Phys 101.

Lecture 8. Mon. Jan. 20, 2003.

Topics covered: Drag.
Circular Motion.

Ref: 6-5, Notes.

Demo: Feather and Hammer.
coffee filter.
ball in a ring.

• Drag — when an object moves in a fluid, it experiences resistance of the fluid. This resistant force is called drag.

e.g: Air Resistance.

— Feather and Hammer fall at the same time.

(A). on the moon: They hit the ground at the same time.

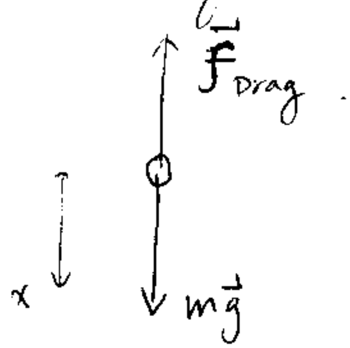
(B). on the earth: Hammer hits the ground first. (because of the air resistance on earth).

e.g: Riding on a motorcycle: f_{Drag} increases with v.

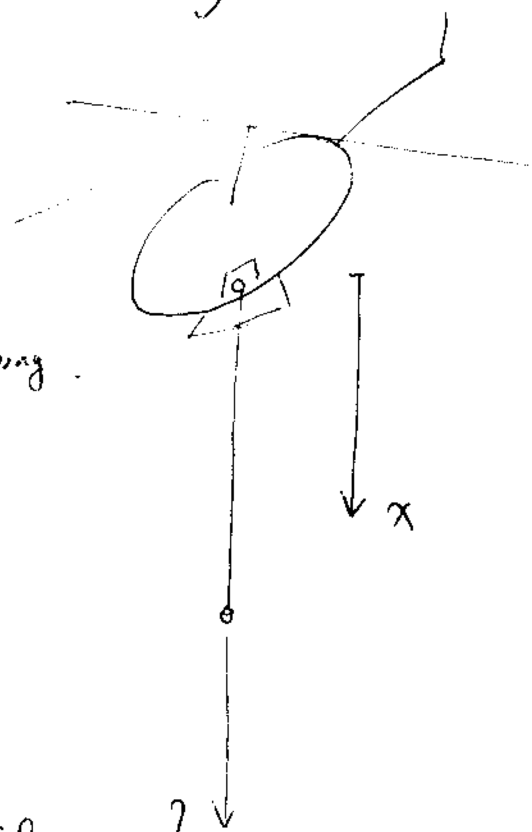
(The faster the speed, the larger the drag force).

- Falling in air — Terminal velocity.

Free-Body Diagram.



$$\vec{F} = m\vec{g} + \vec{f}_{Drag}.$$



when $t=0$, $v=0$, $f_{Drag}=0$.

$F = mg$, $a = g$.

when $t>0$, $v>0$, $\left\{ \begin{array}{l} |f_{Drag}| \neq 0. \\ \text{but } |f_{Drag}| < mg \end{array} \right\}$.

$F < mg$, $a < g$ but $a > 0$.

$\therefore$ $v \uparrow$, i.e., $|f_{Drag}| \uparrow$.

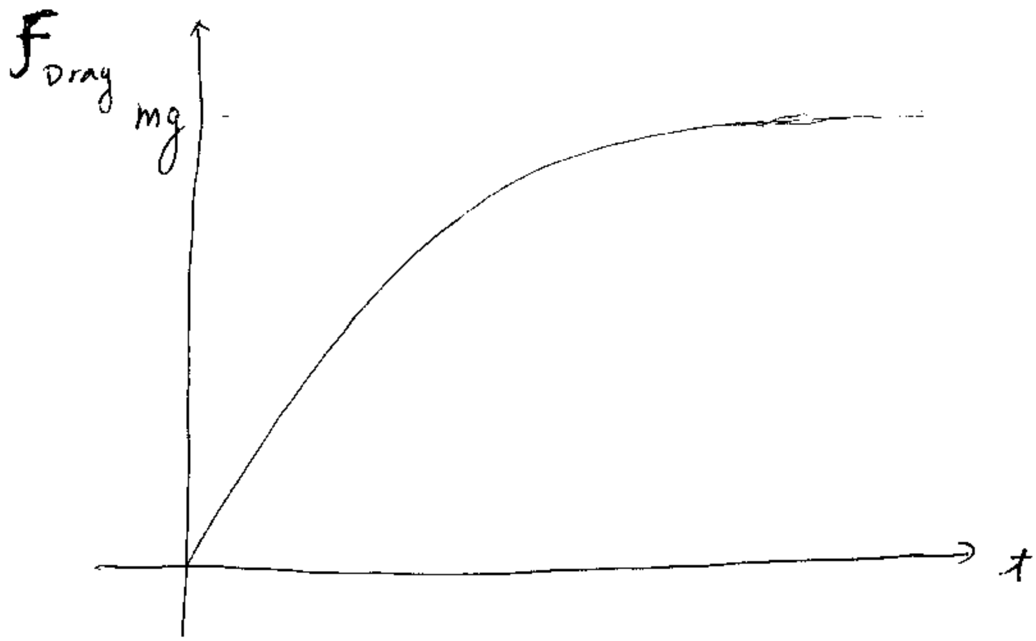
until at some time $|f_{Drag}| = mg$.

i.e. $F = 0$. $a = 0$.

Then, $v = \text{const} = v_{Terminal}$.

$\uparrow$

called the Terminal velocity.



- Relation between f_{Drag} and v

  - slow motion (No Turbulence).

$$f_{Drag} = c_1 v \quad (\propto v)$$

  - fast motion (with turbulence).

$$f_{Drag} = c_2 v^2 \quad (\propto v^2)$$

c_1, c_2 — depend on shape, size of the object and the property of the fluid.

e.g. Falling of Coffee filters.

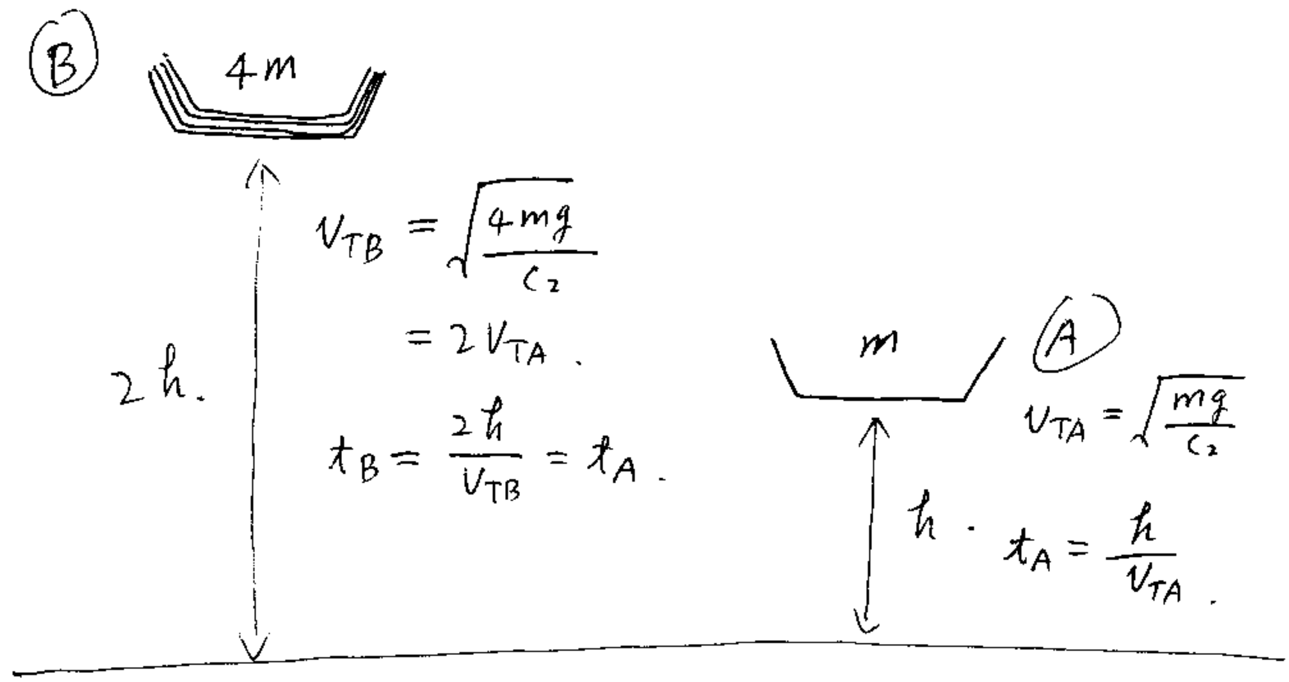
Turbulence.

The motion is considered as fast because of the Turbulence.

$$f_{Drag} = C_2 V^2$$

$$mg = C_2 V_T^2$$

$$V_T = \sqrt{\frac{mg}{C_2}} \propto \sqrt{m}.$$



$$V_{TB} = \sqrt{\frac{4mg}{C_2}} = 2V_{TA}.$$

$$t_B = \frac{2h}{V_{TB}} = t_A.$$

$$V_{TA} = \sqrt{\frac{mg}{C_2}}$$

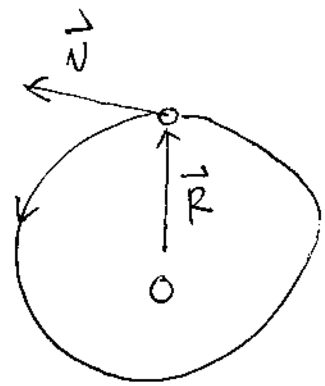
$$t_A = \frac{h}{V_{TA}}.$$

Note. We assume that the Terminal velocity is reached quickly. $\therefore\ t \approx \frac{h}{V_T}$

- Circular Motion

at a constant speed v.

constants:



T — period.

R — Radius.

v — speed.

f — $\frac{1}{T}$. frequency.

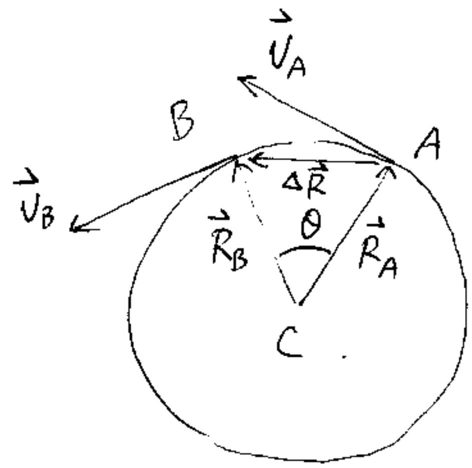
The position of the object is described by vector $\vec{R}$.

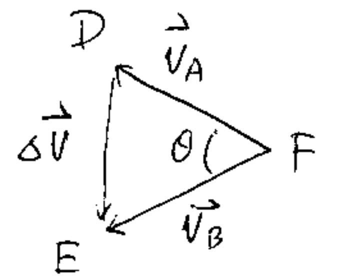
The velocity of the object is $\vec{v}$. The direction of $\vec{v}$ is along the tangential direction.

We need to figure out the acceleration.

idea: $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t}$.

In time interval Δt, the object moves from A to B.





The position is changed from $\vec{R}_A$ to $\vec{R}_B$.

$$\Delta\vec{R} = \vec{R}_B - \vec{R}_A$$

The velocity is changed from $\vec{v}_A$ to $\vec{v}_B$.

$$\Delta\vec{v} = \vec{v}_B - \vec{v}_A.$$

$$\triangle ABC \sim \triangle DEF \quad (\because \angle\theta = \angle\theta)$$

Thus,

$$\frac{|\Delta\vec{R}|}{R} = \frac{|\Delta\vec{v}|}{v}.$$

$$\lim_{\Delta t \to 0} \left(\frac{1}{\Delta t}\right) \cdot \frac{|\Delta\vec{R}|}{R} = \lim_{\Delta t \to 0} \left(\frac{1}{\Delta t}\right) \frac{|\Delta\vec{v}|}{v}.$$

$$\frac{v}{R} = \frac{a}{v}.$$

$\therefore \; a = \dfrac{v^2}{R}$. — magnitude of acceleration.

The direction of $\vec{a}$: centre-seeking. (centripetal acceleration).