Friction

Friction

- **FRICTION:** The force that opposes motion
- **(F_{FS}) Static Friction:** the force you need to overcome to set an object into motion
- **(F_{FK}) Kinetic Friction:** the force you need to overcome to keep an object in motion

- It is always harder to start an object than to keep it moving

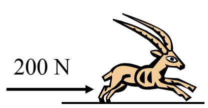
  $F_{FS} > F_{FK}$

  $F_{FS} = F_N * \mu_S$ (F_N = Normal Force) (μ_S = coefficient of static friction)

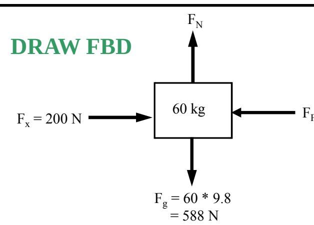
  $F_{FK} = F_N * \mu_K$ (F_N = Normal Force) (μ_K = coefficient of kinetic friction)

Sample

You push horizontally on a 60 kg gazelle as shown in the picture. If $\mu_S = 0.08$ and $\mu_K = 0.05$ how far will the gazelle travel in 4.0 seconds if it starts from rest?



DRAW FBD



WRITE NET FORCE EQUATIONS FOR BOTH X AND Y DIRECTIONS

ΣF_x : $F_x - F_F = ma_x$

$200\text{ N} - F_F = 60\text{kg } a_x$

ΣF_y : $F_N - F_g = ma_y$

$F_N - 588\text{ N} = 60\ (0)$

$F_N = 588\text{ N}$

DETERMINE IF THE OBJECT WILL MOVE

(is $F_x > F_{FS}$)

$F_X = 200\text{ N}$

$F_{FS} = F_N * \mu_s$

$F_{FS} = 588\text{ N}\ (0.08) = 47.04\text{ N}$

$200\text{ N} > 47.04\text{ N}$

It will move!

USE ΣF_X TO SOLVE FOR a_X AND THEN USE A KINEMATIC AS NEEDED

$200\text{ N} - F_{FK} = 60\text{kg } a_x$

$200\text{ N} - 588\text{N}(0.05) = 60\text{ kg } a_x$

$a_x = 2.84\text{ m/s}^2$

$v_i = 0$ m/s

$a = 2.84\text{ m/s}^2$

$t = 4.0$ sec

$\Delta x = ?$

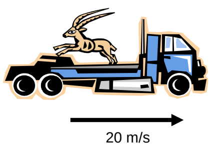
$$\Delta x = v_i t + \frac{1}{2}at^2$$

$$\Delta x = (0m/s)t + \frac{1}{2}(2.84m/s^2)(4.0s)^2$$

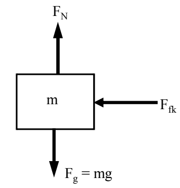
$$\Delta x = 22.75m$$

Sample

The truck is moving at 20 m/s to the right. The coefficient of static friction between the truck and the gazelle is 0.5. What is the shortest time it will take the truck stop without the gazelle sliding into the cab of the truck?



DRAW FBD
(of the gazelle)



WRITE NET FORCE EQUATIONS FOR BOTH X AND Y DIRECTIONS

$$\Sigma F_x : -F_{fk} = ma_x$$

$$\Sigma F_y : F_N - F_g = ma_y$$
$$F_N - mg = 60\,(0)$$
$$F_N = mg$$

$$F_{FK} = F_N\mu_k = mg\mu_k$$

$$-\cancel{m}g\mu_k = \cancel{m}\,a_x$$
$$-9.8\text{ m/s}^2(0.5) = a_x$$
$$a_x = -4.9\text{ m/s}^2$$

$v_i = 20$ m/s
$a = -4.9$ m/s^2
$v_f = 0$ m/s
$t = ?$

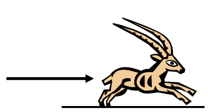
$$v_f = v_i + at$$
$$0m/s = 20m/s + (-4.9m/s^2)t$$
$$t = 4.08s$$

Solving Force Problems

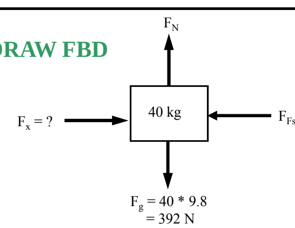
1. **Resolve the vectors.**
2. **Draw Free Body Diagrams (FBD).**
3. **Write the net force equations.**
4. **Plug in numbers and solve for normal force F_N.**
5. **Determine if the object will move. Is the force applied greater than the static frictional force ($F_x > F_{fs}$)?**
6. **Use F_x and kinetic frictional force (F_{fk}) to solve for a_x.**
7. **Use a kinematic equation as needed.**

Practice

You push horizontally on a 40 kg gazelle as shown in the picture. What is the normal force? How much force is needed to start the gazelle moving ($\mu_S = 0.189$ and $\mu_K = 0.085$)?



DRAW FBD



WRITE NET FORCE EQUATIONS FOR BOTH X AND Y DIRECTIONS

$$\Sigma F_x : F_x - F_{Fs} = ma_x$$
$$F_x - F_{Fs} = 40\text{kg}(0\text{ m/s}^2)$$

$$\Sigma F_y : F_N - F_g = ma_y$$
$$F_N - 392\text{ N} = 40\text{kg}(0\text{ m/s}^2)$$
$$F_N = 392\text{ N}$$

Solve for static friction force

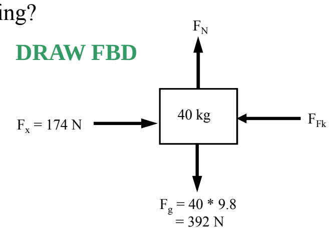
$F_{Fs} = F_N * \mu_s$
$F_{Fs} = 392\ N\ (0.189)$
$F_{Fs} = 74\ N$

Solve for the force needed to start the gazelle moving

$F_x – F_{Fs} = 40kg(0\ m/s^2)$
$F_x = F_{Fs}$
$F_x = 74\ N$

What would the acceleration of the gazelle be if you applied 100 N of force more than was needed to start it moving?

DRAW FBD



WRITE NET FORCE EQUATIONS FOR BOTH X AND Y DIRECTIONS

$\Sigma F_x: \quad F_x – F_{Fk} = ma_x$

$\Sigma F_y: F_N - F_g = ma_y$
$F_N - 392\ N = 40kg(0\ m/s^2)$
$F_N = 392\ N$

SOLVE FOR KINETICE FRICTION FORCE

$F_{Fk} = F_N\mu_k$
$F_{Fk} = (392\ N)(0.085)$
$F_{Fk} = 33.32\ N$

SUBSTITUTE IN THE ΣF_x AND SOLVE FOR ACCELERATION

$\Sigma F_x: \quad F_x – F_{Fk} = ma_x$

$174\ N – 33.32\ N = (40kg)a$

$140.68\ N = (40kg)a$

$3.52\ m/s^2 = a$