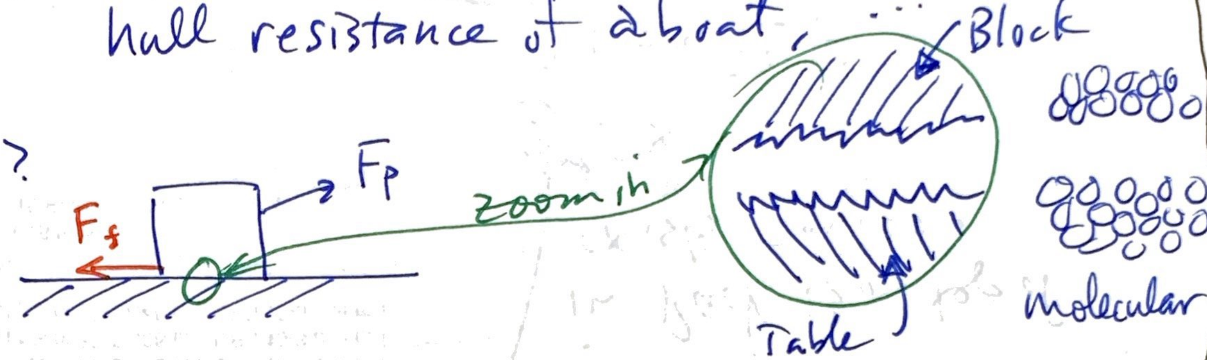
4c Friction

* Frictional Forces are **any force that impedes motion** (linear or rotional)

Ex: surface friction, aerodynamic drag, hull resistance of a boat, ...

* why?



- $F_f \propto F_N \Rightarrow \boxed{F_f = \mu F_N}$

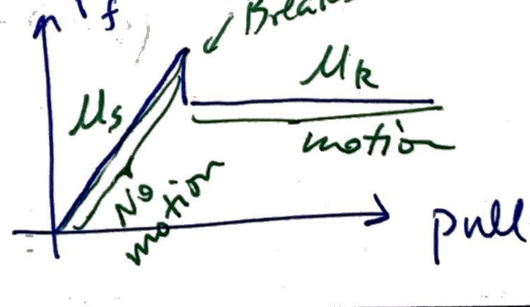
  F_N: weight on the surface

- μ is the proportionality constant. It is called the **Coefficient of friction**.

- Two types of μ:

  μ_k = **Kinetic friction** when the block is **moving**

  μ_s = **static friction** when the block is **not moving**, but **still resisting motion to move**

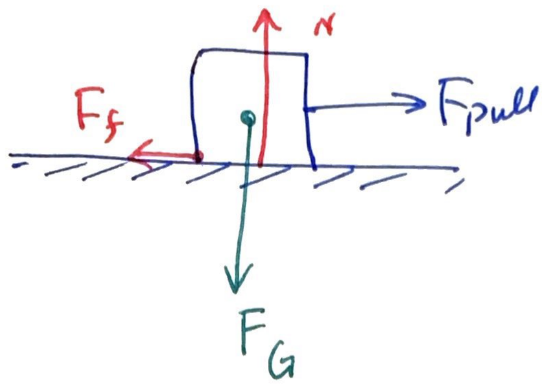


⊛ Values of μ:

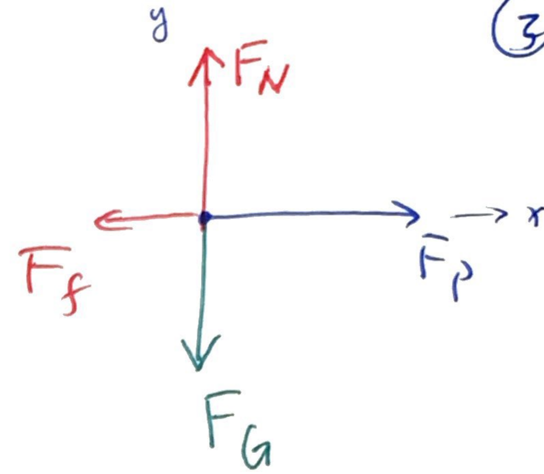
	μ_{static}	$\mu_{kinetic}$
• wood on wood	0.4	0.2
• ice on ice (pre-fusion)	0.1	0.03
• steel on steel	0.15	0.07
• rubber on dry concrete	1.00	0.8
• rubber on wet concrete	0.7	0.5
• synovial joints	0.01	0.01

these values tell us that there will be more friction if we keep the tires from skidding: thus the <u>anti-lock-brakes</u>

(i)



(ii)



(iii)

$$\begin{aligned} x &: -F_f + F_p = ma_x \quad \text{"a"} \\ y &: F_N - F_G = m\cancel{a_y}^{\,0} \\ f &: F_f = \mu F_N \end{aligned}$$

DATA

$m = 10\,kg$

$\mu_s = 0.4$

$\mu_k = 0.3$

Q$_1$: With what force do we pull to set motion to start? (static) $F_p = ?$

$$\left.\begin{aligned} x &: F_p = m\cancel{a}^{\,0} + F_f \\ f &: F_f = \mu F_N \\ y &: F_N = F_G \end{aligned}\right\}$$

$F_p = \mu_s[F_G]$

$F_p = 0.4\,(10\,kg)(9.8\,m/s^2$

$\boxed{F_p = 39N}$ to overcome static friction

Before motion begines

$$F_p = F_f$$

(a) if $F_p = 20N$ what is the Frictional resistance? A=20N

(b) if $= 38N$ then $F = 38N$

(c) if $F_p = 40N$ then we have overcome static friction and we use $\mu_k = 0.3$

since motion is occuring, yet there is still friction, Find that Frictional force

$$x: -F_f + F_p = ma$$
$$y: F_N = F_G$$
$$f: F_f = \mu_k F_N$$

$$\hookrightarrow F_p - \mu_k F_N = ma \quad \text{but } F_N = F_G$$

$$a = \frac{F_p - \mu_k F_G}{m} \qquad F_G = mg = 98N$$

$$a = \frac{40N - (0.3)(98N)}{10kg}$$

$$a = \frac{40N - 29N}{10kg} = \boxed{1.1\ m/s^2}$$

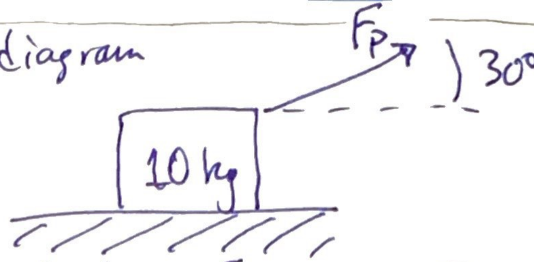
ANS: $F_f = \mu_k F_N = \mu_k F_G = \underline{\underline{\mu_k mg}}$

$$= (0.3)(98N)$$
$$= \underline{\underline{29N}}$$

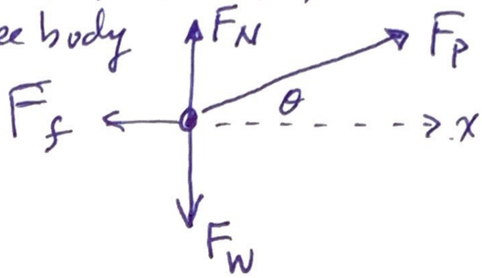
{ Before motion $F_s = F_{pull}$ up to 39 N. }

EX 2-dim pull

(i) diagram



(ii) free body



DATA
$m = 10\,kg$
$F_p = 40N$
$\theta = 30°$
$\mu_k = 0.30$
$a = ?$

(iii) Equations of motion $\sum \vec{F} = m\vec{a}$

$$\boxed{\begin{aligned} x:&\quad F_p\cos\theta - F_f = ma \\ y:&\quad F_N + F_p\sin\theta - F_W = m\cancel{a_y}\rightarrow 0 \\ \text{friction:}&\quad F_f = \mu_k F_N \end{aligned}}$$

3-equations & 3-unknowns
F_N, F_f, a
$F_W = mg$

(iv) Put F_f into the x-equation

$$\begin{aligned} x:&\quad \left\{ F_p\cos\theta - \mu_k F_N = ma \right. \\ y:&\quad \left. F_N + F_p\sin\theta - mg = 0 \right\} \end{aligned}$$

2-eqns & 2 unknowns
F_N, a

To get acc'ln solve y-eqn for F_N and substitute it into the x-eqn: 1st $F_N = -F_p\sin\theta + mg$: y

$$x:\quad F_p\cos\theta - \mu_k(-F_p\sin\theta + mg) = ma \}$$

1-eqn and 1 unkn: a

Solve for "a" : $$\boxed{a = \frac{F_p\cos\theta + \mu_k(F_p\sin\theta - mg)}{m}}$$

(v) answer the question : (populate)

$$a = \frac{40N\cos30° + (0.3)[40N\sin30° - 10kg\, 9.8\,m/s^2]}{10\,kg}$$

$$a = \frac{34.6N + 0.3[20N - 98N]}{10} = \frac{34.6 - 23.4N}{10} = \boxed{1.1\,m/s^2}$$

EX **2-D Incline with Friction**

Skier

(i)

DATA

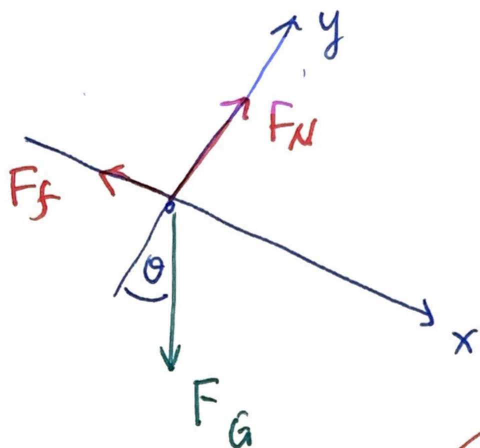
$m = 70\,kg$

$\mu_k = 0.1$

$\theta = 30°$

$a = ?$

(ii)



(iii) Eqns

x: $F_G \sin\theta - F_f = ma$

y: $F_N - F_G \cos\theta = 0$

f: $F_f = \mu_k F_N$

(iv) Solve

$$F_G \sin\theta - \mu_k (F_G \cos\theta) = ma$$

$$\cancel{m}g \sin\theta - \mu_k \cancel{m}g \cos\theta = \cancel{m}a$$

{acc'ln is indep. of mass.

$$\boxed{a = g(\sin\theta - \mu_k \cos\theta)}$$

$$a = (9.8\,m/s^2)\left[\sin 30° - 0.1 \cos(30°)\right]$$

$$a = 9.8\,m/s^2\,[0.41] = \underline{\underline{4.01\,m/s^2}}$$