

Chapter 5 – Force and Motion II

- I. Drag forces and terminal speed.
- II. Uniform circular motion.
- III. Non-Uniform circular motion.

I. Drag force and terminal speed

-**Fluid**: anything that can flow. Example: gas, liquid.

-**Drag force**: \vec{D}

- Appears when there is a relative velocity between a fluid and a body.
- Opposes the relative motion of a body in a fluid.
- Points in the direction in which the fluid flows.

Assumptions:

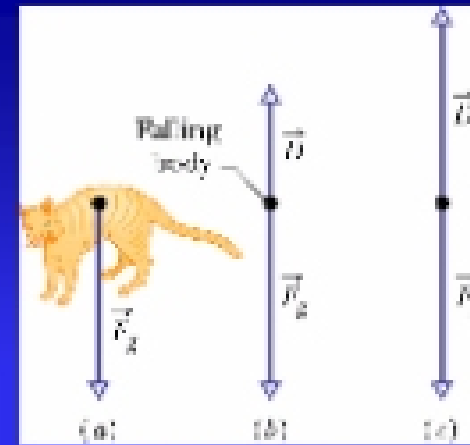
- * Fluid = air.
- * Body is blunt (baseball).
- * Fast relative motion → turbulent air.

$$D = \frac{1}{2} C \rho A v^2 \quad (6.3)$$

C = drag coefficient (0.4-1).

ρ = air density (mass/volume).

A = effective body's cross sectional area \rightarrow area perpendicular to \vec{v}



-Terminal speed: v_t

- Reached when the acceleration of an object that experiences a vertical movement through the air becomes zero $\rightarrow F_g = D$

$$D - F_g = ma \rightarrow \text{if } a = 0 \rightarrow \frac{1}{2} C \rho A v^2 - F_g = 0$$

$$v_t = \sqrt{\frac{2F_g}{C\rho A}} \quad (6.4)$$

II. Uniform circular motion

-Centripetal acceleration:

$$a = \frac{v^2}{r} \quad (6.5)$$

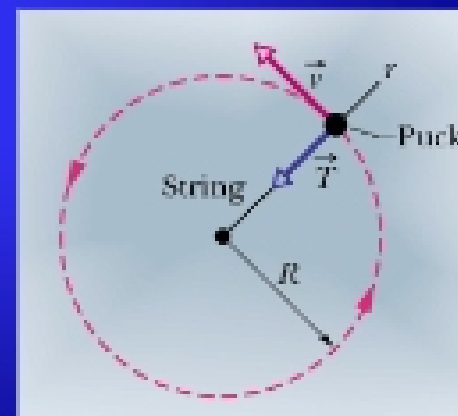
$v, a = \text{ctes}$, but direction changes during motion.

A centripetal force accelerates a body by changing the direction of the body's velocity without changing its speed.

-Centripetal force:

$$F = m \frac{v^2}{R} \quad (6.6)$$

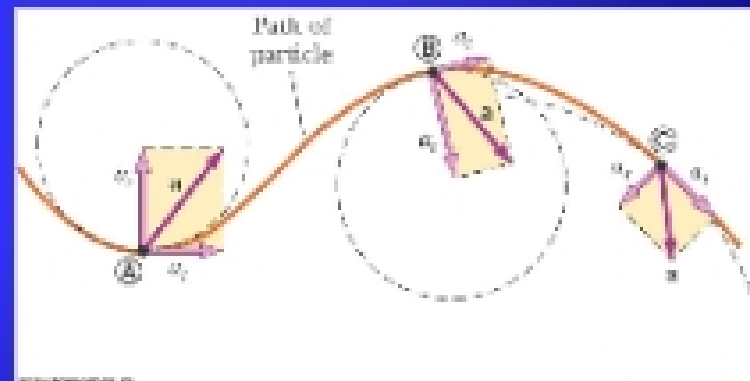
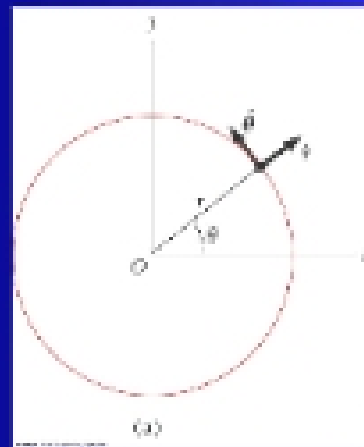
\vec{a}, \vec{F} are directed toward the center of curvature of the particle's path.



III. Non-Uniform circular motion

- A particle moves with varying speed in a circular path.
- The acceleration has two components:
 - Radial $\rightarrow a_r = v^2/R$
 - Tangential $\rightarrow a_t = dv/dt$
- a_t causes the change in the speed of the particle.

$$a = \sqrt{a_r^2 + a_t^2}$$

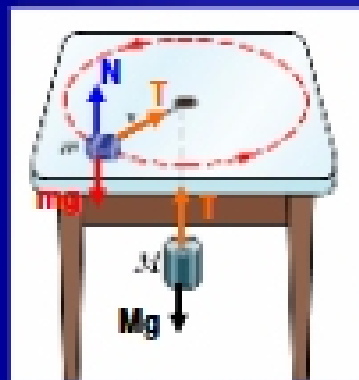


$$\vec{a} = \vec{a}_t + \vec{a}_r = \frac{d|\vec{v}|}{dt} \hat{\theta} - \frac{v^2}{r} \hat{r}$$

$$\sum \vec{F} = \sum \vec{F}_r + \sum \vec{F}_t$$

- In uniform circular motion, $v = \text{constant} \rightarrow a_t = 0 \rightarrow a = a_r$

49. A puck of mass m slides on a frictionless table while attached to a hanging cylinder of mass M by a cord through a hole in the table. What speed keeps the cylinder at rest?



$$\text{For } M \rightarrow T = Mg \rightarrow a_c = 0$$

$$\text{For } m \rightarrow T = m \frac{v^2}{r} \rightarrow Mg = m \frac{v^2}{r} \rightarrow v = \sqrt{\frac{Mgr}{m}}$$

315. Calculate the drag force on a missile 53cm in diameter cruising with a speed of 250m/s at low altitude, where the density of air is 1.2kg/m^3 . Assume $C=0.75$

$$D = \frac{1}{2} C \rho A v^2 = 0.5 \cdot 0.75 \cdot (1.2\text{kg/m}^3) \cdot \pi \cdot (0.53\text{m}/2)^2 (250\text{m/s})^2 = 6.2\text{kN}$$

32. The terminal speed of a ski diver is 160 km/h in the spread eagle position and 310 km/h in the nose-dive position. Assuming that the diver's drag coefficient C does not change from one point to another, find the ratio of the effective cross sectional area A in the slower position to that of the faster position.

$$v_s = \sqrt{\frac{2F_g}{C\rho A}} \rightarrow \frac{160\text{km/h}}{310\text{km/h}} = \frac{\sqrt{\frac{2F_g}{C\rho A_s}}}{\sqrt{\frac{2F_g}{C\rho A_f}}} = \frac{\sqrt{A_f}}{\sqrt{A_s}} \rightarrow \frac{A_s}{A_f} = 3.7$$