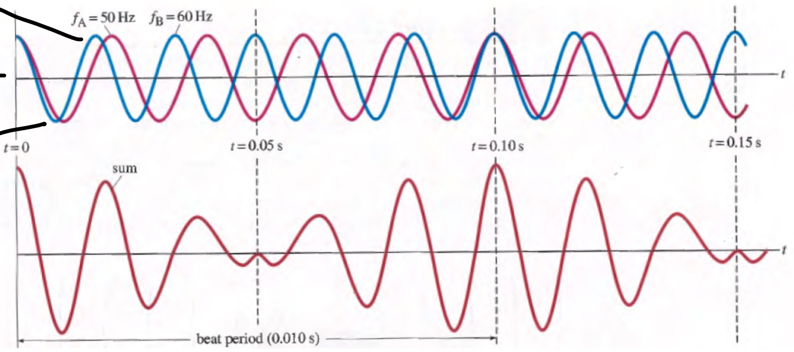
(a) $v_{obj} = 0$ (b) $v_{obj} < v_{snd}$ (c) $v_{obj} = v_{snd}$ (d) $v_{obj} > v_{snd}$

BEATS - INTERFERENCE IN TIME

compression

y axis = pressure

rarefaction



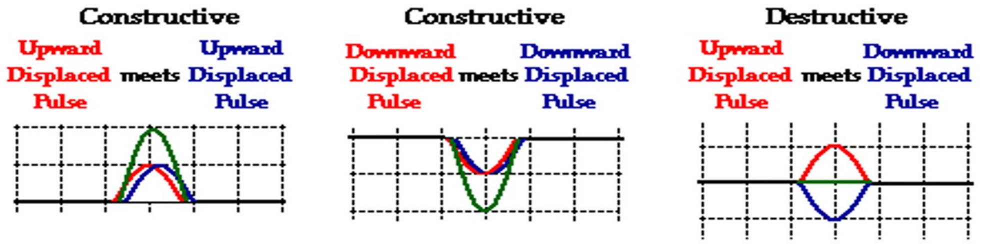
beat frequency

difference in 2 wave frequencies

how many times does it get louder then softer in 1 second

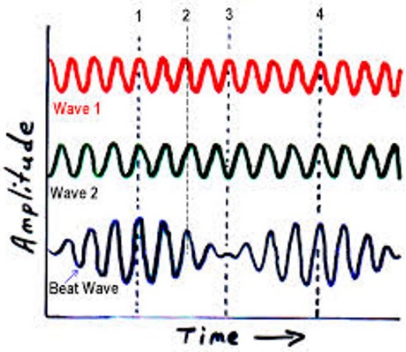
$$\boxed{f_B = f_2 - f_1}$$

CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE



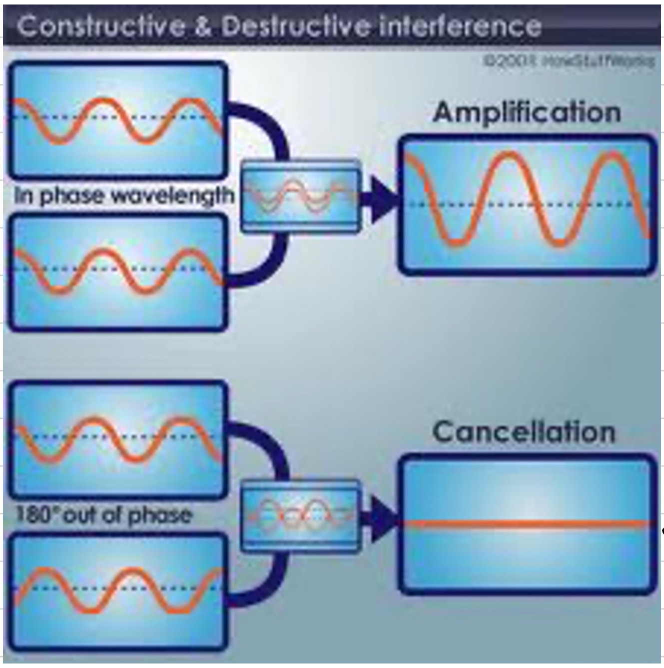
WHAT DO WE NEED FOR BEATS TO OCCUR?

- waves need to be close in frequency but not exactly the same
- waves must be travelling in the same medium at the same time
- will occur even if the amplitudes are not equal, as long as the difference in amplitudes is not great



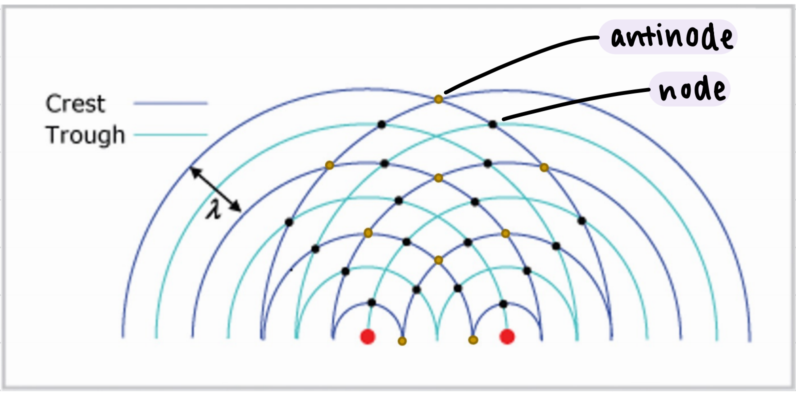
WAVE INTERACTIONS PART 2

INTERFERENCE PATTERNS



constructive interference (produces an antinode)

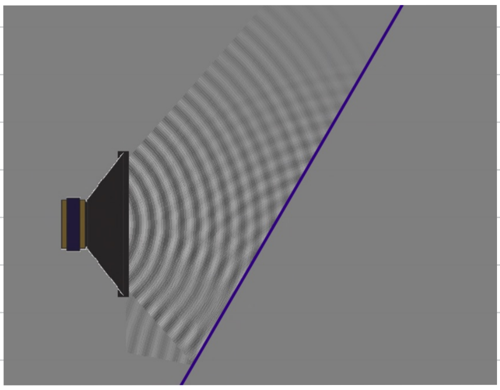
destructive interference (produces a node)



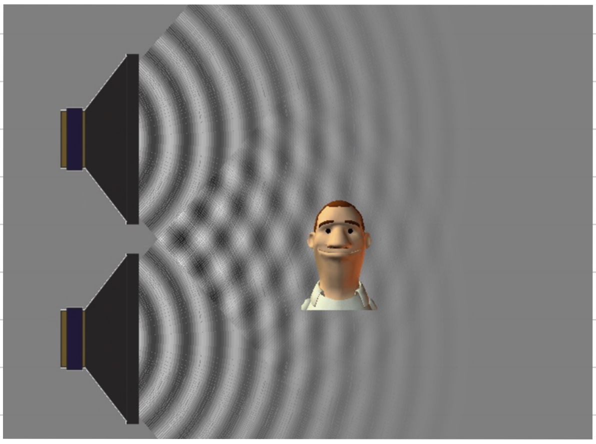
regions of destructive interference (nodes) are shown as black dots
regions of constructive interference (antinodes) are shown as gold dots

notice the nodes are aligned, symmetrical and based on where troughs coincide with crests - the waves here are out of step

INTERFERENCE BY REFLECTION



INTERFERENCE AND SOUND WAVES



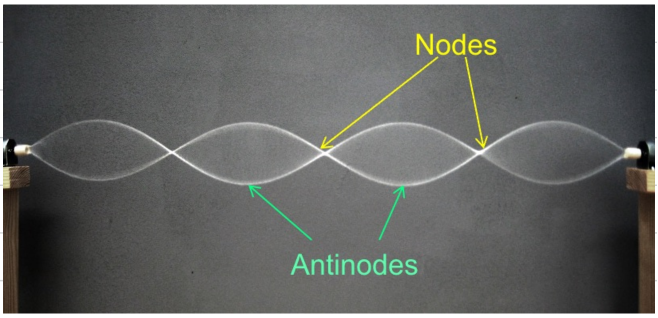
WAVE INTERACTIONS PART 3

RESONANCE

- the frequency or frequencies at which an object tends to vibrate with when hit, struck, plucked, strummed or somehow disturbed is known as the natural frequency of the object
- resonance occurs when the frequency of a forcing vibration = natural frequency of an object
- at resonance, relatively little effort is required to obtain a large amplitude

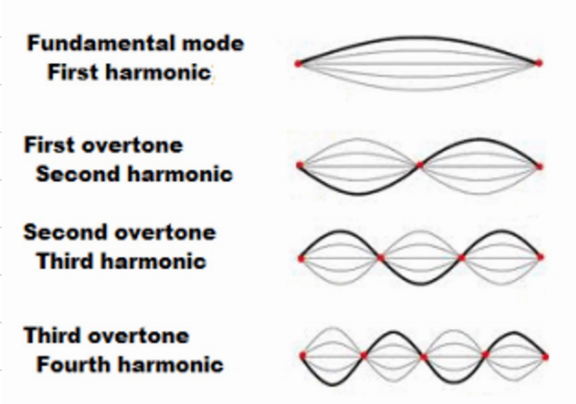
STANDING WAVES

- while they appear stationary, the string continually oscillates. It is the relative position of the nodes and antinodes that remain unchanged
- the result of the interference of 2 waves travelling in opposite directions
- are produced at the natural frequencies



VIBRATIONS IN STRETCHED STRINGS

- stretched strings will freely vibrate at a particular natural frequencies
  - ↳ these frequencies are dependent upon the length of the string, its mass and its tension



$f_1 \quad \lambda_1 = 2\ell$

$f_2 = 2f_1 \quad \lambda_2 = \ell$

$f_3 = 3f_1 \quad \lambda_3 = \frac{2}{3}\ell$

its $\frac{2}{4} = \frac{1}{2}$

$f_4 = 4f_1 \quad \lambda_4 = \frac{1}{2}\ell$

WAVELENGTH OF THE HARMONICS (STRING)

$$\boxed{\lambda_n = \frac{2\ell}{n}}$$

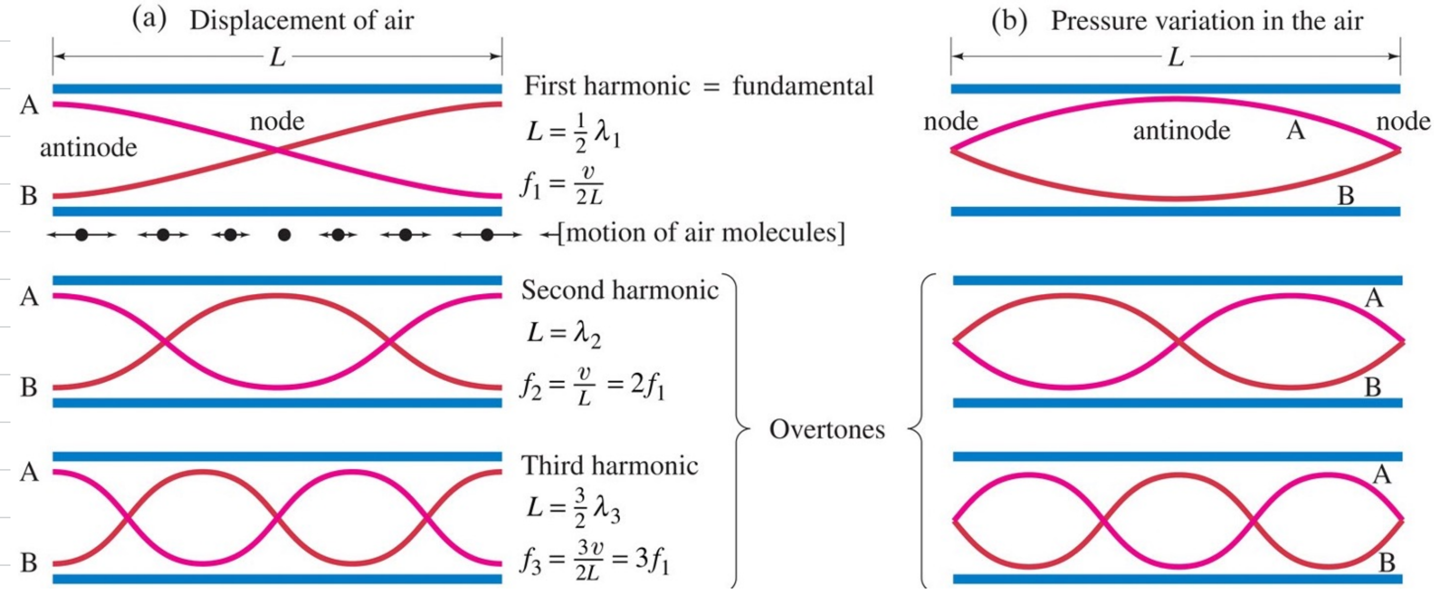
FREQUENCY OF THE HARMONICS (STRING)

$$\boxed{f_n = \frac{nv}{2L}}$$

WIND INSTRUMENTS

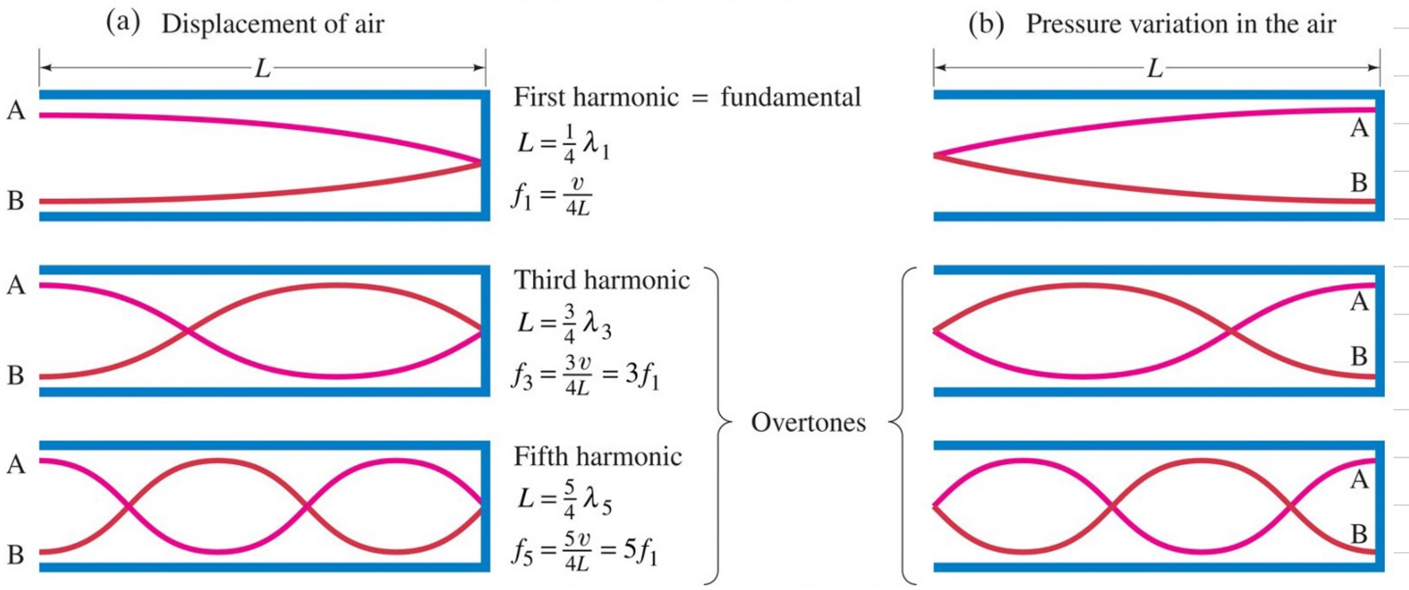
- stationary waves are also possible in air columns
- the air within the tube vibrates with a variety of frequencies that correspond to standing waves will persist
  - ↳ this is determined by the length of the pipe
- waves can be described either in terms of the displacement of air or in terms of the pressure in the air

OPEN PIPES



each graph shows the wave format at 2 times, A and B, a ½ period apart
the actual motion of the molecules for one case, the fundamental, is shown just below the tube at top left

CLOSED PIPES



n=1
n=2
n=3

note: the node at the closed end and the antinode at the open end means only odd multiples of the fundamental are possible on the formula sheet

$\lambda = \frac{4l}{2n-1}$ 3^{rd} harmonic

2^{nd} sound , $n=2$

$\lambda = \frac{4l}{2(2)-1} = \frac{4l}{3}$

$\therefore l = \frac{3\lambda}{4}$

HEATING PROCESSES

unit 1.1

KINETIC PARTICLE MODEL

assumptions behind the kinetic particle model:

- all matter is made up of very small particles (atoms or molecules)
- the particles are in constant motion
- overall, no kinetic energy is lost or gained during elastic collisions between particles
- there are forces of attraction and repulsion between the particles in a material
- the distances between particles in a gas are large compared with the size of the particles

SOLIDS

- in a solid, particles must be exerting attractive forces or bonds on each other for the matter to hold together in its fixed state
- there also must be repulsive forces otherwise it would collapse
- the particles are held in a fixed position by the forces (usually in a lattice)
- the particles aren't completely still, they vibrate around average positions

LIQUIDS

- still a balance of attractive and repulsive forces
- the particles have more freedom to move around
- particles collide but remain attracted to each other ∴ the liquid remains within a fixed volume but with no fixed shape

GASES

- particles are in constant, random motion, colliding with each other and the walls of the container
- particles move rapidly in every direction ∴ filling the volume of any container
- particle speed is high enough that when the particles collide, the attractive forces aren't strong enough to keep the particles close together
- repulsive forces = particles move + spread in other directions

INTERNAL ENERGY + TEMPERATURE

- heat (measured in Joules) = transfer of thermal energy from hot → cold objects
  ↳ is observed by a change in temperature, change of state or expansion
- when a solid is 'heated', its particles gain kinetic energy or potential energy
- heat = energy being transferred
- internal energy = total kinetic + potential energy of the particles in a substance
- heating an object changes the internal energy by affecting its kinetic/potential energy
- internal energy is associated with the rapid and chaotic motion of the particles

ABSOLUTE ZERO

- the limit to how cold things can get
- kinetic theory suggests that as a gas is cooled, its volume decreases

any change in the internal energy (ΔU) of a system is equal to the energy added by heating ($+Q$) or removed by cooling ($-Q$) minus the work done on ($+W$) or by ($-W$) the system:

$$\boxed{\Delta U = Q + W}$$

CONDUCTION unit 2.2

- if 2 objects are at different temperatures and are in thermal contact then thermal energy will transfer from the hot object to the cold one

CONDUCTION

- heat is transferred from one place to another without net movement of particles
- all materials will conduct heat to some extent but is most significant in solids
- good conductors conduct heat readily
- poor conductors are called insulators
- conduction can happen in 2 ways:
  - ↳ energy transfer through molecular or atomic collisions
  - ↳ energy transfer by free electrons

THERMAL TRANSFER BY COLLISION

- particles in a solid are constantly vibrating within the material structure and ∴ interact with neighbouring particles
- if one part of the material is heated, the particles there will vibrate and the neighbouring particles will pass on this kinetic energy via the bonds
- can be quite slow since the mass of the particles is relatively large and vibrational velocities are fairly low
- materials for which this method of conduction is the only means of heat transfer are likely to be poor conductors of heat or even thermal insulators
  - ↳ glass, wood and paper are poor conductors of heat

THERMAL TRANSFER BY FREE ELECTRONS

- some materials, particularly metals, have electrons that aren't involved in a bond ∴ they are freely moving (delocalised)
- if a metal is heated, then the positive ions will gain extra energy alongside the free electrons
- an electron's mass is less than the positive ions, even a small energy gain will result in a very large gain in velocity
- the free electrons provide means by which heat can be quickly transferred throughout the whole material
- ∴ metals are good conductors of electricity and heat

THERMAL CONDUCTIVITY

- the ability of a material to conduct heat
- is temperature dependent and measured in $Wm^{-1}K^{-1}$

Factors affecting thermal conduction

- nature of the material, larger the thermal conductivity, the more rapidly it will conduct heat energy
- temp. difference between the 2 objects, greater temp. difference, the faster the rate of energy transfer
- thickness of the material, the thicker it is, the greater the number of collisions between particles or movement of electrons to transfer energy from one side to the other required
- surface area, increasing the surface area relative to the volume of a system increases the number of particles involved in the transfer process, increasing the rate of conduction

the rate at which heat is transferred is measured in Joules per second (Js^{-1}) or watts (W)

CONVECTION

unit 2.2

- the transfer of thermal energy within a fluid (liquid or gas) by the movement of hot areas from one place to another
- involves the mass movement of particles within a system over a distance that can be quite considerable

HEATING BY CONVECTION

- heat can be transferred quickly through liquids and gases through convection
- as a fluid is heated, it gains kinetic energy and the particles push apart due to the increased vibration of the particles
  - ↳ this causes the density of the heated fluid to decrease and it rises
  - ↳ colder fluid, with slower moving particles, is more dense and heavier ∴ it falls, moving in to take the place of the warmer fluid
  - ↳ this forms a convection current
- it is difficult to quantify the thermal energy transferred via convection but some estimates can be made, the rate at which convection will occur is affected by:
  - ↳ the temperature difference between the heat source and the convective fluid
  - ↳ the surface area exposed to the convective fluid
- the effectiveness of convection in transferring heat depends on the placement of the source of heat
  - ↳ e.g. heating element in a kettle is always near the bottom
- there are 2 main causes of convection
  - ↳ forced convection, for example, ducted heating in which air is heated and then blown into a room
  - ↳ natural convection, when a fluid rises as it is heated

RADIATION

- life on Earth depends on the transfer of energy from the Sun through the near-vacuum of space
- radiation = the transfer of heat without the movement of matter

ELECTROMAGNETIC RADIATION

- radiation is a shortened term for electromagnetic radiation
  - ↳ this includes visible, ultraviolet and infared light
  - ↳ together with other forms of light, these make up the electromagnetic spectrum
- electromagnetic radiation travels at the speed of light
  - ↳ when it hits an object, it will be partially reflected, partially transmitted and partially absorbed
- the absorbed part transfers thermal energy to the absorbing object - causing a rise in temperature
- electromagnetic radiation is emitted by all objects that are at a temperature above absolute zero (0K or -273°C)
- the λ and frequency (f) of the emitted radiation depends on the internal energy of the object
  - ↳ as temperature is related to the internal energy of an object, the higher the temperature, the higher the frequency and the shorter the λ of the radiation emitted

EMISSION AND ABSORPTION OF RADIANT ENERGY

- all objects both absorb and emit thermal energy by radiation
  - ↳ if an object absorbs more thermal energy than it emits, its temp. will increase
  - ↳ if it emits more than it absorbs, its temp. will decrease
  - ↳ if the object and its surroundings are in thermal equilibrium, there is no temperature change
- while all objects emit some radiation, they don't all emit and absorb at the same rate
- a number of factors affect both the rate of emission and the rate of absorption
  - ↳ surface area - the larger the exposed surface area, the higher the rate of radiant transfer
  - ↳ temperature - the greater the difference between the temp. of the absorbing or emitting surface and the temp. of the surrounding objects, the greater the rate of energy transfer by radiation
  - ↳ wavelength of the incident radiation - matte black surface almost perfectly absorb radiant energy at all wavelengths and highly reflective surfaces are good reflectors of all wavelengths. for all other surfaces, the absorption of particular wavelengths will be affected by the wavelength of the energy

HEATING PROCESSES

ASSUMPTIONS OF KINETIC THEORY

- all matter is made up of tiny particles (atoms or molecules)
- particles are in constant motion
- collisions between the particles are perfectly elastic (no K·E is lost/gained during the collision)
- there are attractive and repulsive forces between the particles in a material - insignificant in a gas

HEAT VS INTERNAL ENERGY VS THERMAL ENERGY

Internal Energy

- internal energy is the sum total of all the kinetic and potential energy of all the particles (atoms or molecules or ions) in an object
- internal energy is limited to a definite amount
- internal energy is represented by the potential energy and kinetic energy in the bonds of any material
  - ↳ in a gas, the molecules are so far apart that there are no intermolecular interactions. So there is no potential energy ∴ the energy is entirely kinetic

Heat

- the transfer of energy from one object to another because of a difference in temperature
  - ↳ it flows from hot to cold

the SI unit of heat = Joules (J)

- heat is not the energy an object contains
- heat can flow indefinitely between two objects provided a temperature difference is maintained between them
- the direction of heat flow between two objects depends on their temperature, not how much internal energy they contain

Thermal Energy

- the proportion of the internal energy of a system that is responsible for the temperature of the system

TEMPERATURE

- temperature is a measure of the degree of hotness of a substance
- it is the average K·E of the substance
- heat energy normally moves from regions of higher to lower temperature

what is the condition for thermal equilibrium?

- two objects are said to be in

SPECIFIC HEAT CAPACITY

specific heat capacity of a substance is the amount of energy required to increase the temperature of one kilogram by one degree celcius (or kelvin), without change of phase

symbol: c

unit: $Jkg^{-1}K^{-1}$ J/kg/K

to calculate the transfer of energy required for a particular temperature change the

mass in kg

change in temp. (°C or K)

$$\boxed{\Delta Q = mc\Delta T}$$

heat energy transferred (J)

specific heat capacity of object material

THERMAL EQUILIBRIUM

for thermal equilibrium, the heat gained by the colder material equals the heat energy lost by the hotter material

- this doesn't mean that both materials will have the same internal energy. That would only occur if the two materials have the same mass and specific heat

METHOD OF MIXTURES

1. heat lost by hottest material = the heat gained by the cooler material
2. the mixed materials will reach an equilibrium temperature
3. assumptions must be made when using this method

1L of water = 1 kg

LATENT HEAT

- latent heat is the energy required to change the state of 1kg of a substance: symbol L

$$\boxed{Q = Lm}$$

L_f = latent heat of fusion
L_v = latent heat of vaporisation

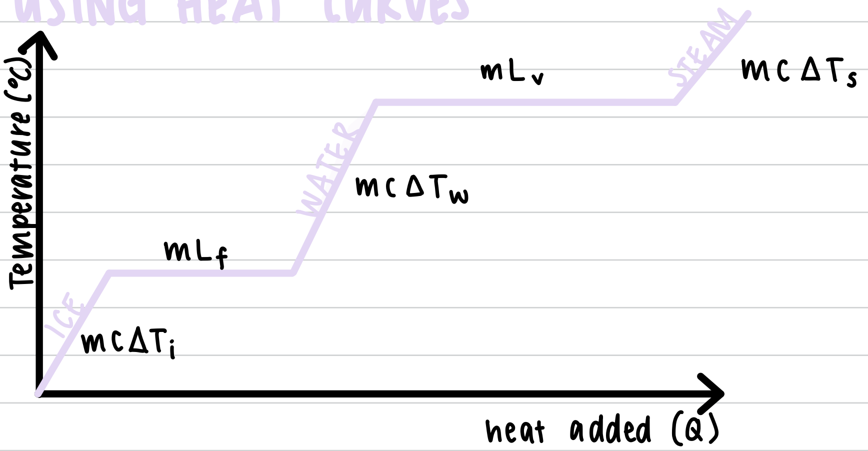
TERMINOLOGY

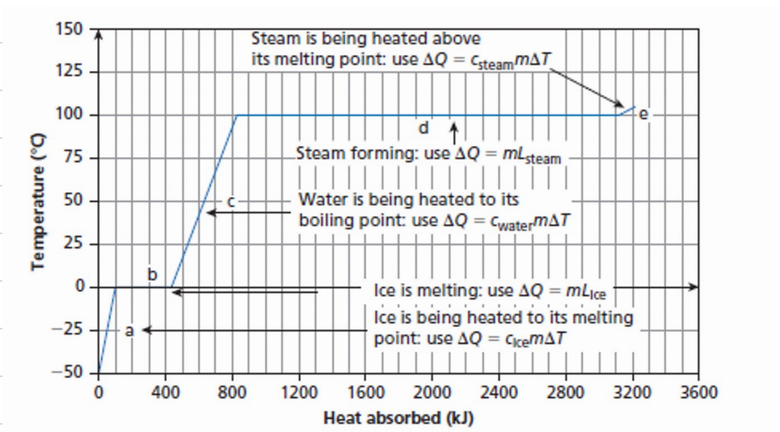
Specific latent heat of:	Change of state
Melting	Solid to liquid
Solidification/fusion	Liquid to solid
Vaporisation	Liquid to gas
Condensation	Gas to liquid

SOME LATENT HEAT CAPACITIES

Substance	Latent heat of fusion (kJ kg^{-1})	Latent heat of vaporisation (kJ kg^{-1})
Aluminium	390	10 500
Alcohol	105	841
Copper	205	4 800
Iron	276	6 340
Silver	105	2 350
Water	334	2 260

USING HEAT CURVES





ELECTRICITY

CHARGE INTERACTIONS

- like charges repel, opposite charges attract
- a neutral object has the same number of positive charges as negative charges

MEASURING CHARGE

symbol : q
unit : coulomb, C

- one electron has a charge of 1.6×10^{-19} C
- to get one coulomb of charge, you need 6.2×10^{18} electrons or protons
- charge cannot be created or destroyed, but it can move from one object to another

Which of the following amounts of charge are possible? Why?

a) 1.2×10^{-19} C
b) 2.4×10^{-19} C
c) 4.0×10^{-19} C — only multiples of 1.6×10^{-19} can work (cannot split an electron)
d) 4.8×10^{-19} C

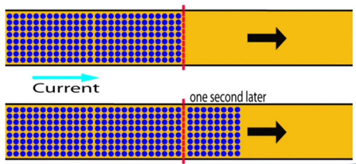
How many electrons make 0.5 Coulombs of charge?

$0.5 / 1.6 \times 10^{-19} = 3.125 \times 10^{18}$ electrons — is electrons not protons because protons are in the nucleus of the atom + that cannot be moved (but electrons can be transferred)

ELECTRIC CURRENT

definition : the rate of flow of electrical charge
symbol : I
unit : amps (A)
1 amp = 1 coulomb per second

Definition: the rate of flow of electrical charge



$$I = \frac{q}{t}$$

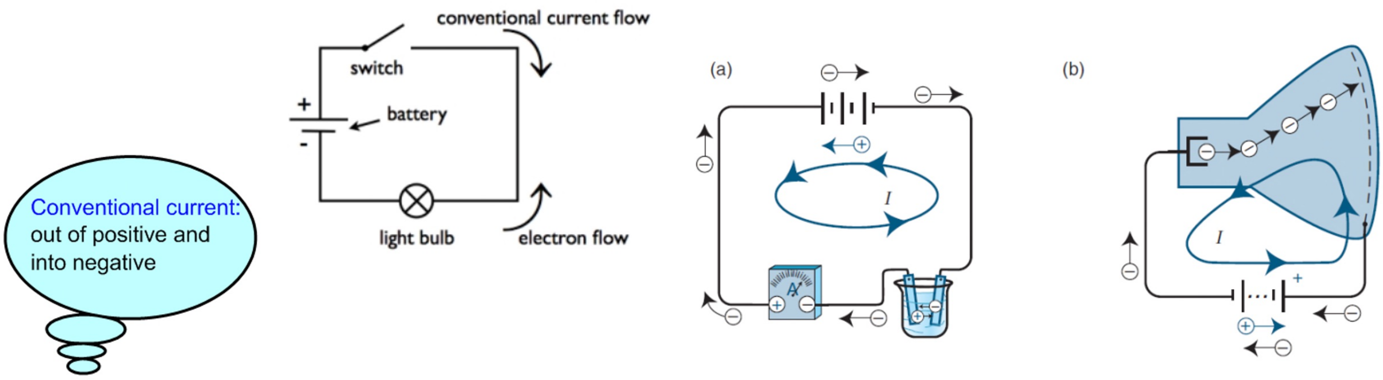
1 ampere (A) = 1 coulomb per second ($C\ s^{-1}$)

how many charged particles pass a point in our circuit each second.

$q = I.t = 0.005\ A \times 3600\ s = 18\ C$

ELECTRIC CURRENT

- the direction of convectional current is the direction of the flow of positive charge
- electrons flow in the opposite direction



DIRECT CURRENT AND ALTERNATING CURRENT

- direct current (DC) current flows one way
- alternating current (AC) the current direction alternates - changes direction approximately 50 times each second

ELECTRICAL POTENTIAL

- an electrical potential drives the current in a circuit
- because of this, it is sometimes referred to as the electromotive force (EMF, ε)

symbol : ε

definition : the energy per unit charge

units : volts ($1V = 1\,J \cdot C^{-1}$)

ELECTRICAL POTENTIAL

- work (W) is done whenever you lose or gain energy
- a charge (q) moving through a potential difference (ΔV) will lose energy given by $\Delta E = q\Delta V$ or simply $E = pV$ (or $W = qV$)

$$\boxed{V = \frac{W}{q}}$$

POWER

Power (P) is defined as the rate of change of energy transfer, either delivery or dissipation. It is the energy transfer per unit of time

$$P = \frac{W}{t} \qquad P = \frac{W}{t}$$

$$P = \frac{Vq}{t} = V\left(\frac{q}{t}\right) \qquad W = Pt$$

$$P = VI \qquad W = VIt$$

ANOTHER UNIT FOR ELECTRICAL ENERGY

the total energy is the product of the power and time

$E = Pt$ ($1J = 1$ watt $\times$ 1 second)

As time is most likely to be measured in hours (not seconds), we use the unit of energy 'watt hour' or 'kilowatt hour' where:

$$E(kWh) = P(kW) \times t(h)$$
$$= 10^3 W \times (60 min \times 60 s)$$

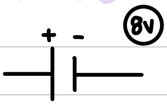
Thus

1 kilowatt-hour $= 1 kWh = 3\cdot6 \times 10^6 J$

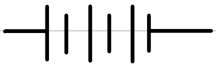
ELECTRICAL CIRCUIT SYMBOLS

DC

CELL



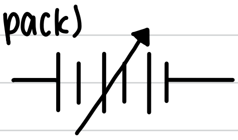
BATTERY



(made out of cells)

VARIABLE POWER SOURCE

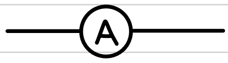
(power pack)



AC POWER SUPPLY

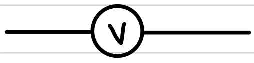
POWER

AMMETER



(measures current)

VOLTMETER

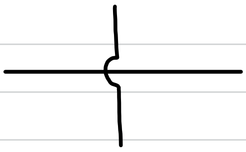


(measures voltage)
↑ increase in potential difference

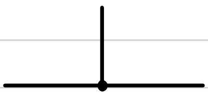
MEASURING

WIRE

WIRES CROSSED BUT NOT CONNECTED

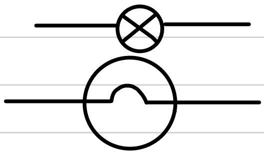


WIRES CONNECTED



WIRES

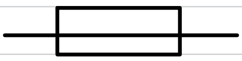
LIGHT GLOBES



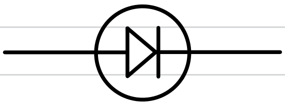
OPEN SWITCH

CLOSED SWITCH

FUSE

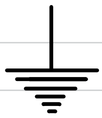


DIODE



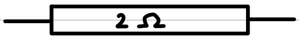
EARTH WIRE

'Earth'



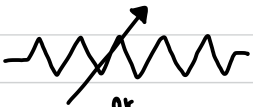
RESISTOR

or



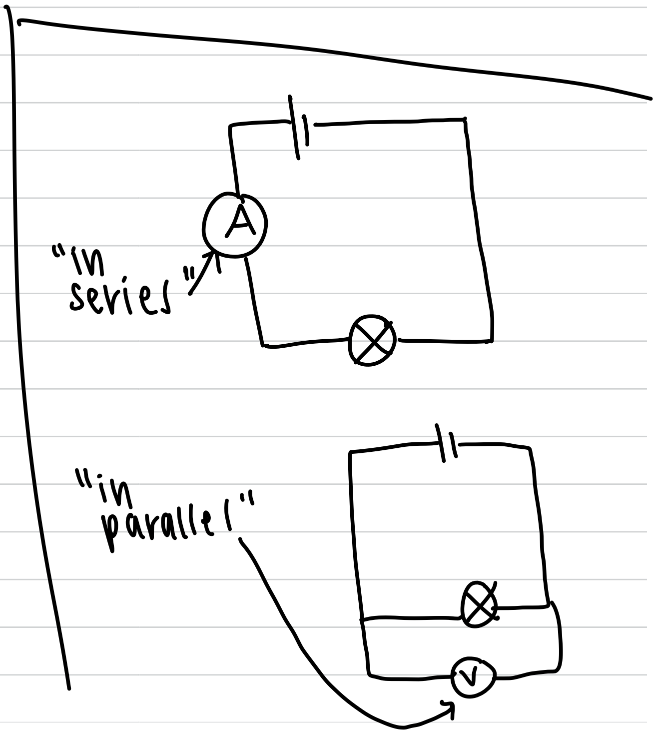
-way of changing current
(think of a narrow doorway)

VARIABLE RESISTOR



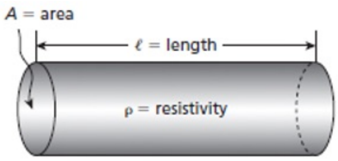
variable resistor

or



RESISTANCE

RESISTIVITY



resistance

$$\boxed{R = \rho \frac{\ell}{A}}$$

length

cross-sectional area

resistivity (Ωm)

resistance $\propto \ell$

$R \propto \frac{\ell}{A}$

+ affected by temp

OHM'S LAW

resistance affects current and voltage

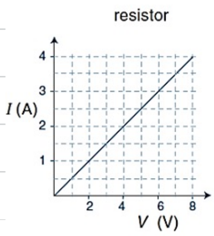
units : ohms Ω

$1\Omega = 1 V A^{-1}$

$$\boxed{R = \frac{V}{I} \qquad V = IR}$$

OHMIC RESISTOR

the resistance of ohmic devices is constant for a wide range of voltages and currents

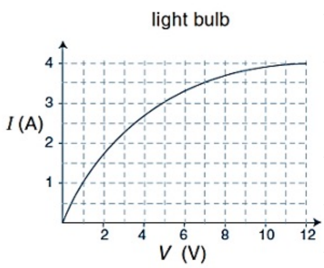


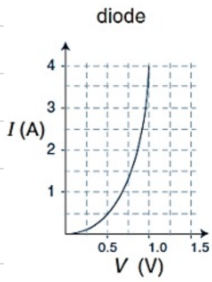
gradient = $\frac{rise}{run} = \frac{I}{V} = \frac{1}{R}$

$R = \frac{V}{I}$

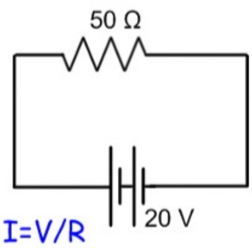
NON-OHMIC RESISTOR

in a non-ohmic device, the resistance changes as you vary voltage and current





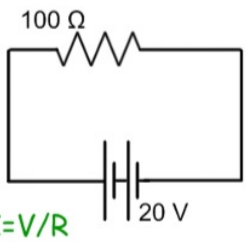
resistors are used in electrical devices to control the amount of current passing through the device



I=V/R

= 20/50

= 0.4 A



I=V/R

= 20/100

= 0.2 A

LIMITATIONS TO OHM'S LAW

- temp. needs to be constant
- some materials are affected by being bent, stretched or stressed in some way. This law only obeyed when all physical conditions remain constant
- it does not apply to semi-conductors, gases or solutions

KIRCHOFF'S LAWS

1 In any electrical circuit, the sum of all currents entering a point is equal to the sum of the current flowing out of it

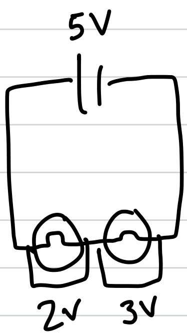
* the larger the current - the smaller the resistance *

diagram

2. total potential drop around a closed circuit must equal the total EMF in the circuit

voltage of battery

diagrams



RESISTORS IN SERIES vs PARALLEL

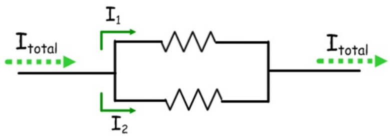
Resistors in series

- Resistors are connected one after each other

- Same current goes through each resistor

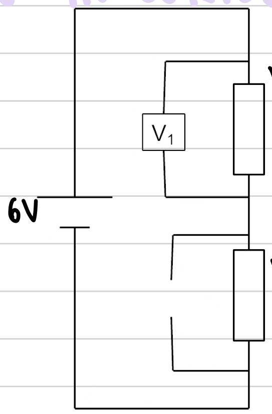
Resistors in parallel

- Resistors are connected opposite each other



- Circuit current must split so that some current flows through each resistor in a parallel connection

RESISTORS IN SERIES CIRCUITS



8Ω

$V_1 = I_1 R_1$

$= 0.5 \times 8$

$= 4V$

4Ω

$V = I_2 R_2$

$= 0.5 \times 4$

$= 2V$

these add to 6V (battery)

I = constant

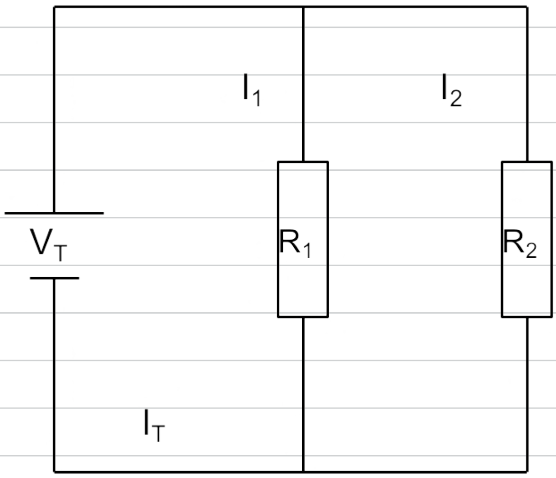
$R_t = R_1 + R_2 + \ldots$

$V_t = V_1 + V_2$

$V_{total} = I_{total} \times R_{total}$

$I_{total} = \frac{V_t}{R_t} = \frac{6}{12} = 0.5A$

PARALLEL CIRCUITS



$$\boxed{V_t = V_1 = V_2}$$

$$\boxed{I_t = I_1 + I_2}$$

$$\boxed{\frac{1}{R_t} \quad \frac{1}{R_1} \quad \frac{1}{R_2} \cdots \frac{1}{R_n}}$$

$$R_{total} = \left[\frac{1}{R_1} + \frac{1}{R_2} + \ldots \right]^{-1}$$

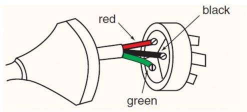
note: I splits
V is constant

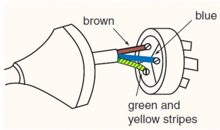
ELECTRICAL SAFETY

- fuse
- earth wire
- double insulation
- circuit breaker
- switch
- RCD

Wiring - colour codes

Wire	Previous (old)	International (new)
Active	red	brown
Neutral	black	blue
Earth	green	green / yellow





SHORT CIRCUITS + OVERLOADING

- overloading is usually the result of a short circuit (when too much current passes through)
- short circuits occur when an electrical circuit contains very little resistance
  - ↳ when this occurs, a large amount of current flows through the circuit
  - ↳ ∴ the wires will heat up, causing the insulation to melt or catch alight

FUSE + CIRCUIT BREAKERS

- designed to prevent electrical fires - not electrocution
- their function is to interrupt the flow of the current if it exceeds a certain value
- fuse - thin piece of wire which is designed to melt and break the circuit when a large amount of current flows through it
- circuit breaker - switch, usually found in power boards, which will break the circuit if the maximum designed current is exceeded

RCDs - RESIDUAL CURRENT DEVICE

- detect a difference between the current in the active wire and the current in the neutral wire
- if a difference is detected (usually because the current is going through to the earth through a fault or a person), the RCD switches off the supply in approximately 20ms

EARTH WIRE

- occurs on household items that usually have a metal case
- if the active inside the appliance becomes loose and touches the case, then the whole case will become electrically live
- an earth wire is permanently connected to the case so that if the active wire touches the case a short circuit will be created and the current will flow directly to earth

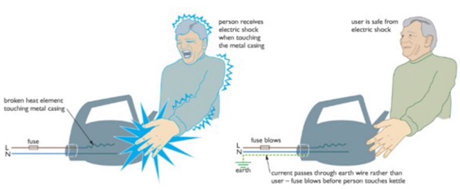


Figure 7.8 *The earth wire provides protection when electrical appliances develop a fault.*

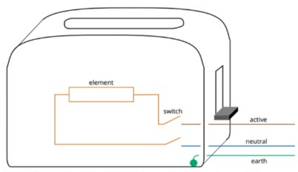
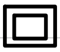


FIGURE 5.6.7 The earth wire inside a metal toaster is permanently connected to the casing.

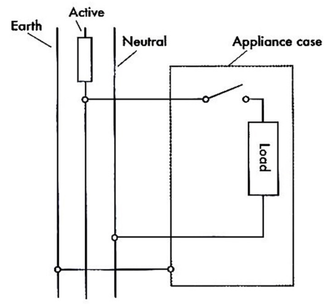
DOUBLE INSULATION

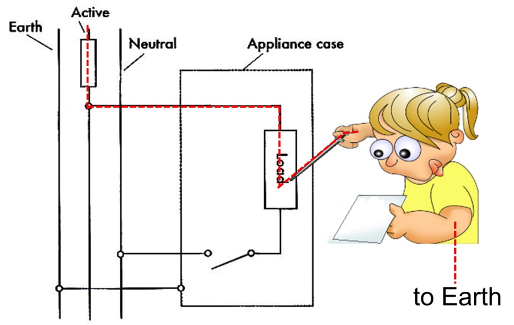
- another way of protecting against a loose wire inside an appliance
- involves 2 insulating barriers to protect users
- usually achieved by making the appliance case out of plastic
- symbol : 

SWITCHES

- always connected to the active wire

ALWAYS connect them to the active wire.

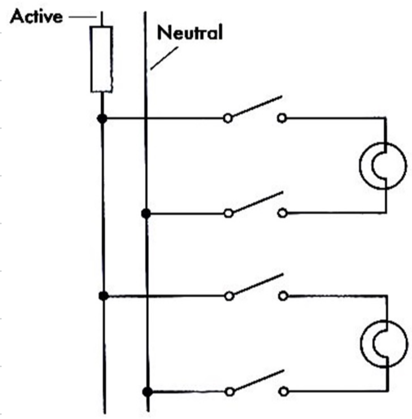




DOUBLE POLE SWITCHES

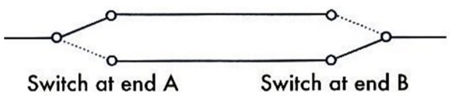
these connect (and disconnect) both the active and neutral wires when the switch is operated

prevents the device from being connected to the mains even though the switch is off

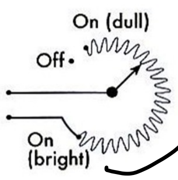


OTHER COMMON SWITCHES

Two way switches



Dimmer switch - comprises of components that act like a rheostat (variable resistor)



connected in series, reduces voltage available to the light globe thereby reducing the power and overall brightness (can't use $P = I^2 R$ equation) No longer used as they waste a lot of energy

ELECTRIC SHOCK

Current (mA)	Effect on the body
1	able to be felt
3	easily felt
10	painful
20	muscles paralysed—cannot let go
50	severe shock
90	breathing upset
150	breathing very difficult
200	death likely
500	serious burning, breathing stops, death inevitable

Time (s)	Effect on the body
less than 0.2	noticeable but usually not dangerous
0.2–4	significant shock, possibly dangerous
more than 4	severe shock, possible death

effect of electric shock depends on:
- amount of current
- duration
- path through the body