Revision lecture Phys1121-1131. UNSW

Necessary tools:

- Vectors,
  - components (force digrams for Newton 2),
  - addition and subtraction (relative velocities etc)

$$\mathbf{v} = \mathbf{v}_{frame} + \mathbf{v}'$$

  - dot product (for work)
  - $\mathbf{a.b} = ab \cos \theta$
  - $\mathbf{a.b} = a_x b_x + a_y b_y$
- Simultaneous equations
  - solve n equations in n unknowns
- Simple differentiation and integration

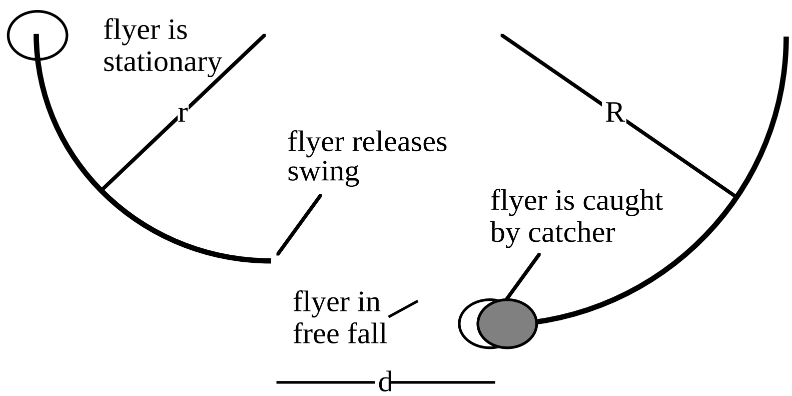
How big?

kg, m, s, $m.s^{-1}$, $m.s^{-2}$

N	kN	mN
J	kJ	mJ
$kg.m.s^{-1}$	10^3 $kg.m.s^{-1}$	
K	kJ	($kJ.kg^{-1}.K^{-1}$)
kW		

Question. A trapeze act in a circus is the one in which people swing and jump, high in the air. In a simple model of a simple trick, we treat the people as particles (ie neglect the internal motion and rotation), and neglect air resistance.

One person, called the flyer, with mass m, starts from rest on a swing that swings with radius r. Her initial motion is vertically down, as shown. When she is travelling horizontally, she releases the swing and travels in free fall for a horizontal distance d, at which point she is caught by the catcher, whose mass is M, and who is stationary at the instant of the catch. During the catch, their displacement is << R, where R is the radius of the arc in which they swing together after the catch. Determine how high they rise after the catch.



i) Circular motion,
   what do we need? what principle?

ii) Projectile motion
   what do we need? what principle?

iii) Collision (elastic or not?)
   Is momentum conserved?
   So..... what do we need?

iv) Circular motion
   what do we need? what principle?

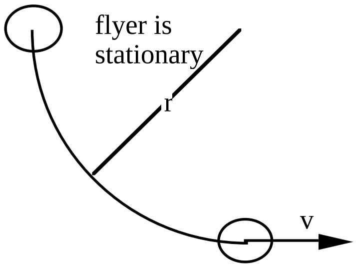
i) final v M.E. conserved

ii) final v_X
   a) (M.E. conserved.) b) v_X constant

iii) Collision is ***in***elastic. M.E. ***not*** conserved
   Momentum is *not* conserved in y direction
   Negligible external force in x direction so
   $\mathbf{p}_X$ is conserved.

iv) M.E. conserved

i)



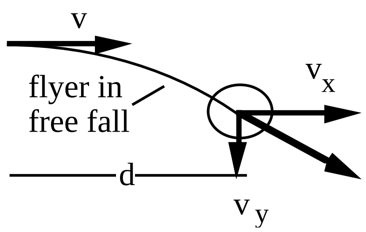
First swing: Non conservative forces do no work, so mechanical energy is conserved.

$U_i + K_i = U_f + K_f$

$mgr + 0 = 0 + \frac{1}{2}mv^2$

$v = \sqrt{2gr}$

ii)

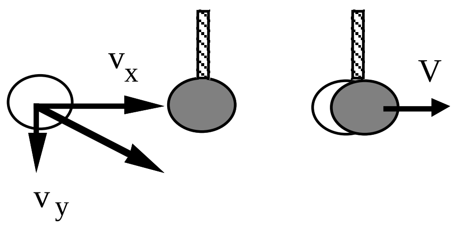


Projectile motion

$v_x = v$

(is all we need)

iii) Collision



Momentum ***not*** conserved in vertical direction: large external force in rope.

No external *horizontal* forces, so

$p_{xi} = p_{xf}$

$mv_x = (M+m)V$

$V = \frac{mv}{M+m}$

iv) No non conservative forces:

$U_i + K_i = U_f + K_f$

$0 + \frac{1}{2}(M+m)V^2 = (M+m)gh + 0$ (*new zero for U*)

$h = \frac{V^2}{2g} = \frac{1}{2g}\left(\frac{mv}{M+m}\right)^2 = r\left(\frac{m}{M+m}\right)^2$

Consolidate with similar probs

Two or more steps (collision plus conservative steps)

- Ballistic pendulum (very similar)
- Collision and spring
  - Bullet proof vest
  - Hammering the chest

<u>Collision</u>	<u>Conservative step</u>
bullet hits vest	compression of chest
hammer hits brick	compression of chest
p conserved	K + U
	$\frac{1}{2}mv^2 + \frac{1}{2}kx^2$ conserved

Revision of Heat

Temperature (T) and heat Q:

T is equal in any 2 bodies at thermal equilibrium

T is intensive thermal energy $k_B T/2$ in each molecular motion

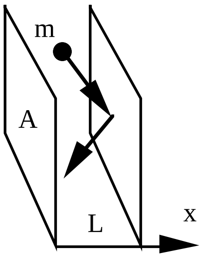
Q is extensive (total) thermal energy

($\propto$ m: $Q = cm\Delta T$)

Absolute temperature scale

$T \propto P$ in a low density gas

Kinetic Theory



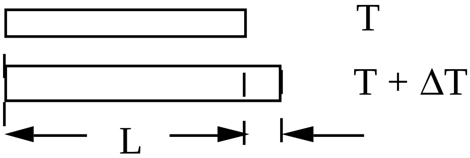
Newtonian calc $\rightarrow$

$$PV = \frac{N}{3} m \overline{v^2}$$

$$P = \frac{1}{3}\rho \overline{v^2}$$

$$\therefore \quad \bar{\varepsilon} = \frac{1}{2} m \overline{v^2} = \frac{3}{2}\frac{PV}{N} = \frac{3}{2} kT$$

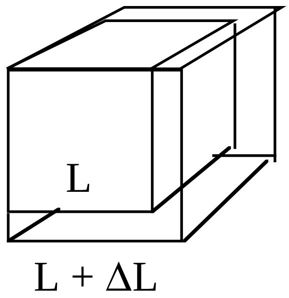
Thermal Expansion



$\therefore$ **Define** $\frac{\Delta L}{L} = \alpha \Delta T$ $\frac{\Delta V}{V} = \beta \Delta T$

α is coefficient of linear expansion

β is coefficient of volume expansion



$\Delta V = (L + \Delta L)^3 - L^3$

$= .....$

$\approx V \cdot 3\alpha\Delta T$

$\therefore \ \beta \approx 3\,\alpha$

Differential expansion problems (see notes)

Example: what is β for an ideal gas?

$$\beta \equiv \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \qquad \text{and} \qquad PV = nRT$$

$$V = \frac{nRT}{P}$$

$$\beta = \left(\frac{P}{nRT}\right)\frac{\partial}{\partial T}\left(\frac{nRT}{P}\right) = \frac{1}{T}$$

Heat Capacity: (for a body) $C = \frac{\Delta Q}{\Delta T}$

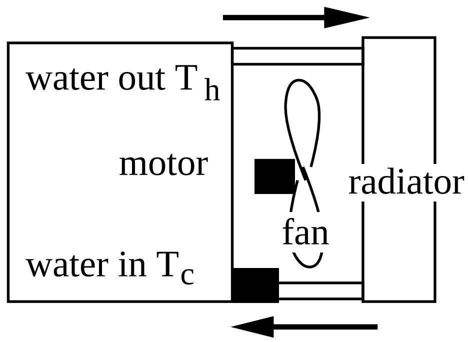
extensive quantity

Specific Heat: (of a substance) $c = \frac{\Delta Q}{M\Delta T}$

intensive quantity

Latent Heat: heat required per unit mass for change of phase (at constant T).

Question. In steady state, T of motor is not changing.



Water in to radiator at 80°C and out at 50°C.
Motor generates 30 kW of heat. What is the flow rate through the radiator?

measure flow rate in kg/s: $\frac{dm}{dt} = ?$ (i)

heat needed to raise T of water.

We are given $\frac{dQ}{dt} = 30$ kW (ii)

What quanitity do we need?

Specific heat $c \equiv \frac{1}{m}\frac{Q}{\Delta T}$

Heat to warm dm of water $dQ = dm.c\Delta T$ (iii)

(i, iii & iii) $\frac{dm}{dt} = \frac{1}{dt}\cdot\frac{dQ}{c\Delta T} = \frac{1}{c\Delta T}\frac{dQ}{dt}$

$$= \frac{1}{4.2\ \text{kJ.kg}^{-1}.\text{K}^{-1} * 30\text{K}}\ 30\ \text{kW}$$

$$= 0.24\ \text{kg/s} \qquad (14\ \text{litres/min})$$

If motor is 33% efficient, how rapidly can it drive a 1 t car up a 1:10 hill (neglect air resistance)?

1/3 efficient. If 30 kW wasted, 15 kW produced. (45kW used)

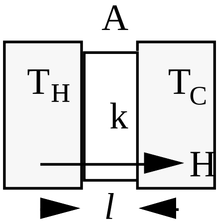
$$\frac{d}{dt}\, mgh = 15 \text{ kW}$$

$$\frac{dh}{dt} = \frac{15 \text{ kW}}{1000 \text{ kg}\ \ 9.8 \text{ ms}^{-2}} = 1.5 \text{ ms}^{-1}$$

On 1:10 hill, v = 15 m/s = 54 kph (> speed limit)

(at this speed air resistance < component of weight)

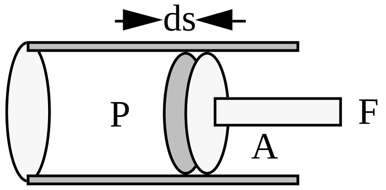
Heat conduction



$$H \equiv kA\, \frac{T_H - T_C}{l}$$

In *steady state*, heat is lost at the same rate it is produced. (Several examples in notes)

Work done against pressure P



$dW = \mathbf{F.ds} = PA\,ds = PdV$

1st Law $dU = dQ - dW$
where U is a state function

Isobaric P constant
Adiabatic Process: $\Delta Q = 0$ (fast or insulated)
Isothermal process: T constant

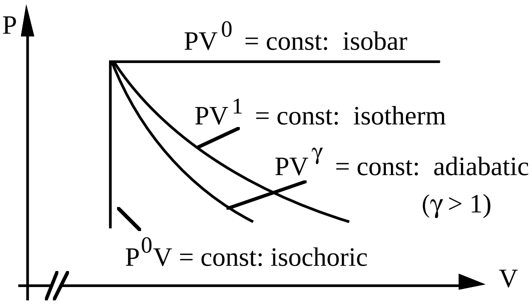
Work out work:
Isobaric: $W = \int P\,dV = P\Delta V$

Isothermal: $W = \int P\,dV = \int \frac{nRT}{V} dV = nRT\, ln \frac{V_f}{V_i}$

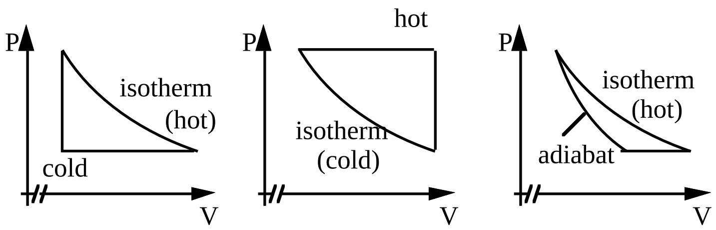
Adiabatic: $PV^{\gamma} = \text{constant}$

$\gamma \equiv \frac{c_P}{c_V} > 1$ (~1.4 for air)

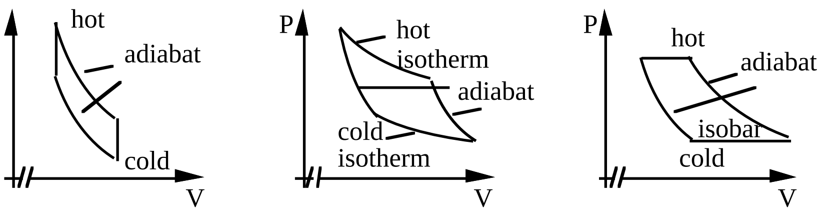
P-V diagrams and thermal cycles



Simple cycles typical of those found in tut and exam questions



Idealised cycles sometimes approximated



conceptually easiest | most efficient | ~ thermo-acoustic

What happens to W, U and Q in

isothermal expansion

adiabatic expansion

isobaric expansion

whole cycle