Dynamics of a skydiver

--Effects of air drag

Drag force in gases and liquids

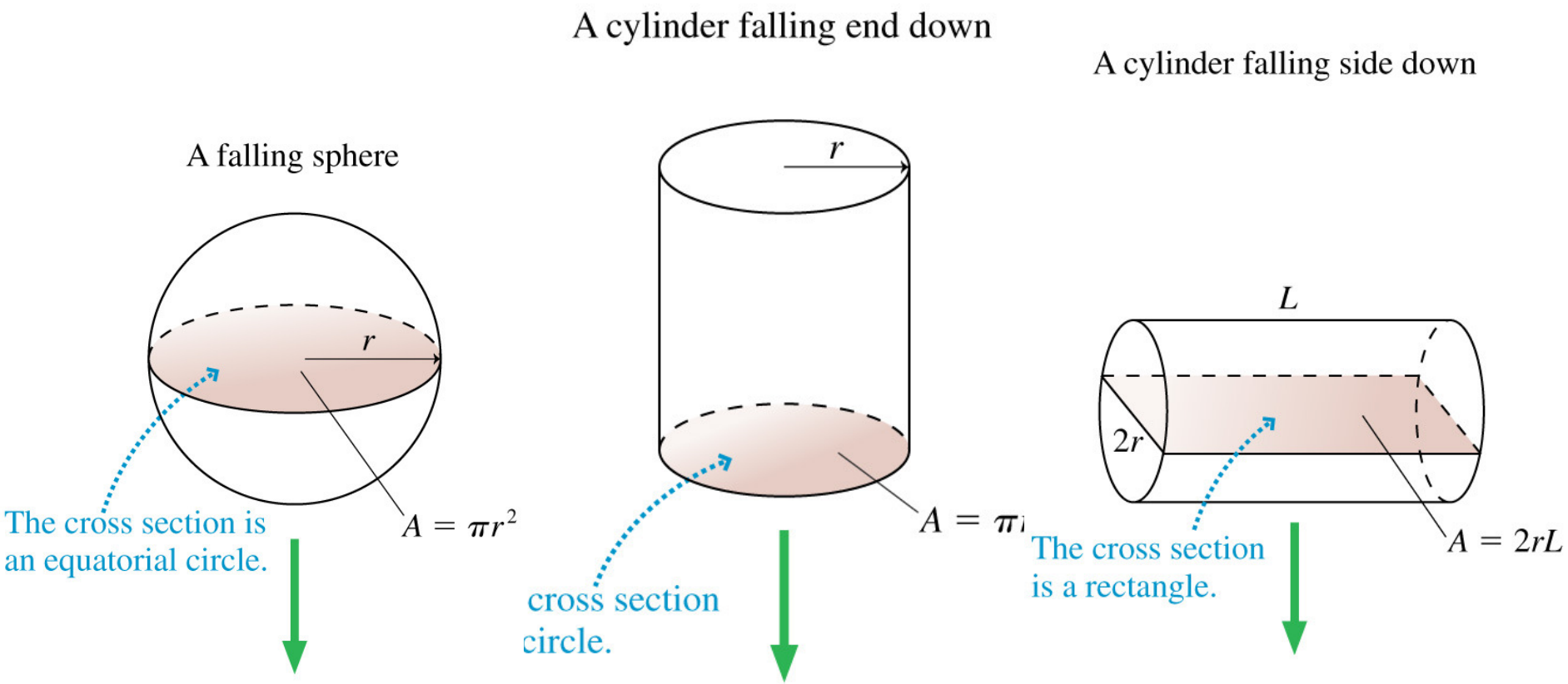
Drag force increases with velocity

D= c A v^2 (in a MP problem, D=Kv^2 so K=c A);

A is the cross-section area of an object;
v is the velocity.
c is the drag coefficient.
(What is the right SI unit for ‘c’?)

For the air, c=1/4 in SI units.

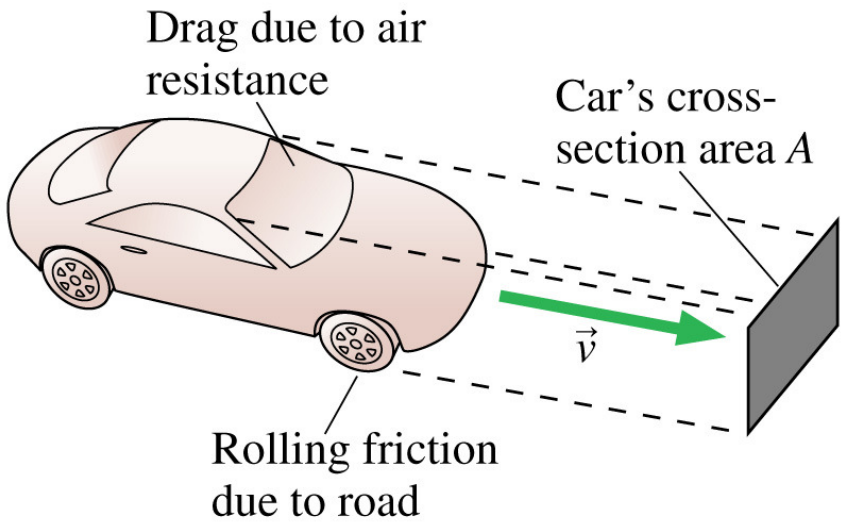
Which area ?



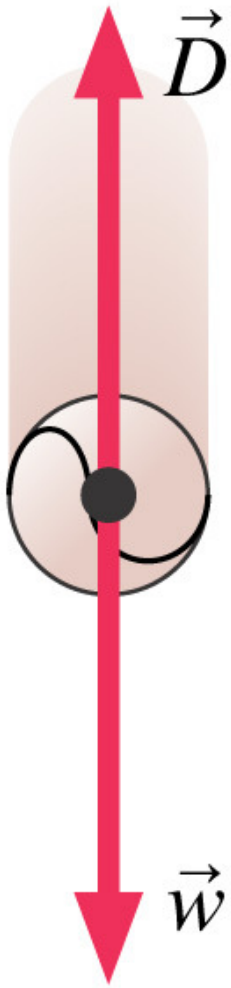
A skydiver can be thought as a cylinder.

Air drag versus friction

A typical passenger car with rolling friction coefficient 0.02. At which speed does the air drag become bigger than the friction force?

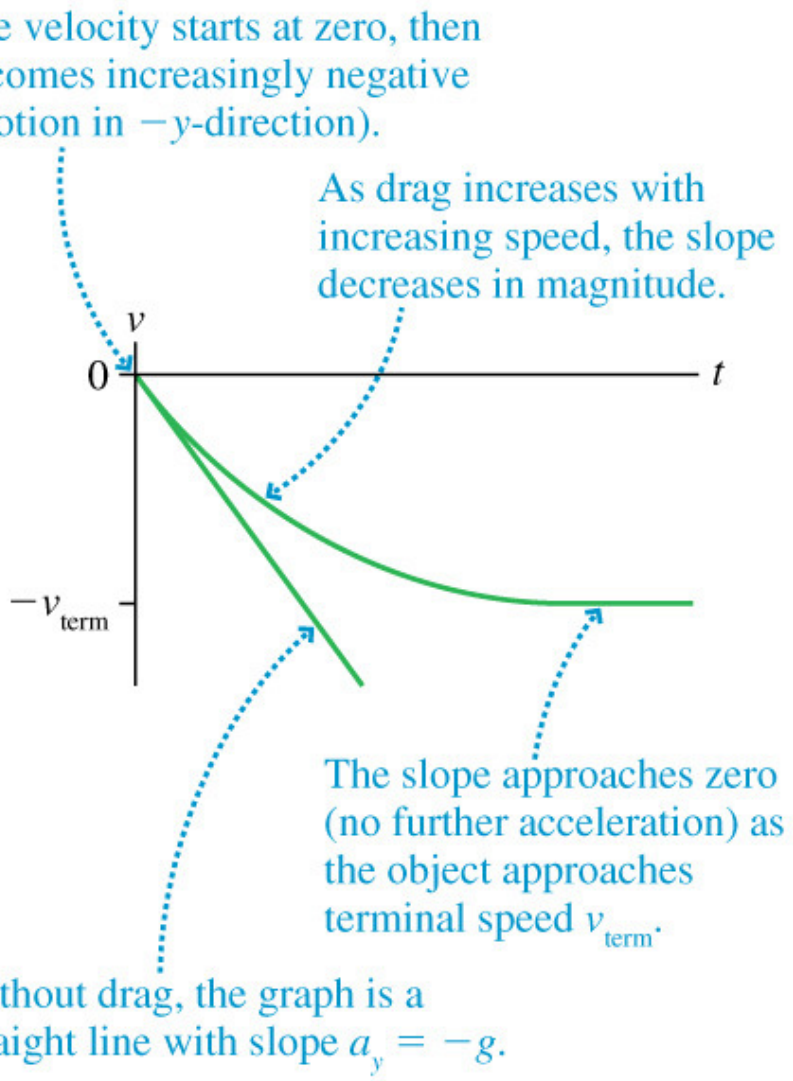


Hint: The cross-section is assumed to be 2m^2; car weight is about 1500kg.



Terminal speed is reached when the drag exactly balances the weight: $\vec{a} = \vec{0}$.

Velocity graph for a free falling Styrofoam ball



Q1

When a skydiver coming off a plane at 3000m altitude approaches the ground, he is likely to

1) free fall with a=9.8m/s^2;
2) accelerate upward to slow down;
3) zero acceleration.

Skydiver

A skydiver jumps off a plane at 3000m.
He falls with his belly “facing down” to 1000m altitude before opening up his parachute.

Qualitatively,

Velocity graph for a skydiver ?
How net forces depends on time?

Example: estimate terminal velocities of a skydiver.

Terminal velocity of

- Falling objects such as skydivers
- car with engine providing a constant force
- boat with engine providing a constant force

Terminal velocity is reached when the net force is zero!!

Summary of air drag and terminal velocity

1) Calculate the drag force at different velocities.

For the same object, Eq.1 below holds.

$$D = cAv^2 (or \quad Kv^2); c(air) = \frac{1}{4} kg/m^3. \qquad \frac{D_1}{D_2} = (\frac{v_1}{v_2})^2.$$

2) Calculate terminal velocities of a skydiver a) or a race car b) when the net force becomes zero.

$$1) mg = cAv_T^2 \Rightarrow v_T = \sqrt{\frac{mg}{cA}}; \quad \frac{v_T(1)}{v_T(2)} = \sqrt{\frac{A_2}{A_1}} (same\ diver).$$

$$2) F_{thrust} = cAv_T^2 \Rightarrow v_T = \sqrt{\frac{F_{thrust}}{cA}}; \frac{v_T(1)}{v_T(2)} = \sqrt{\frac{F_{thrust}(1)}{F_{thrust}(2)}} (same\ car)$$