Physics ~~Chap~~ Component 1 - 1.1 / Basic Physics

Base units
- mass = kg
- distance = m
- time = s
- current = A
- quantity = mol
- Temperature = K

(+ candela)

Eg. Resistance in terms of base units

$$\Omega = \frac{V}{A} = \frac{J}{C} \times \frac{1}{A}$$
$$= \frac{Nm}{As} \times \frac{1}{A}$$
$$= \frac{kg\,ms^{-2}m}{A^2 s} = kg\,m^2 s^{-3} A^{-2}$$

You can check equations ~~by~~ by seeing if they are homogenous (base units are the same on both sides)

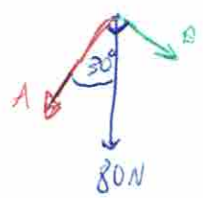
scalar = just magnitude
↳ eg. speed, time, density, pressure

vector = magnitude and direction
↳ displacement, velocity, acceleration, force

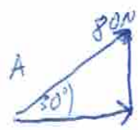
Vector component resolution

You can resolve a vector into two perpendicular components

eg

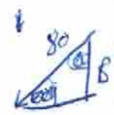


what are A and B?



$\cos 30 = \frac{A}{80}$

$A = 69.3N$



~~$\sin 60 = \frac{B}{80}$~~

$\cos 60 = \frac{B}{80}$

$B = 40N$

Density

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

Turning effect of force = moment = Force × perpendicular distance from pivot

When a body is in equilibrium the resultant force is zero and the net moment is zero.

Physics Component 1 - 1.2 / Kinematics = speed, distance, acceleration

do not memorise

Displacement - the change in position of an object / m

mean speed - Total distance travelled by an object divided by the time it took to cover that distance / ms^{-1}

instantaneous speed - The speed of an object at a particular moment

velocity - The speed of something in a given direction / ms^{-1}

acceleration - The rate of change of velocity / ms^{-2}

Suvat equations

(s) $v = u + at$

(t) $v^2 = u^2 + 2as$

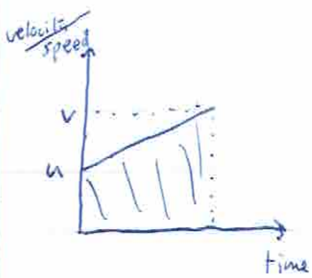
(v) $s = ut + \frac{1}{2}at^2$

(u) $s = vt - \frac{1}{2}at^2$

(a) $s = \frac{1}{2}(u+v)t$

missing value

↳ Derivations



area = distance = $\frac{1}{2}(u+v)t$

$s = \frac{1}{2}(u+v)t$ ①

~~mean~~ acceleration = $\frac{\Delta \text{velocity}}{t}$

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

$v = u + at$ ②

subs ② into ①

$s = \frac{1}{2}(u+u+at)t$

$= \frac{1}{2}(2u+at)$

$= \frac{1}{2}(2ut+at^2)$

$s = ut + \frac{1}{2}at^2$

or $s = \frac{1}{2}(v-at+v)t$

$= \frac{1}{2}(2vt - at^2)$

$s = vt - \frac{1}{2}at^2$

rearrange ① => $t = \frac{2s}{u+v}$

subs into ② $v = u + a\left(\frac{2s}{u+v}\right)$

$v = u + \frac{2as}{u+v}$

$v^2 = u^2 + 2as$

$v^2 = u^2 + 2as$

Physics Component 1 - 1.3 / Dynamics "Forces"

Newton's 3rd Law - Forces always exist in pairs such that if object B exerts a force on A, then A exerts an equal and opposite force on B, which is coplanar and of the same type.

$$\Sigma F = ma$$

when mass is constant

$$P_{(momentum)} = mv$$

$$\text{Impulse} = Ft = \Delta P$$

$\therefore \; F = \frac{\Delta P}{\Delta t}$ $\therefore$ Force = rate of change of momentum where mass is constant

Priciple of conservation of momentum = In an isolated system with no external forces the initial total momentum of objects before a collision equals the final total momentum of objects after a collision

Newton's 2nd Law - ~~A~~An objects rate of change of momentum is directly proportional to the force acting upon it, and this change occurs in the direction of the ~~force~~ applied force

Physics Component 1 - 1.4 / Energy Concepts

Work :- Work is the product of a force and distance moved in the direction of the force when the force is constant.

↳ $W = Fd$ = ($W = Fd\cos\theta$, θ = angle between F and d)

better

$W = \Delta E$

- Conservation of energy is very important in this topic

$G.P.E = mg\Delta h$ $E.P.E = \frac{1}{2}kx^2$ $KE = \frac{1}{2}mv^2$

- Power is the rate of energy transfer

$P = \frac{\Delta E}{\Delta t}$ $P = \frac{W}{\Delta t}$

Dissipative forces like friction and drag cause energy to be transferred from a system and reduce the overall efficiency of the system.

$$\text{Efficiency} = \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$$

Useful Equations

$$W = \frac{1}{2}Fx = \frac{1}{2}kx^2 = E_p$$

$W = \Delta E$

$$P = mv$$

Physics Component 1 - 1.5 / Circular Motion

Period of rotation/orbit: The period is the time taken to complete one cycle/revolution
- Unit = seconds, symbol = T

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

Frequency: - The number of cycles/rotations per second
- unit = s^{-1} = Hz, symbol = f (or ν in black bodies topic)

Radians: - a measure of angle
- $\boxed{1 \text{ rad} = \frac{180}{\pi}°}$ $2\pi \text{ rads} = 360°$

Angular velocity: - defined by $\omega = \frac{d\theta}{dt} = \dot{\theta}$ ← Time derivative of θ = rate of change of θ
- $\therefore \boxed{\omega_{average} = \frac{\Delta\theta}{\Delta t}}$
- unit = s^{-1} = Hz (or rads/sec) (or rpm) $1 \text{rpm} = \frac{\pi}{30}$ rads/second
- $\therefore$ if circular motion is uniform, then $\dot{\theta}$ = constant

Centripetal force is the resultant force acting on a body moving at constant speed in a circle and ALWAYS POINTS TOWARDS THE CENTRE. This force does <u>no</u> work as it is perpendicular to the direction of movement. Centripetal acceleration is a result of the object's changing <u>direction</u> and also is always directed towards the centre of the ~~circle~~ circular motion.

<u>Equations</u>

$f = \frac{1}{T}$ $\omega = \frac{d\theta}{dt} = \dot{\theta} = \frac{\Delta\theta}{\Delta t} \text{(avg)} = \frac{v}{r} = \frac{2\pi}{T} = 2\pi f$

$l = \theta r$ $V_{tangent} = \omega r$ $a = \omega^2 r = \frac{v^2}{r}$

$F_c = \frac{mv^2}{r} = \omega^2 rm$

F_c ← centripetal force

$$\boxed{F_R = \mu N}$$

F_R ← friction, μ ← material's friction coefficient, N ← normal reaction to weight

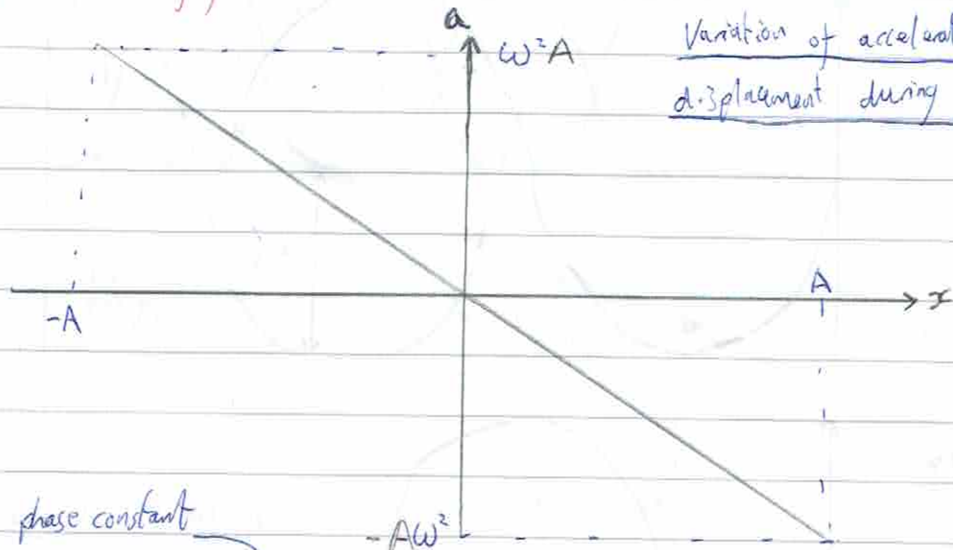
don't really need at all

Physics Component 1 - 1.6 / Vibrations (SHM)

Simple harmonic motion = when an object moves so that its acceleration is always directed towards a fixed point and is proportional to its displacement from that point

= when an object is moving back and forth about a fixed point basically

(mathematically) $a = -\omega^2 x$



Variation of acceleration with displacement during SHM

phase constant

$x = A\cos(\omega t + \varepsilon)$

$\omega = \frac{2\pi}{T}$ $\quad T = 1/f$

differentiate

$v = -A\omega \sin(\omega t + \varepsilon)$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{L}}$

differentiate

$a = -A\omega^2 \cos(\omega t + \varepsilon)$ ~~$-A\omega^2(A\cos$~~ $\quad a = -\omega^2(A\cos(\omega t + \varepsilon))$

$\underline{a = -\omega^2 x}$ ∴ these equations work with SHM

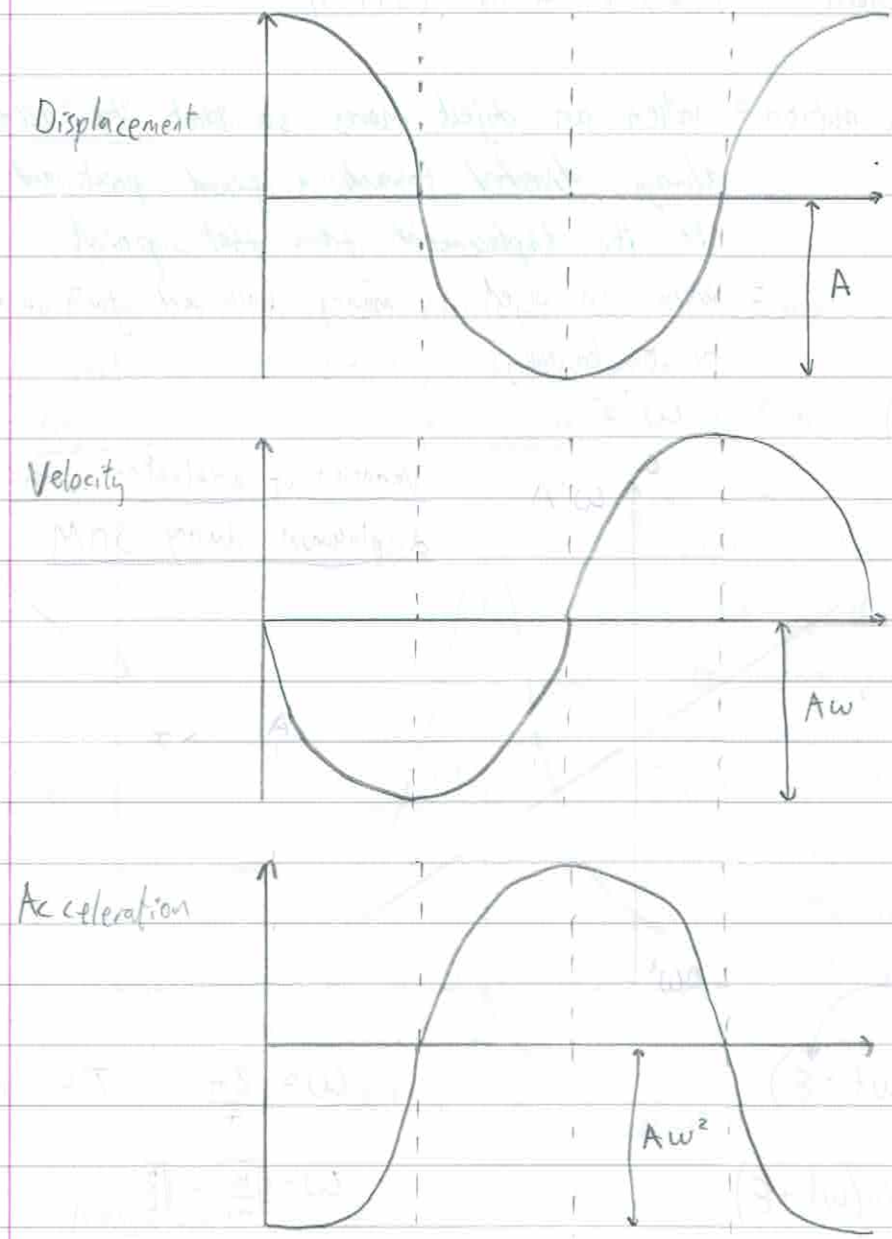
Amplitude = maximum value of displacement

Period = the time for one cycle of oscillation

frequency = no. of oscillations per second = 1/period

phase = stage in oscillation cycle at time t

phase constant = stage in oscillation ~~at~~ cycle at time t = 0



if asked to reproduce in exam do the first one then v is the gradient of x and a is the gradient of v

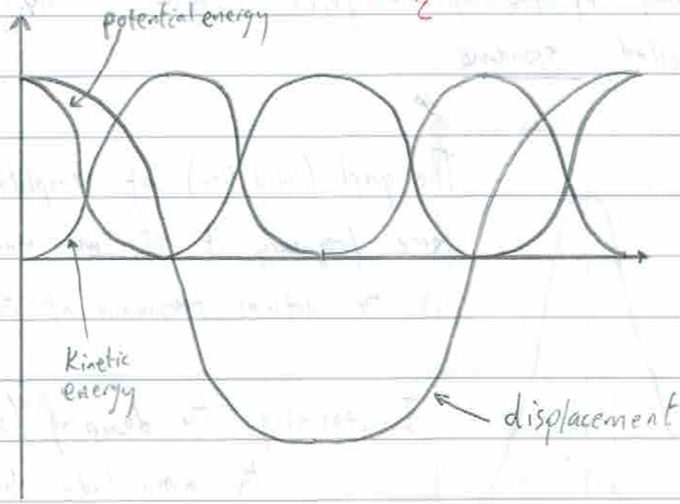
Energy in SHM

don't need these two but may be useful

potential energy = $U = \frac{1}{2}kx^2 = \frac{1}{2}m\omega^2A^2\cos^2(\omega t + \varepsilon)$

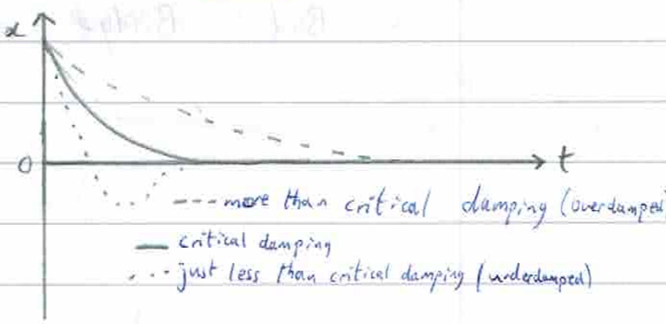
Kinetic energy = $K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2A^2\sin^2(\omega t + \varepsilon)$

Total energy = $E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2 = \frac{1}{2}mA^2\omega^2$



Damped Oscillations (or natural/free oscillations)

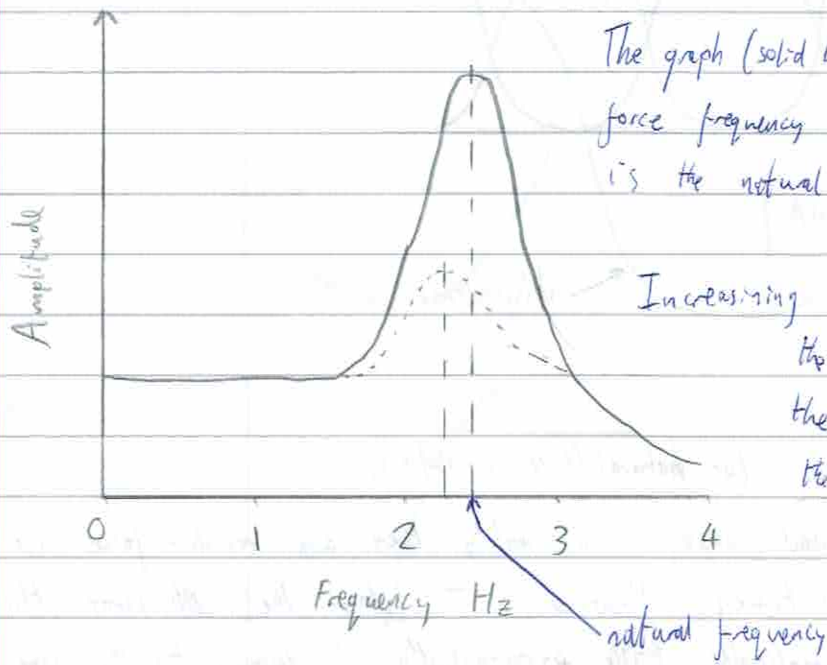
SHM is an ideal case, in reality there are resistive forces which causes E and A to decrease over time. However, T stays the same throughout the motion. The amplitude falls exponentially (it decreases by the same fraction each cycle). The resistive forces also mean that the period is slightly higher than in an ideal situation (this effect is very small <u>unless</u> the damping is very heavy)



Critical damping is when the object doesn't oscillate but returns to equilibrium <u>as fast as possible</u> without overshoot. This can be very useful in cases like car suspension to prevent oscillations.

Forced Oscillations

When a system capable of oscillations is subject to a sinusoidally varying driving force forced oscillations occur. The system soon settles down to oscillating at the frequency of the driving force. The amplitude of the oscillations is largest when the frequency of the applied force is equal to the system's natural frequency. This is called resonance.



The graph (solid line) of amplitude against driving force frequency is at maximum when the frequency is the natural frequency of the system.

Increasing the damping (dotted line) reduces the amplitude but it also broadens the resonance curve. It also reduces the natural frequency slightly.

Resonance

Useful: microwave cooking, circuit tuning
Bad: Bridge design

Physics Component 1 - 1.7 / Kinetic Theory

Equation of state for an ideal gas: $pV = nRT$ (SI units)

n: no. of moles; R: molar/ideal gas constant

or

$pV = NkT$ $\qquad k = \frac{R}{N_A}$

N: no. of molecules; k: Boltzmann constant

~~Assumptions: KE~~

Assumptions of the Kinetic Theory of gases

- Gas in question consists of a large number of identical particles, of negligible volume, in a state of random motion (constant velocity between collisions)
- Forces are only exerted on particles during collisions (no long-range interparticular forces or forces due to the presence of any type of field)
- All collisions are perfectly elastic (KE conserved)
- The duration of collisions are negligible compared to the time between them
- The laws of classical (rather than quantum) physics pertain at this scale
- Random distribution of energy among the molecules

The pressure exerted by a gas is due to molecular movement

$$p = \frac{1}{3}\rho\langle c^2\rangle = \frac{1}{3}\frac{N}{V}m\langle c^2\rangle$$

ρ: density

$\langle c^2\rangle = c_{rms}^2$

ρ = density
n = no. of moles
N = no. of particles
m = mass of particle

M = molar mass
M_r = relative molecular mass
M_T = mass of gas
N_A = avagadro's number

$N = nN_A \quad M_T = Nm$
$M_T = nN_Am$

eduqas symbol M → molar mass (kg/mol) $= \frac{M_T}{n}$

molar mass (kg) $= \frac{M_r}{1000}$

$n = \frac{M_T}{M}$

Avagadro's number/constant = ~~The number of particles~~ The number of particles that are contained in one mole of a substance

- $\boxed{6.02 \times 10^{23}\ mol^{-1}}$

You may need to combine $pV = \frac{1}{3} Nm\langle c^2\rangle$ with $pV = nRT$ and show that total translational kinetic energy of a mole of a monatomic gas is given by $\frac{3}{2}RT$ 1 and the mean KE of a particle is $\frac{3}{2}kT$ 2 and that T is proportional to mean KE. 3

$P = \frac{1}{3} \rho C_{rms}^2$

$pV = \frac{1}{3} N_m \langle c^2\rangle \Rightarrow pV = \frac{1}{3} M_T C_{rms}^2$

$P = \frac{1}{3} \frac{M}{V} C_{rms}^2$

$PV = \frac{1}{3} M_T C_{rms}^2 \longrightarrow$

$PV = nRT \longrightarrow$

$nRT = \frac{1}{3} M_T C_{rms}^2$

$nRT = \frac{1}{3}(\cancel{n} N_A) m C_{rms}^2$

$\frac{1}{3} N_A m C_{rms}^2 = RT$

or

$\frac{1}{3} m C_{rms}^2 = \frac{RT}{N_A}$ $\left(\frac{R}{N_A} = k\right)$

$\frac{1}{3} m C_{rms}^2 = kT$

$m C_{rms}^2 = 3kT$

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

$\frac{1}{2} m C_{rms}^2 = \frac{3}{2} kT$

Avg KE of particles $= \frac{3}{2} kT$

$\langle KE\rangle = \frac{3}{2} kT$ 2

$\frac{3}{2} k = \text{constant}$

$\therefore \langle KE\rangle = cT$

$\therefore T \propto \langle KE\rangle$ 3

$N_A \frac{1}{3} m C_{rms}^2 = RT$

$\frac{1}{2} N_A m C_{rms}^2 = \frac{3}{2} RT$

$N_A m = M$

mass of one mole

$\frac{1}{2} M C_{rms}^2 = \frac{3}{2} RT$

$\boxed{\text{Total translational KE of a mole of monatomic gas} = \frac{3}{2}RT}$ 1

$\therefore$ Total KE of 1 mole $= \frac{3}{2} RT$

$\langle KE\rangle = \frac{3}{2} kT$

Physics Component 1 - 1.8 / Thermal Physics

The internal energy of a system is the sum of the kinetic energies (relative to its centre of mass) of its particles and the potential ~~energy~~ energies of interactions between them.

↳ absolute zero is the temperature of a system when it has minimum internal energy

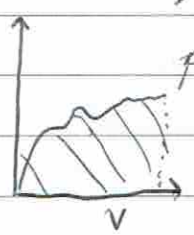
The internal energy of an ideal monatomic gas is wholly kinetic so it is given by $U = \frac{3}{2}nRT$

Heat enters or leaves a system through its boundary or container wall, according to whether the system's temperature is lower or higher than that of its surroundings, so heat is energy in transit and not contained within the system.

If no heat flows between two systems in contact, then they are said to be in thermal equilibrium and are at the same temperature.

Energy can also ~~enter~~ enter / leave a system by means of work, so work is also energy in transit.

↳ To calculate the work done by a gas under constant pressure use: $W = p\Delta V$



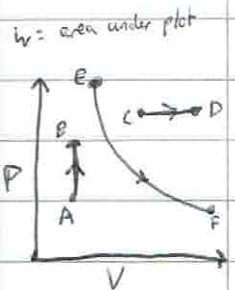
↳ even if the pressure changes, W can be found using the area under the p-V graph

The first Law of Thermodynamics

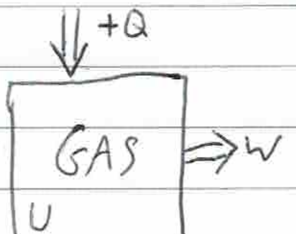
$\Delta U = Q - W$ The change in the internal energy of a gas is equal to the heat added to the gas, minus the work done by the gas.

work can be done by a gas during expansion, and can be done on a gas during compression

W = area under plot



A→B = constant volume: W=0
C→D = constant pressure: Q=0
E→F = constant temp
= isothermal
= ΔU=0



negative value	meaning
$(-\Delta U)$	loss in internal energy
$(-Q)$	heat lost from gas
$(-W)$	work done on gas

isothermal = a change that occurs at constant temp.

Also, if referring to 'rapid' expansion/compression, Q=0

For a solid or liquid, W is usually negligible, so: $Q = \Delta U$ ← kinda obvious

Specific Heat Capacity

$Q = mc\Delta\theta$ = defining specific heat capacity

Q: energy supplied, J
m: mass, Kg
c: S.H.C, $JKg^{-1}K^{-1}$
$\Delta\theta$: temp. change, K

↳ Thermal energy that must be supplied to increase the temp. of 1 Kg of a substance by 1 K without state change

'specific' = per unit mas

Since c = S.H.C
mc = heat capacity