1. A box is being pulled along a horizontal table by a rope connected to a donkey's shoulders at an angle of 15° to the table. There is a spring between the rope and the box with k = 12.2 N/cm. The mass of the box is 14.7 kg. If friction is opposing the box's motion with a constant force of 5.6 N, and the box is accelerating at 4.1 m/s^2 horizontally:
   - a. How many centimeters does the spring stretch? (5.59 cm)
   - b. What is the size of the normal force? (126.41 N)

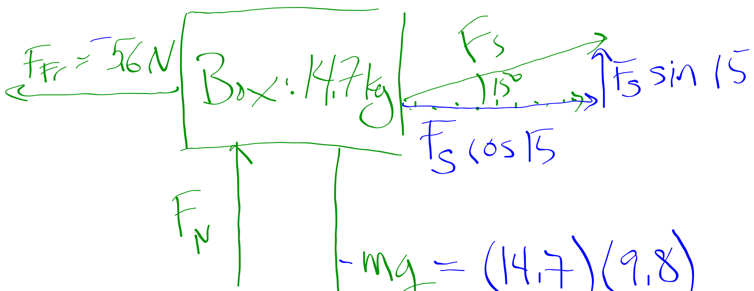
$F_s = kx$

$68.2 = 12.2\,x$

$x = 5.6\,cm$

$k = 12.2\,N/cm$

$a = 4.1\,m/s^2$



$-mg = (14.7)(9.8)$

$= -144.06\,N$

$\Sigma F_x = ma_x$

$-5.6N + F_s \cos 15 = (14.7)(4.1)$

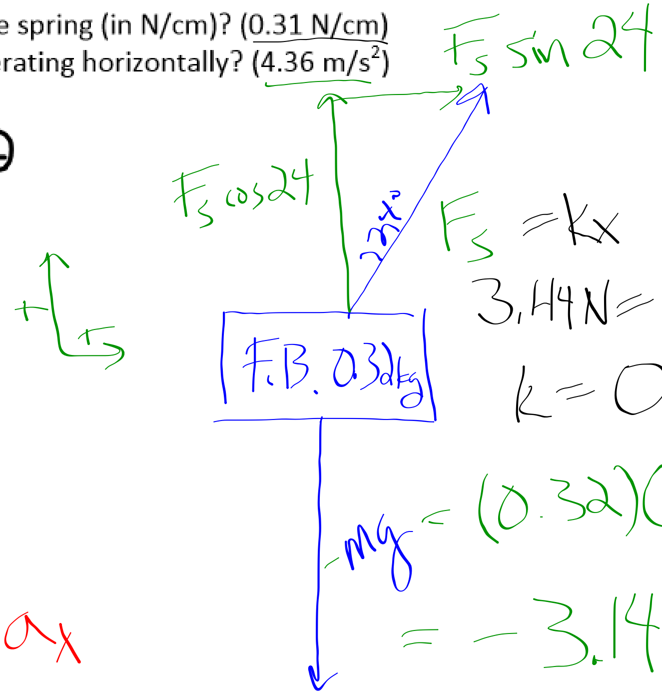
$F_s = \dfrac{(14.7)(4.1) + 5.6}{\cos 15} = 68.2\,N$

$\Sigma F_y = m\cancel{a_y}^{0} = 0$

$F_N + -144.06 + 68.2 \sin 15 = 0$

$F_N = 126.41\,N$

2. A football with a mass of 0.32 kg is hooked to an airplane by a spring at a constant angle (with the vertical) of 24°. The spring is stretched out 11 cm. The football is not moving in the vertical direction.
   a. What is the spring constant of the spring (in N/cm)? (0.31 N/cm)
   b. How quickly is the football accelerating horizontally? (4.36 m/s^2)



$F_s = kx$

$3.44\text{ N} = k(11\text{ cm})$

$k = 0.31\ \text{N/cm}$

$-mg = (0.32)(9.8)$

$= -3.14\text{ N}$

$\sum F_x = ma_x$

$F_s \sin 24 = (0.32)a_x$

$\sum F_y = ma_y = 0$

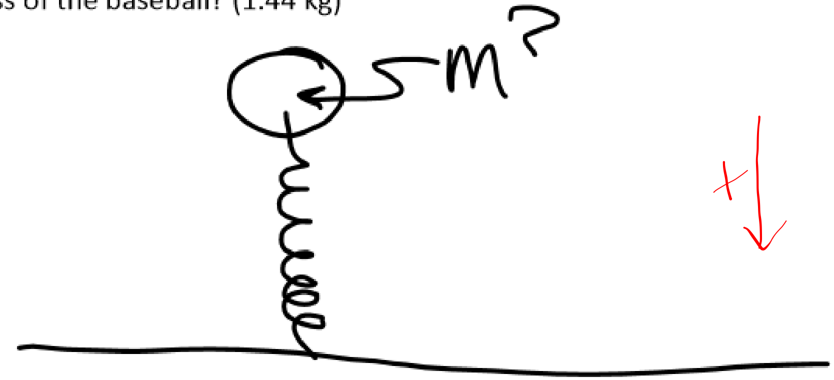
$F_s \cos 24 + -3.14 = 0$

$F_s = 3.44\text{ N}$

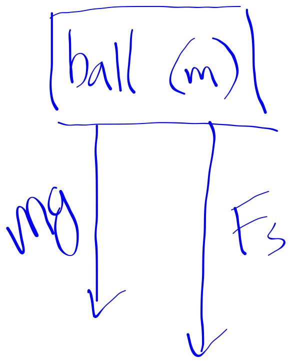
$\dfrac{3.44 \sin 24}{0.32} = a_x$

$4.37\ \text{m/s}^2 = a_x$

3. A baseball is thrown directly up into the air. It is attached to a spring that is hooked to the ground. The spring has a k of 0.41 N/cm. When the spring has stretched out 5.6 cm, the baseball has an instantaneous acceleration of 11.4 m/s^2 downward. What is the mass of the baseball? (1.44 kg)



$+\downarrow$



$F_s = kx = 0.41\,N/cm \cdot 5.6\,cm = 2.3\,N$

$\Sigma F = ma$

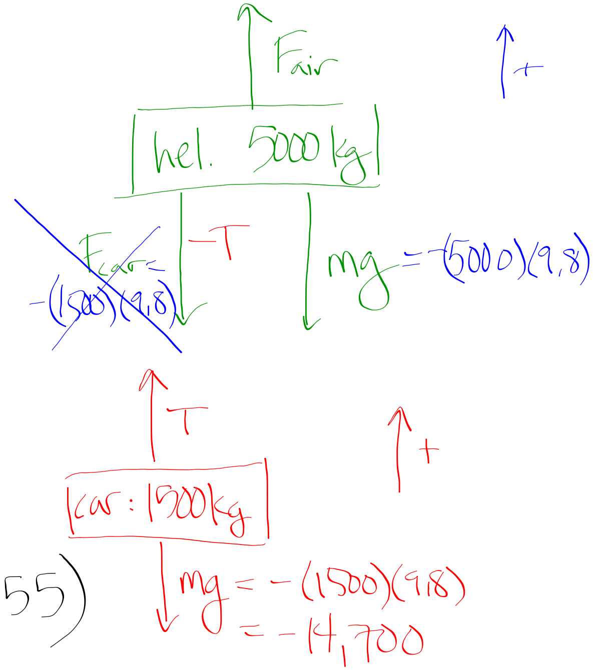
$mg + F_s = ma$

$m(9.8) + 2.3 = m(11.4)$

$2.3 = 1.6m$

$m = 1.44\ kg$

6. (p. 68 #36) A 5000-kg helicopter accelerates upward at 0.550 m/s^2 while lifting a 1500-kg car.
   a) What is the lift force exerted by the air on the blades of the helicopter?
   b) What is the tension in the cable (ignore its mass) that connects car to helicopter?



$$\Sigma F_{car} = m a_{car}$$

$$T - 14,700 = 1500(0.55)$$

$$T = 15,525 \text{ N}$$

$$\Sigma F_{hel.} = m a_{hel.}$$

$$F_{air} + -T + -mg = m a_{hel.}$$

$$F_{air} + -15,525 + -(5000)(9.8) = (5000)(.55)$$

$$F_{air} = \boxed{67,275 \text{ N}}$$

- Play w/app for 5 mins.
- Set up cart & hanging mass
  - Put random masses on each
  - Draw FBD's for cart & mass
  - Use $\Sigma F = ma$ for both cart & mass to predict acceleration.
- Run the trial
  - Use the tape to calculate the actual acceleration
  - You'll know: time (Δt) and position (Δx) ($v_0 = 0$)
  - Use the Big 4!

FRICTION

FRICTION:

The force between two surfaces in contact with one another that ALWAYS resists relative motion between the two surfaces.

Friction is a smart force -- it is there when it needs to be, and not when there is no relative motion.

What factors determine the size of the force of friction?

$$\boxed{F_{FRICTION} = \mu F_N}$$

$F_{Fr} = \mu F_N$

F_N = the force clamping the two surfaces together (and this usually is the normal force)

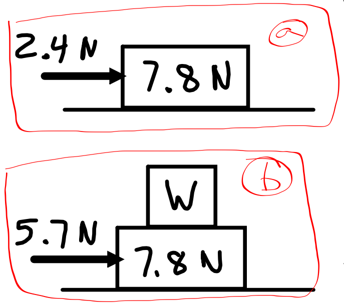
"mu"

μ = the coefficient of friction
-- It is unitless
-- It is usually less than 1.0 (but it can be bigger)
-- It is specific and unique for any two surfaces
-- $\mu_{STATIC} > \mu_{KINETIC}$

μ_s → describes the maximum amount of force friction can create between two surfaces

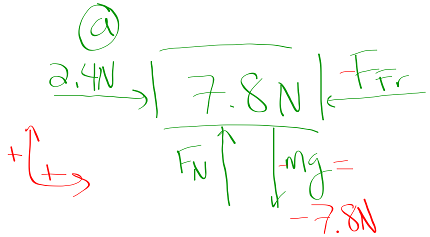
μ_k → describes the actual force of friction on a moving object

EXAMPLE 1



For the 7.8 N object to move across the surface by itself at constant speed, a 2.4 N force must be applied.

If the 2.4 N force must be increased to 5.7 N when an object with weight W is placed on the 7.8 N object, what is W? Assume the two blocks move at constant velocity.



$\Sigma F_x = m\cancel{a_x} = 0$

$2.4N + -F_{Fr} = 0$

$F_{Fr} = 2.4N$

$\Sigma F_y = m\cancel{a_y} = 0$

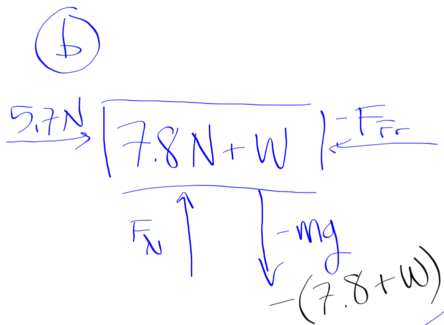
$F_N + -7.8 = 0$

$F_N = 7.8N$

$F_{Fr} = \mu F_N$

$2.4 = \mu 7.8$

$\mu = 0.31$



$\Sigma F_x = 0$

$5.7 + -F_{Fr} = 0$

$F_{Fr} = 5.7N$

$\Sigma F_y = 0$

$F_N + -(7.8+W) = 0$

$W = F_N - 7.8$

$F_{Fr} = \mu F_N$

$5.7 = 0.31(F_N)$

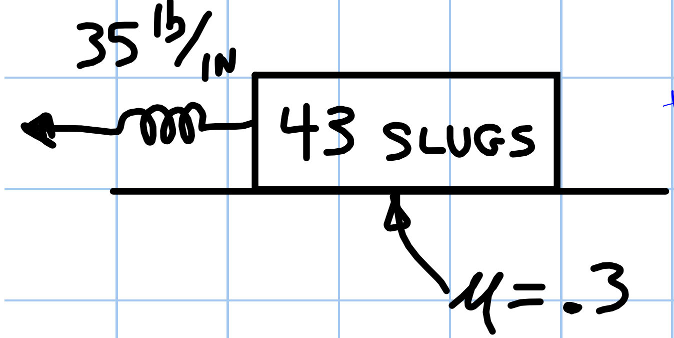
$F_N = 18.39N$

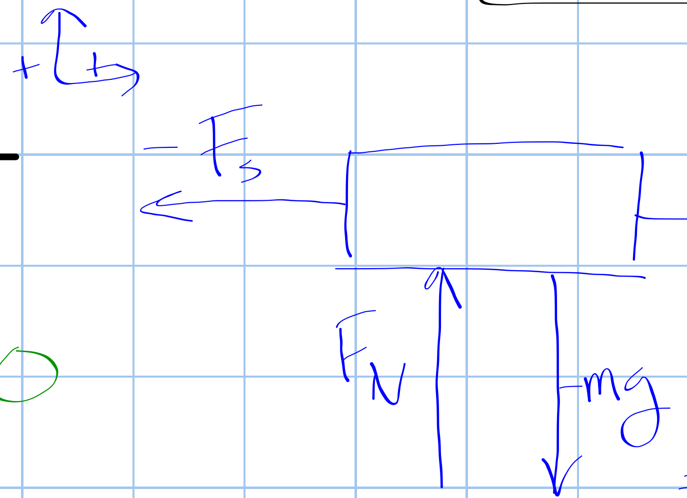
$W = 18.39 - 7.8$

$= 10.59N$

EXAMPLE 2

How far must the spring be stretched to slide the mass along the surface at constant speed?





$F_{Fr} = \mu F_N = (.3)(1384.6) = 415.38\text{ lb}$

$-mg = -(43)(32.2) = -1384.6\text{ lb}$

$\Sigma F_y = m\cancel{a_y} = 0$

$F_N + -1384.6 = 0$

$F_N = 1384.6$

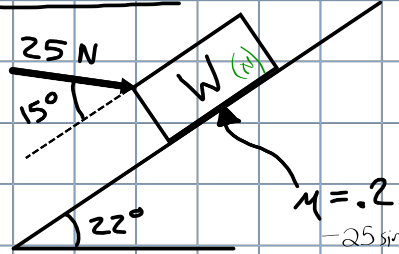
$\Sigma F_x = m\cancel{a_x} = 0$

$-F_s + 415.38 = 0$

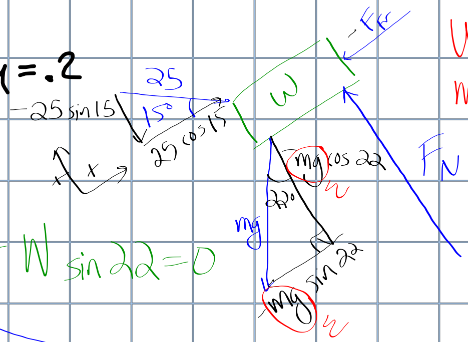
$F_s = 415.38 = kx = 35\text{ lb/in}\ x$

$x = 11.9\text{ in}$

Example 3



What is W if the object moves up the incline at constant speed? (W is a weight)



$W = mg$

$m = W/g = W/9.8$

$\Sigma F_x = ma_x = 0$

$25 \cos 15 + {}^-F_{fr} + {}^-W \sin 22 = 0$

$F_{Fr} = \mu \cdot F_N = \boxed{0.2 F_N}$

$\Sigma F_y = ma_y = 0$

$-W \cos 22 + {}^-25 \sin 15 + F_N = 0$

$25 \cos 15 + {}^-0.2 F_N + {}^-W \sin 22 = 0$

$\boxed{F_N} = W \cos 22 + 25 \sin 15$

$\boxed{F_N} = \dfrac{25 \cos 15 + {}^-W \sin 22}{0.2}$

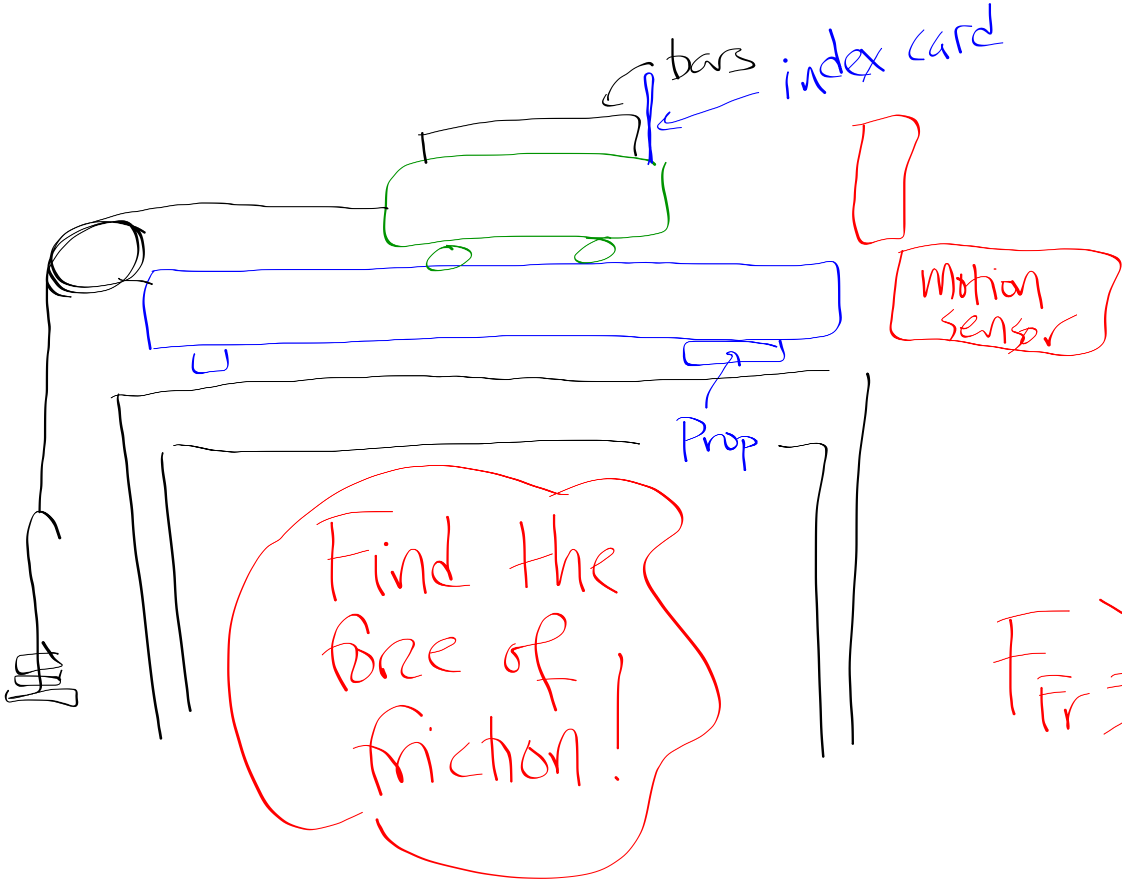
$W \cos 22 + 25 \sin 15 = \dfrac{25 \cos 15 + {}^-W \sin 22}{0.2}$

$0.93 W + 6.5 = \dfrac{24.1 - 0.37 W}{0.2}$

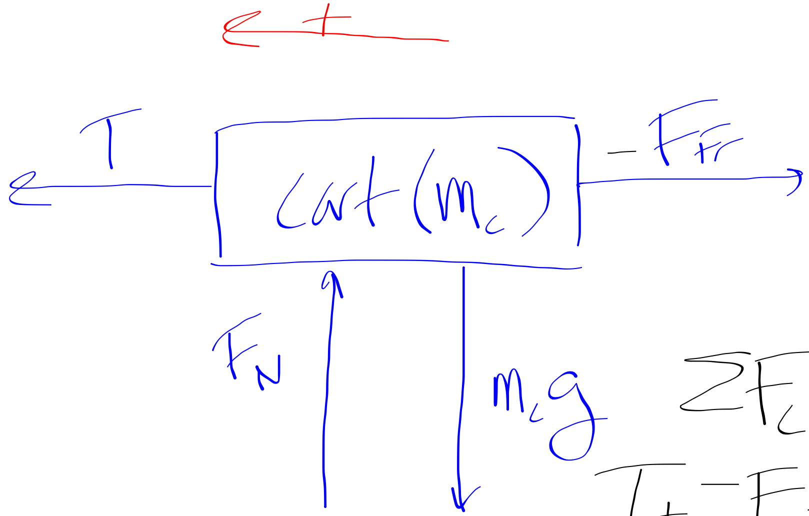
$0.19 W + 1.3 = 24.1 - 0.37 W$

$0.56 W = 22.8$

$W = 40.7\ N$

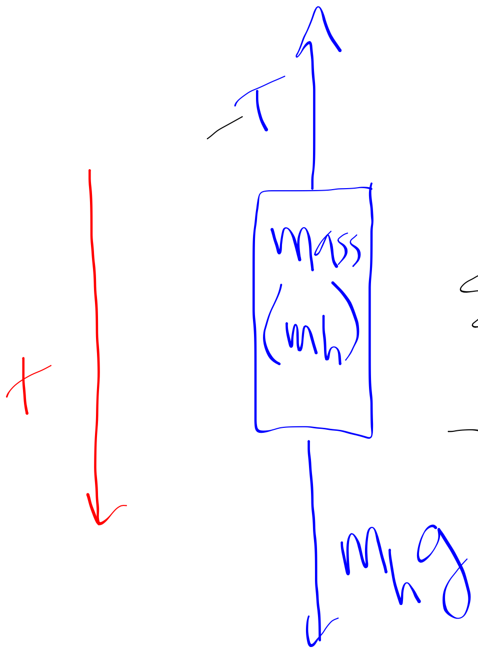


$\cancel{F_{Fr} = \mu F_N}$



$$\Sigma F_c = m_c a$$

$$T - F_{Fr} = m_c a$$



$$\Sigma F_h = m_h a$$

$$-T + m_h g = m_h a$$

$$\cancel{F_{Fr} = \mu F_N}$$

t	x	v ← *
–	–	–
–	–	–
–	–	–
0.31	0.21	1.2
⋮		v_0
0.46	0.78	

Δt x_0, x → a!