NEWTON'S LAWS

1. The three Laws of Motion

2. Forces we typically deal with

3. The world of forces and the world of motion

4. Sample Problems

1. The three Laws of Motion

If an object is stopped or moving at a constant velocity, the net Force is zero.

$$\sum F = 0$$

If an object is accelerating, the acceleration is proportional to the net Force, and inversely proportional to the mass of the object.

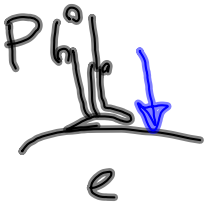
$$\sum F = ma$$

When one object exerts a force on second object, the second exerts an identical force back in the opposite direction

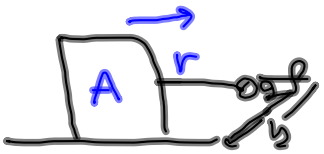
2. Forces we typically deal with

Gravity
pull of Earth on objects

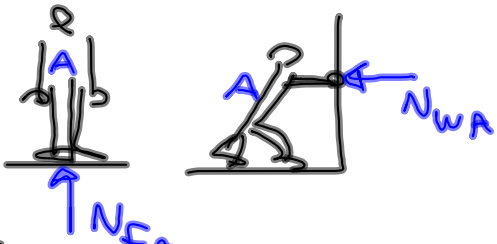
$G_{ep} = mg$



Tension
pull of ropes, cables, chains, etc.

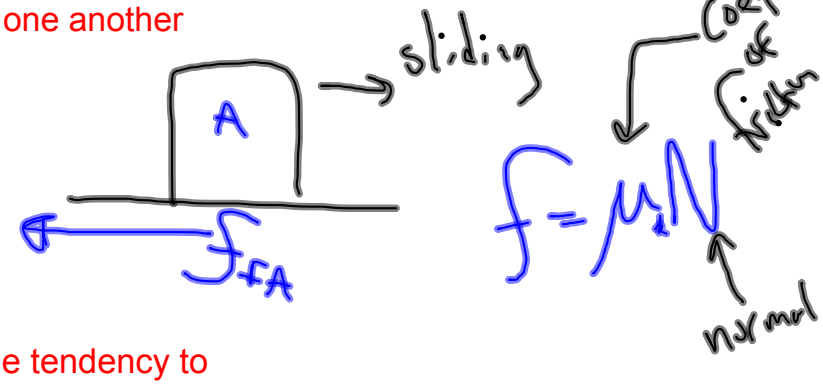


Normal
perpendicular push of surfaces

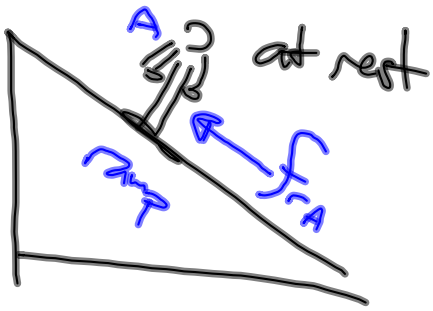


Drag
fluids oppose motion

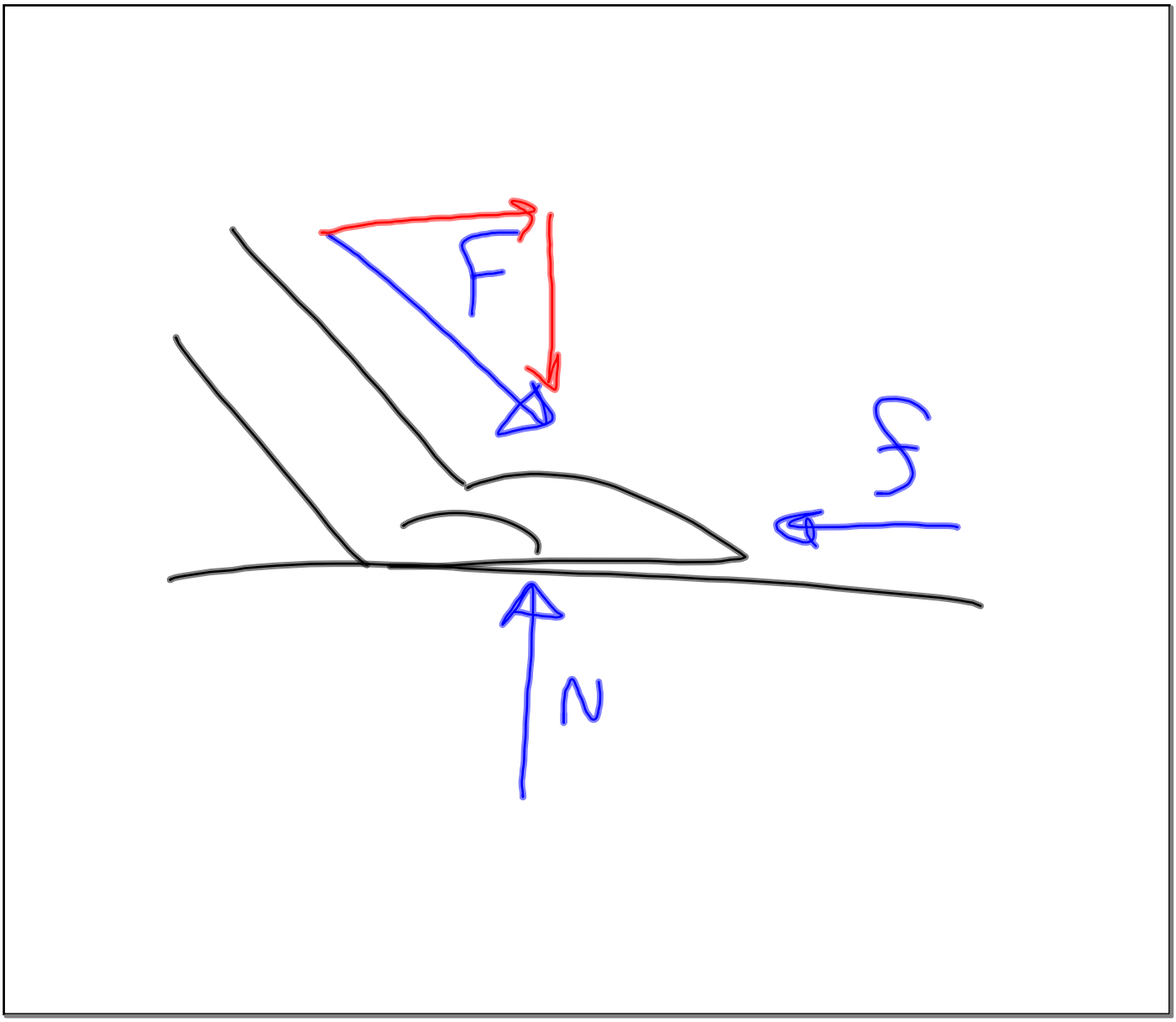
Kinetic Friction
surfaces sliding past one another
oppose motion



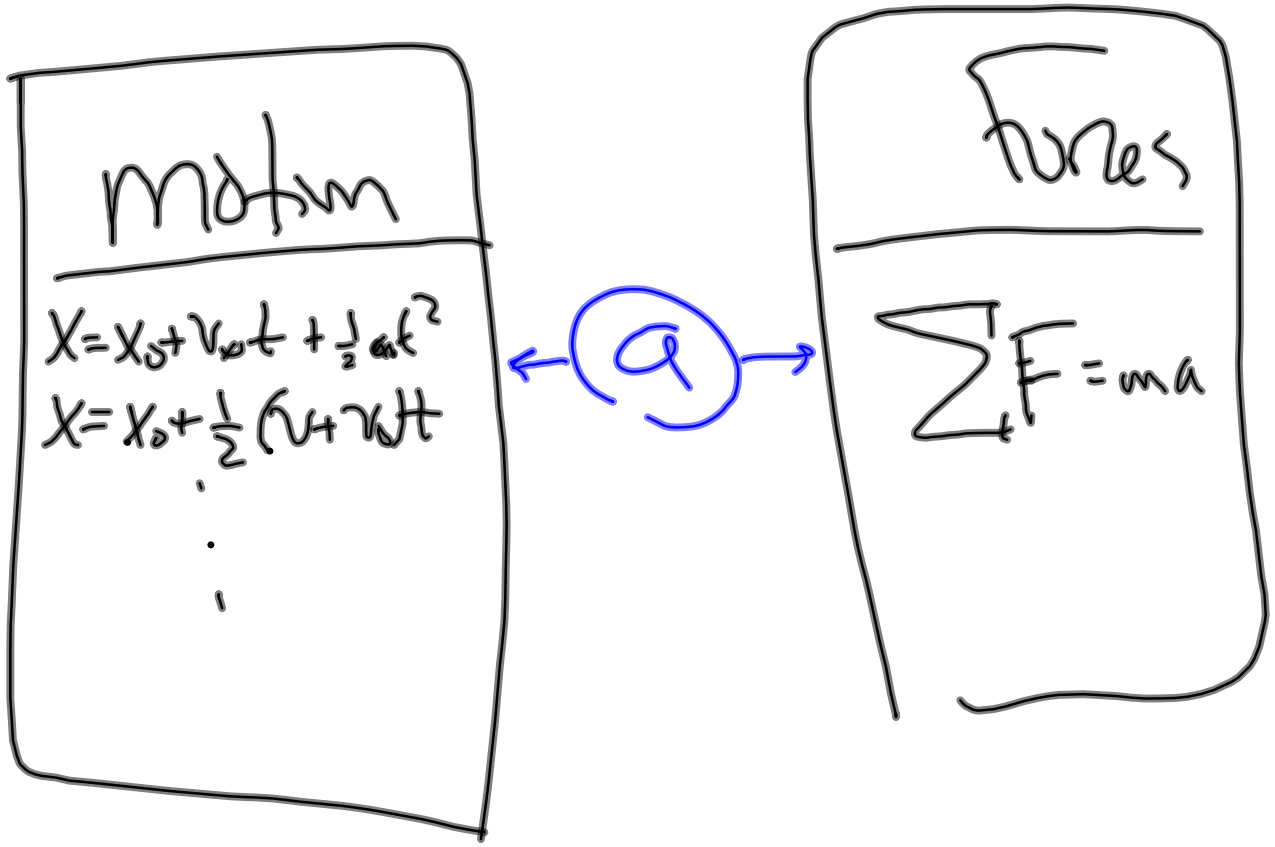
Static Friction
surfaces oppose the tendency to
slide past one another up to a point



$f_{max} = \mu_s N$


F
f
N

3. The world of forces and the world of motion



4. Sample Problems

(step 0: Draw a Free Body Diagram)

elevator

pulling a sled

friction (kinetic)/friction (static)

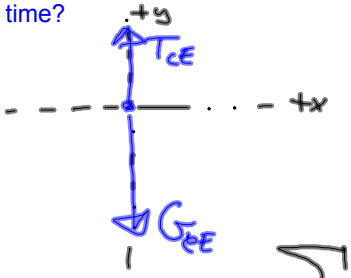
Inclined planes

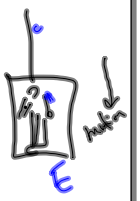
4. Sample Problems

(step 0: Draw a Free Body Diagram)

elevator

A 70 kg person steps into a 300 kg elevator on the top floor and pushes a button to go down. The elevator goes from rest to 5 m/s downward over the course of 4 seconds. What is the tension in the cable during that time?





$$\sum F = ma$$

$$T_{CE} - G_{EE} = ma$$

back to world of motion

$v_0 = 0$ $\quad v = v_0 + at$

$v = -5\ m/s$ $\quad -5 = 0 + a(4)$

$t = 4\ s$

$a = ?$ $\quad -1.25\ m/s^2 = a$

back to forces

$T - G = ma$ $\quad (300\ kg + 70\ kg)$ → solved for it!

$G = mg$

$= (300\ kg + 70\ kg)\ 9.8$

$= (370)(9.8)$

$= 3,626\ N$

$T - 3,626 = (370)(-1.25)$

$T - 3,626 = -462.5$

$T = 3,626 - 462.5$

$T = 3,163.5\ N$

4. Sample Problems

(step 0: Draw a Free Body Diagram)

pulling a sled

There is 40 N of tension in the string. The string makes an angle of 50 degrees with the horizontal and the sled's mass is 8 kg. Neglect friction with the snow

a) What is the acceleration of the sled?
b) What is the Normal force exerted by the snow on the sled?

$$\sum F_x = ma_x$$

$$T\cos 50 = ma_x$$

$$\sum F_y = 0$$

$$N + T\sin 50 - G = 0$$

find accel

$$T\cos 50 = ma_x$$

$$(40_N)(\cos 50) = (8_{kg})a_x$$

$$3.2\,m/s^2 = a_x$$

find N

$$N + T\sin 50 - G = 0$$

$$N + (40_N)\sin 50 - (8_{kg})(9.8) = 0$$

$$N + 30.64 - 78.4 = 0$$

$$N = 47.8\,N$$

4. Sample Problems

(step 0: Draw a Free Body Diagram)

friction (kinetic)/friction (static)

The box weighs 1,000 N. The coefficient of static friction between the box and ground is 0.5; the coefficient of kinetic friction between the box and ground is 0.25.

a) If the box is at rest, will 400 N of tension in the rope move it?
b) Now there are 600 N of tension in the rope. Determine the box's acceleration.

a) calculate max static f

$f_{max} = \mu_s N$

find Normal, first

$\sum F_y = 0 \Rightarrow N - G = 0$

$N = G = 1000\,N$

$f_{max} = (0.5)(1000\,N)$

$= 500\,N$

400 N of Tension does not exceed the max friction → doesn't move

b) 600 N of friction exceeds f_{max}

Therefore switch to kinetic friction.

$f_{kinetic} = \mu_k N = (0.25)(1000\,N)$

$= 250\,N$

$T - f = ma$ → $G = mg$, $1000\,N = m(9.8)$, $102.04\,kg = m$

$(600\,N) - (250\,N) = (102.04)a$

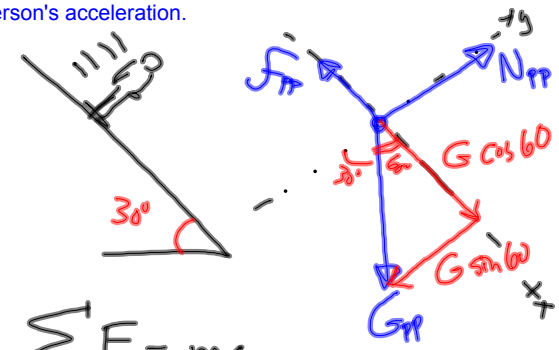
$3.43\,m/s^2 = a$

4. Sample Problems

(step 0: Draw a Free Body Diagram)

Inclined planes

The 100 kg person is sliding down a 30 degree incline. The coefficient of kinetic friction is 0.1. Find the person's acceleration.



$$\sum F_x = ma_x$$

$$G\cos 60 - f = ma_x$$

$$\sum F_y = 0$$

$$N - G\sin 60 = 0$$

get the normal force from the y-direction equation, then use it to get friction and solve for accel. with the x-direction

$$N - G\sin 60 = 0$$

$$N - (100)(9.8)\sin 60 = 0$$

$$N - 848.68_N = 0$$

$$N = 848.68_N$$

$f = \mu N = (0.1)(848.68_N) = 84.868_N$

$$G\cos 60 - f = ma_x$$

$$(100)(9.8)\cos 60 - 84.868_N = (100)a_x$$

$$490_N - 84.868_N = (100)a_x$$

$$4.05 \frac{m}{s^2} = a_x$$