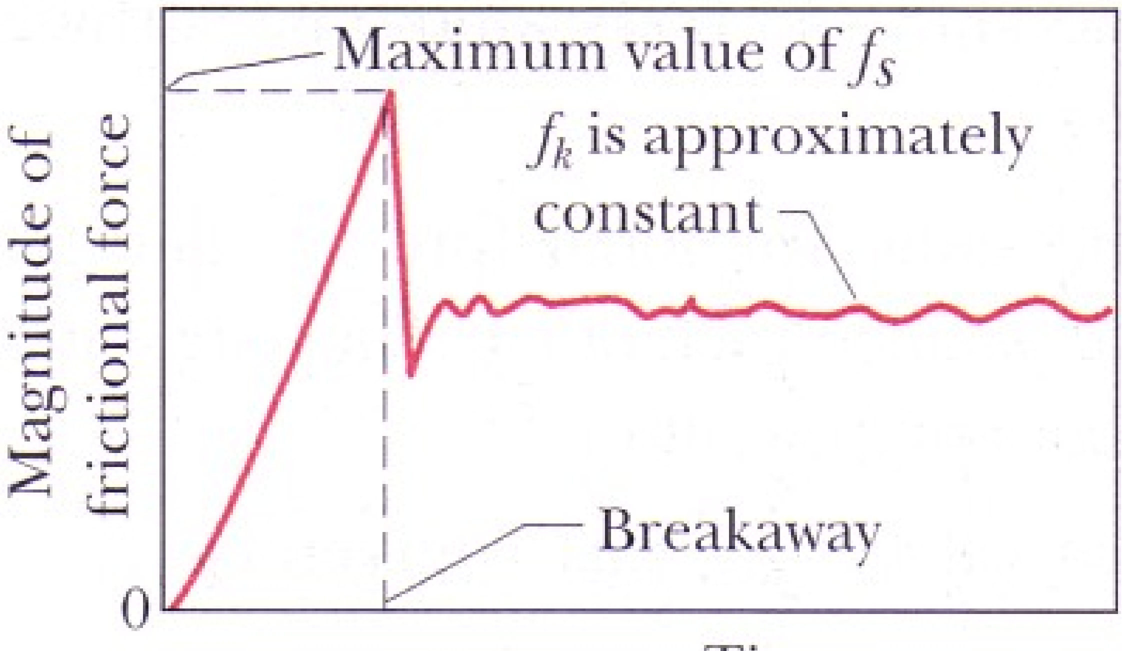
Class 13 - Force and Motion II
Chapter 6 - Wednesday September 22nd

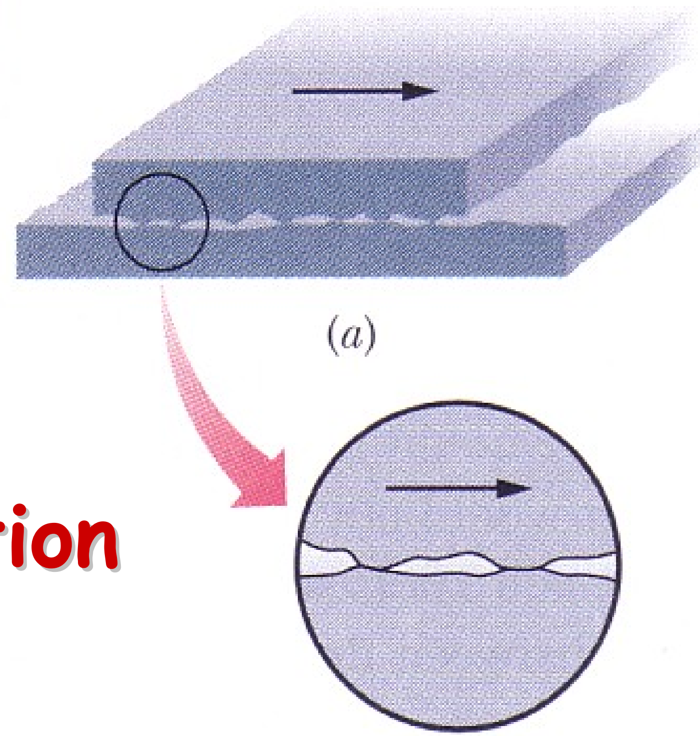
- Friction
- More on friction (sample problems)
- Air resistance

Reading: pages 99 thru 124 (chapter 6) in HRW
<u>Read and understand the sample problems</u>
Assigned problems from chapter 6:
8, 18, 20, 28, 30, 32, 40, 50, 52, 68, 84, 102
These will be due on Sunday October 3rd
Note: chapter 5 homework deadline THIS SUNDAY!

Exams available for pick-up. After Friday class, they will be filed in NPB1100.



(g)


(a)
(b)

Microscopic origin of friction

Static friction

1. In static situations, the static frictional force exactly cancels the component of the applied force parallel to the surface.

2. There is a maximum static frictional force which depends on the normal force between the surface and the object, i.e.

$$f_{s,\max} = \mu_s N$$

where μ_s is the **coefficient of static friction** and N is the magnitude of the normal force. μ_s is a parameter that depends on both surfaces. Once the force component parallel to the surface exceeds $f_{s,max}$, then the body begins to slide along the surface.

Kinetic friction

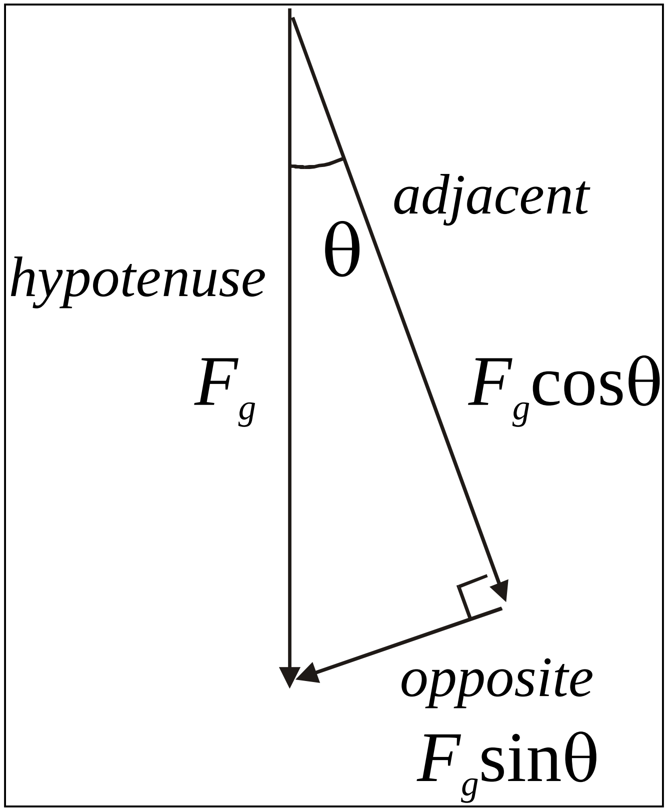
3. If a body begins to slide along the surface, the magnitude of the frictional force instantly decreases to a value f_k given by

$$f_k = \mu_k N$$

where μ_k is the **coefficient of kinetic friction** and N is the magnitude of the normal force. Therefore, during the sliding, a kinetic frictional force of magnitude f_k opposes the motion.

4. When several agents push in different directions on an object, the frictional force opposes the component of the net force on the object which is parallel to the surface.

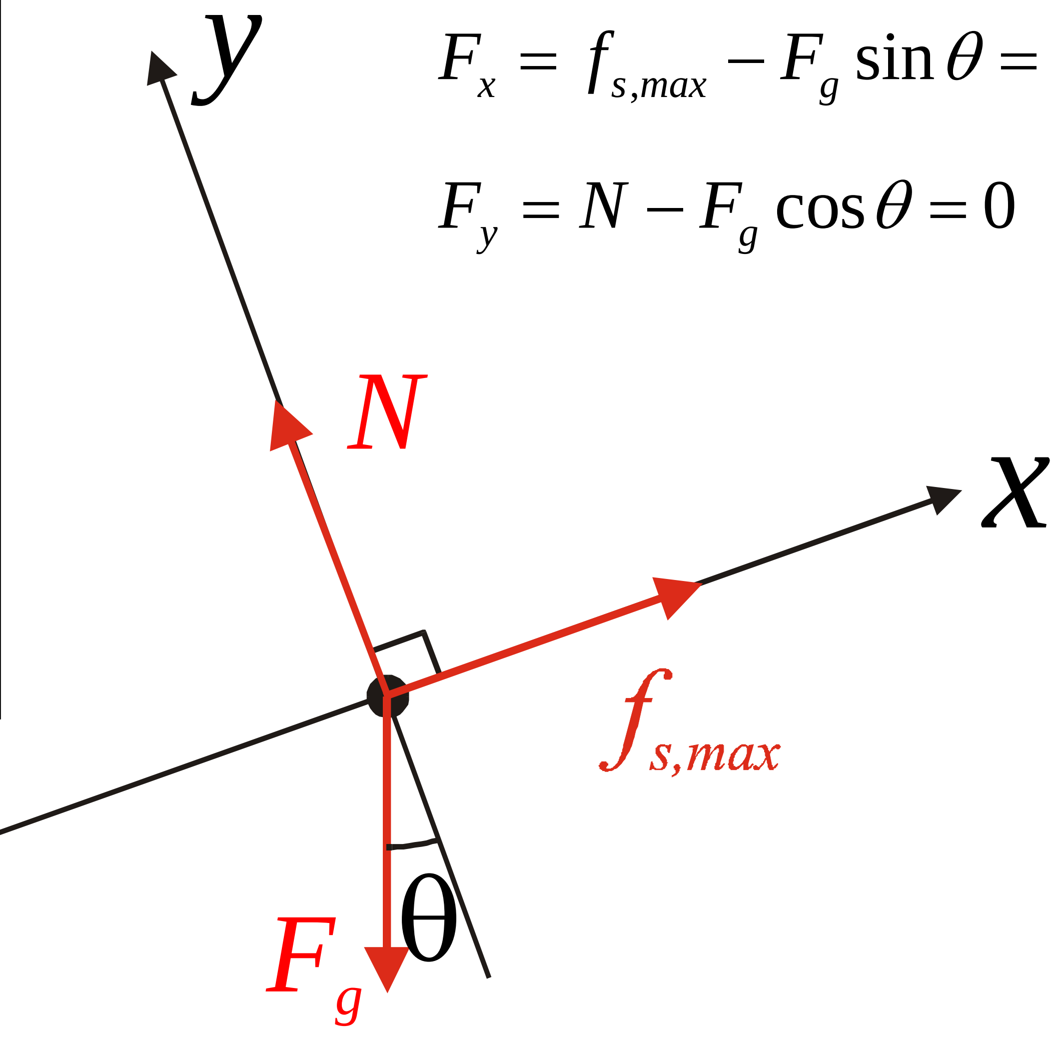
A word about resolving forces



When does the block slide?

$$F_x = f_{s,max} - F_g \sin\theta = 0$$

$$F_y = N - F_g \cos\theta = 0$$



Alternative recipe (!!!!) method

Measure θ from the *x*-axis

$$\varphi = -(90^o + \theta)$$

Then:

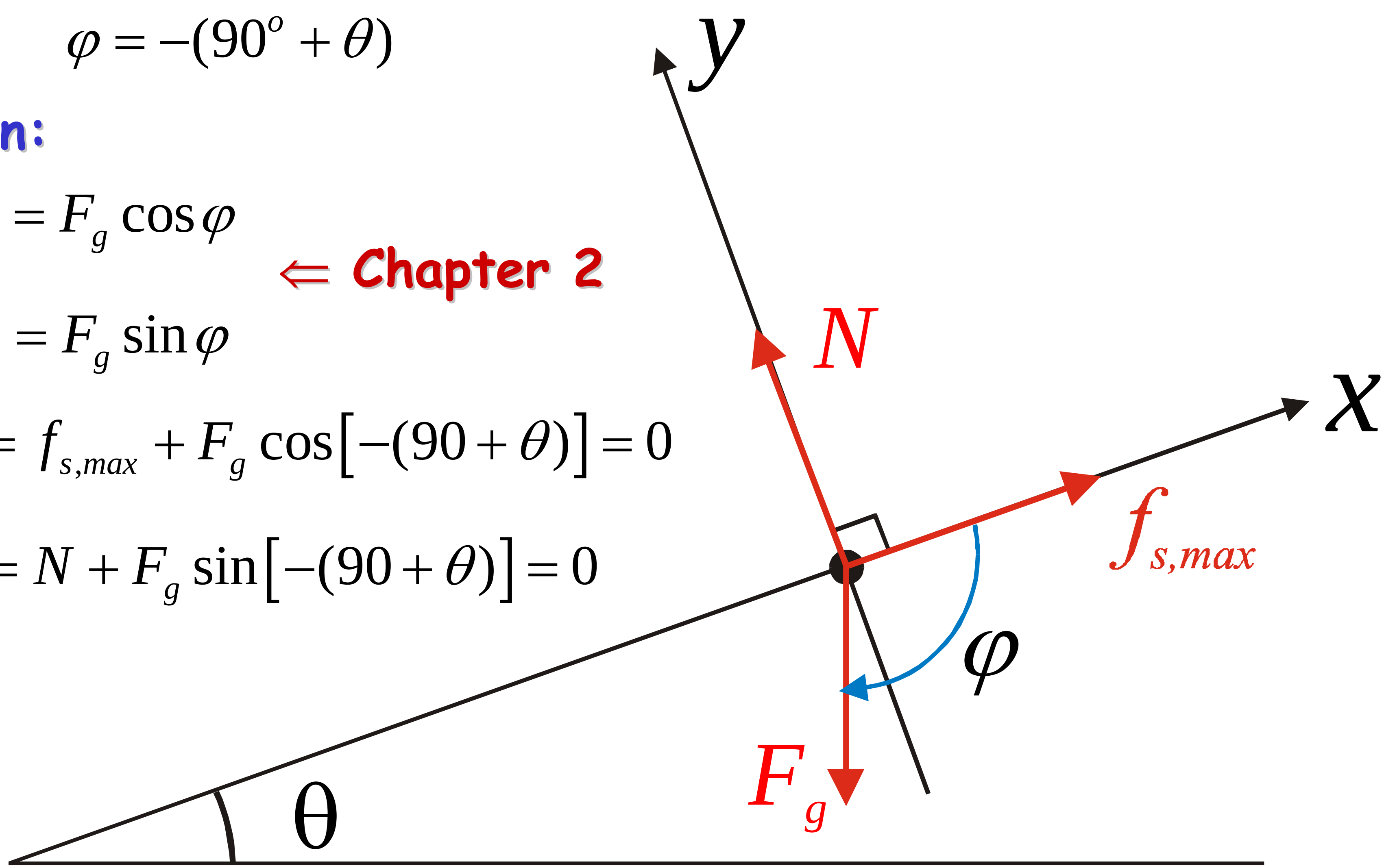
$$F_{g,x} = F_g \cos\varphi$$

⇐ **Chapter 2**

$$F_{g,y} = F_g \sin\varphi$$

$$F_x = f_{s,max} + F_g \cos\left[-(90+\theta)\right] = 0$$

$$F_y = N + F_g \sin\left[-(90+\theta)\right] = 0$$



Compare methods (2nd law)

$$F_x = f_{s,max} - F_g \sin\theta = 0$$

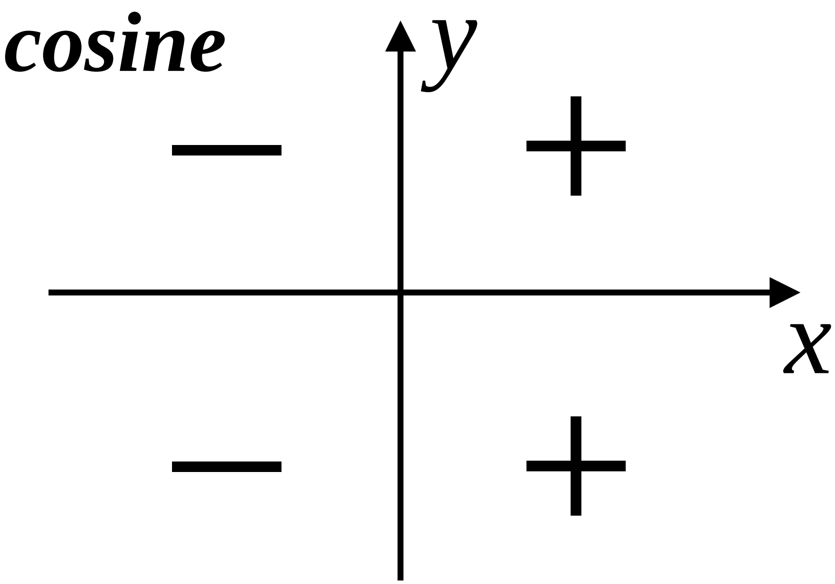
$$F_y = N - F_g \cos\theta = 0$$

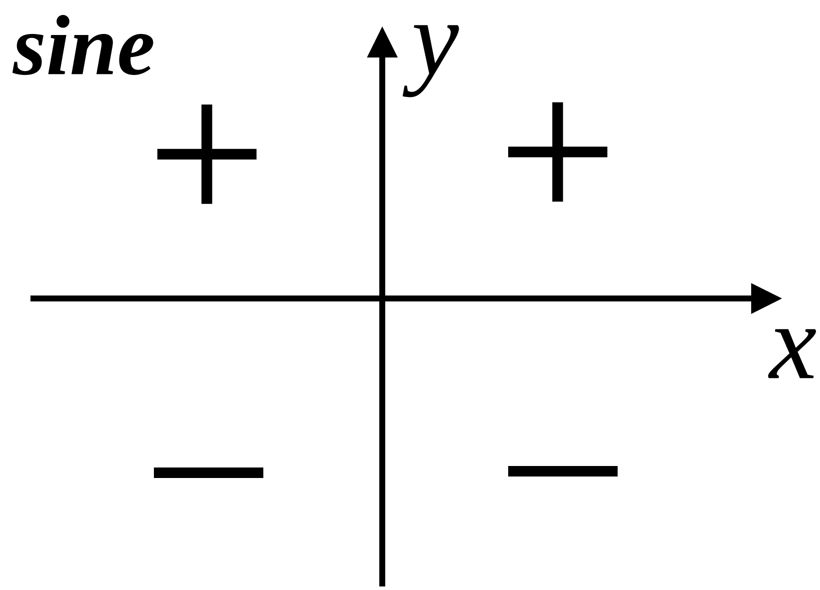
$$F_x = f_{s,max} + F_g \cos\left[-(90+\theta)\right] = 0$$

$$F_y = N + F_g \sin\left[-(90+\theta)\right] = 0$$

$$\cos\left[-(90+\theta)\right] \equiv \cos(90+\theta)$$

$$\sin\left[-(90+\theta)\right] = -\sin(90+\theta)$$





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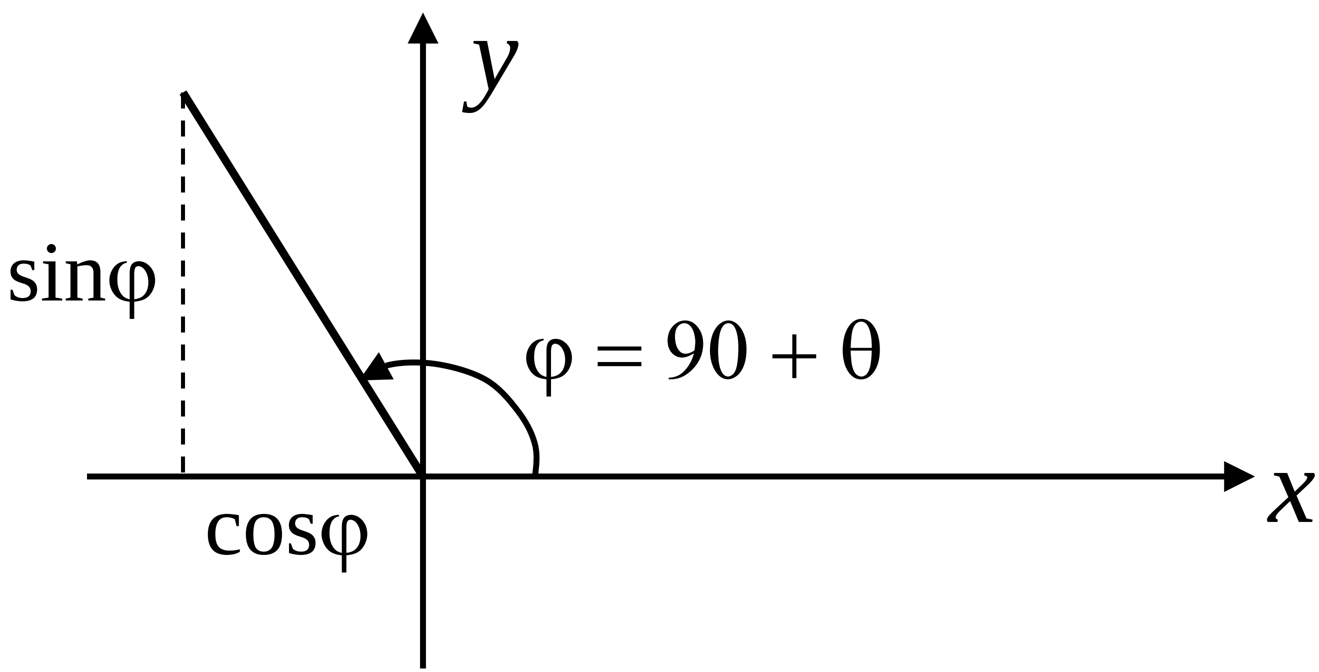

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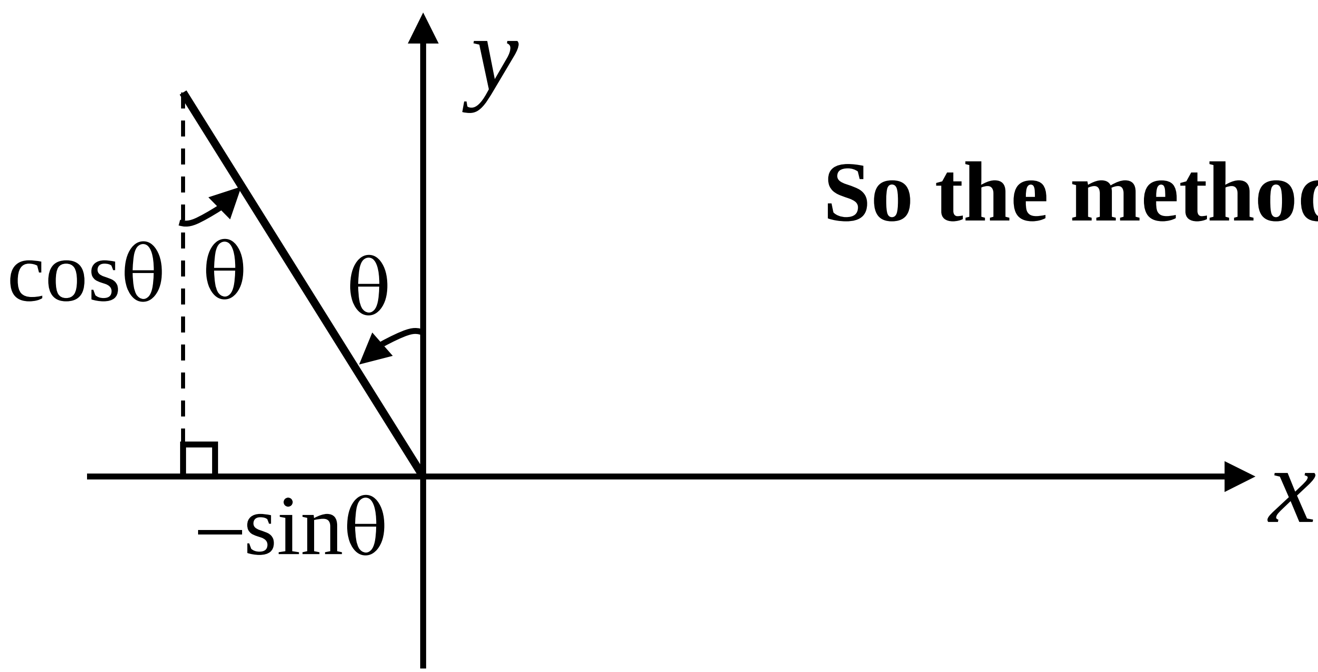
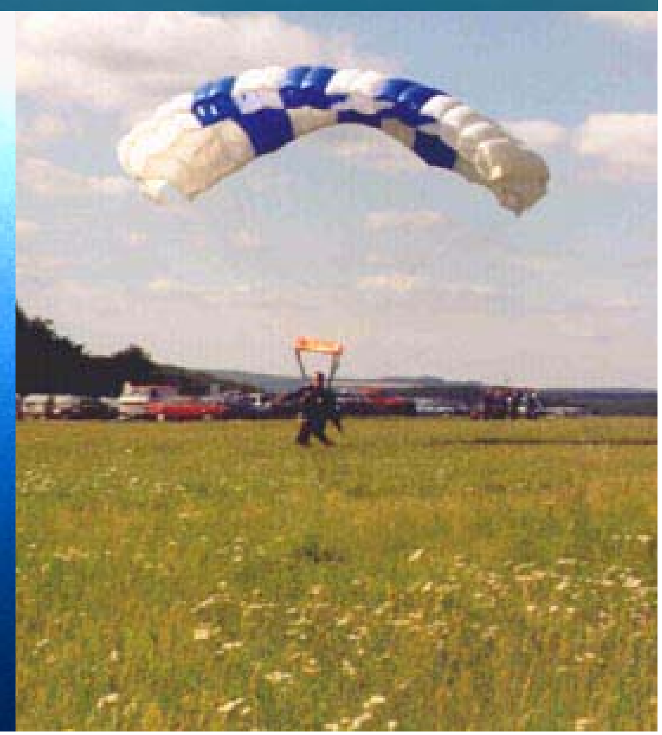
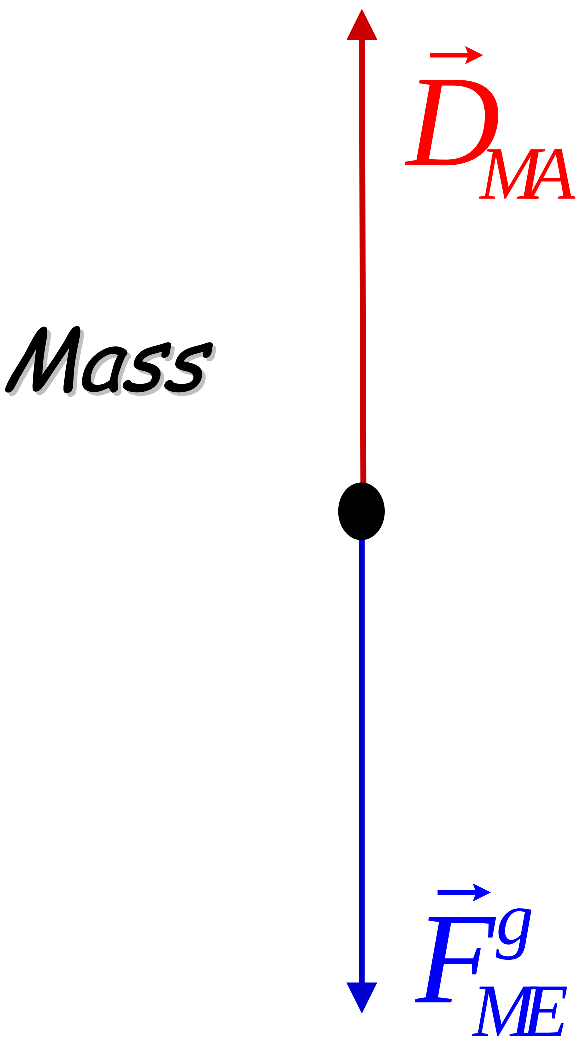


So the methods agree!!



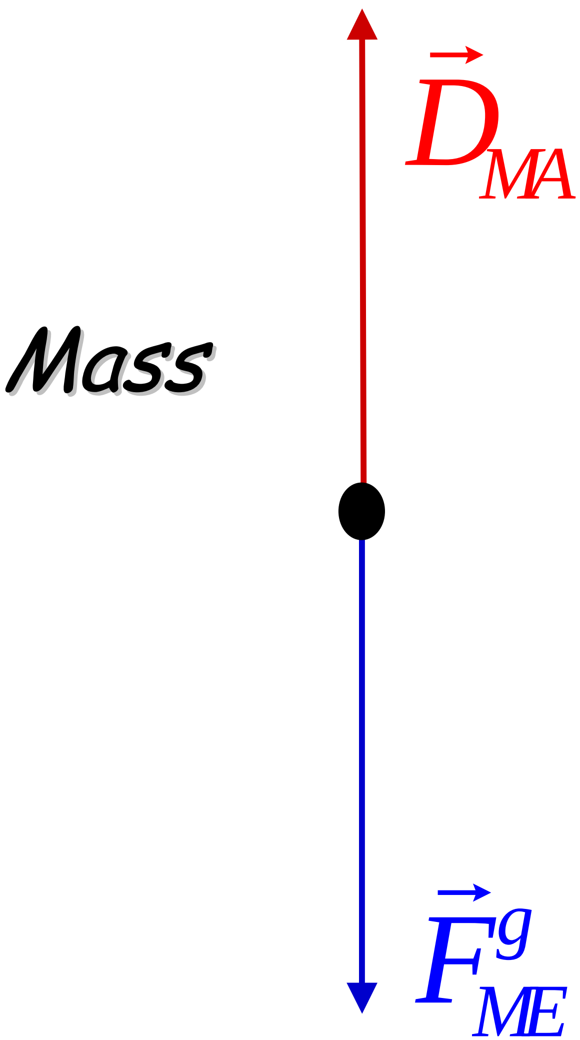
Drag force and terminal speed



$$D = \tfrac{1}{2} C \rho A v^2$$

- v is the velocity of the body.
- ρ is the air density (mass unit per volume).
- A is the effective cross sectional area of the body.
- C is the drag coefficient (typical values range from 0.4 to 1).

Drag force and terminal speed



$$D = \tfrac{1}{2} C \rho A v^2$$

Newton's 2nd law:

$$D - F^{g} = \tfrac{1}{2} C \rho A v^2 - mg = ma$$

Terminal speed when a = 0.

$$\tfrac{1}{2} C \rho A v^2 = mg$$

$$\text{or} \quad v = \sqrt{\frac{2mg}{C \rho A}}$$

Terminal speeds in air

TABLE 6-1 Some Terminal Speeds in Air

Object	Terminal Speed (m/s)	95% Distance[a] (m)
Shot (from shot put)	145	2500
Sky diver (typical)	60	430
Baseball	42	210
Tennis ball	31	115
Basketball	20	47
Ping-Pong ball	9	10
Raindrop (radius = 1.5 mm)	7	6
Parachutist (typical)	5	3

[a]This is the distance through which the body must fall from rest to reach 95% of its terminal speed.