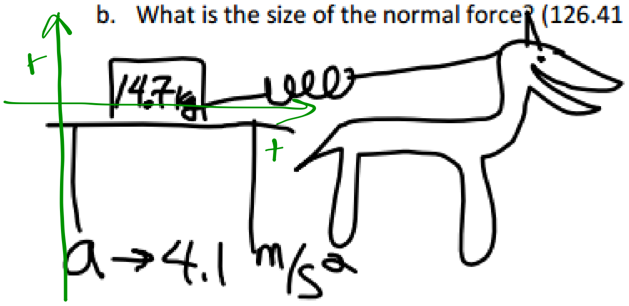
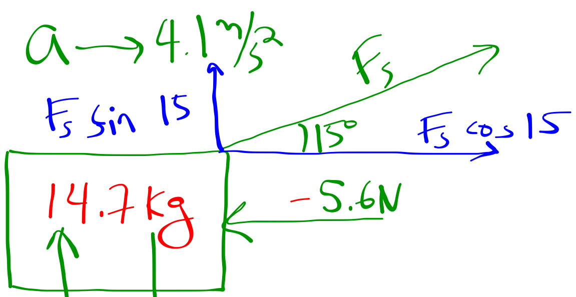
1. A box is being pulled along a horizontal table by a rope connected to a donkey's shoulders at an angle of 15° to the table. There is a spring between the rope and the box with k = 12.2 N/cm. The mass of the box is 14.7 kg. If friction is opposing the box's motion with a constant force of 5.6 N, and 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_N

$mg = 14.7 \cdot 9.8$

$$\Sigma F_x = -5.6 + F_s \cos 15 = m \cdot a$$

$$F_s = \frac{14.7 \cdot (4.1) + 5.6}{\cos 15}$$

$$F_s = 68.2\ N$$

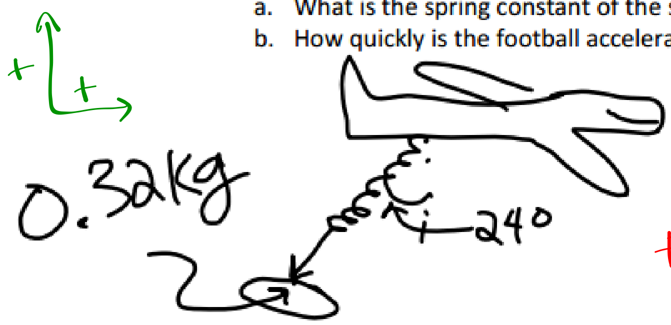
$$\Sigma F_y = F_N - (14.7 \cdot 9.8) + F_s \sin 15 = 0$$

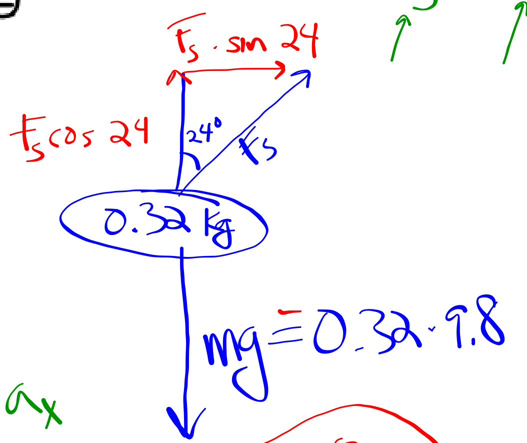
$$F_N = -F_s \sin 15 + 14.7 \cdot 9.8$$

$$F_N = 126.5\ N$$

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)

$F_s = kx$





$$\sum F_x = F_s \sin 24 = ma_x$$

$$F_s \sin 24 = (0.32)a_x$$

$$\sum F_y = (-0.32)(9.8) + F_s \cos 24 = m\cancel{a_y}^{0} = 0$$

$$F_s = \frac{(0.32)(9.8)}{\cos 24} = 3.43\,N$$

$$F_s = kx$$

$$k = \frac{3.43\,N}{11\,cm} = 0.31\,N/cm$$

$$a_x = \frac{F_s \sin 24}{m} = \frac{3.43 \cdot \sin 24}{0.32} = 4.36\,m/s^2$$

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   a. What is the spring constant of the spring (in N/cm)? (0.31 N/cm)
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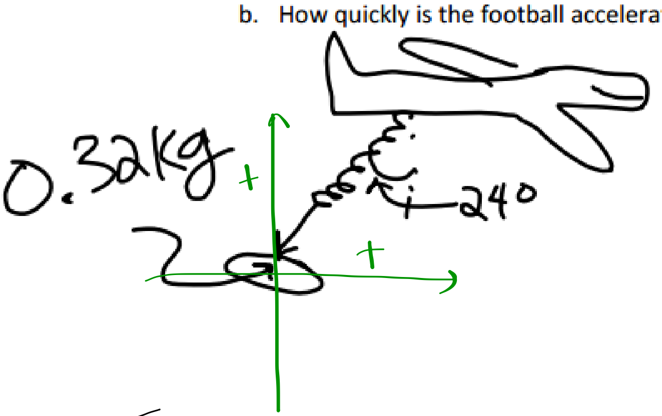
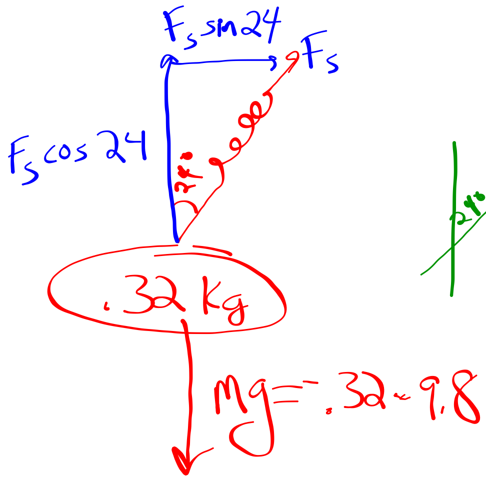
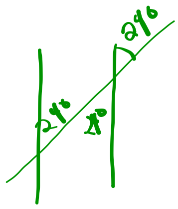






$$\Sigma_X = F_s \sin 24 = m \cdot a_x$$

$$F_s = \frac{(.32)\,a_x}{\sin 24}$$

$$\Sigma F_Y = (-.32)(9.8) + F_s \cos 24 = 0$$

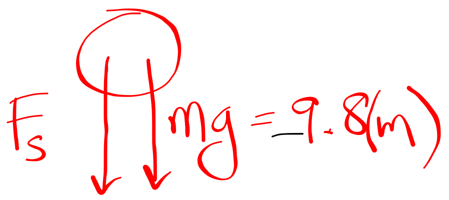
$$F_s = \frac{(.32)(9.8)}{\cos 24} = 3.43\text{N}$$

$$F_s = kx$$

11 cm

$$k = \frac{3.43\text{N}}{11\text{cm}} = 0.31\,\frac{\text{N}}{\text{cm}}$$

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)



$$\Sigma F_y = F_s - 9.8(m) = m a_y$$

$$kx - 9.8(m) = m(-11.4 \, m/s^2)$$

$$(.41 \, N/cm)(5.6 \, cm) - 9.8m = -11.4m$$

$$m = \frac{(.41)(5.6)}{-1.6} = 1.44 \text{ kg}$$

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?

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

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

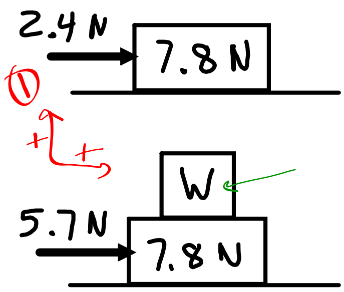
μ = the coefficient of friction
-- It is unitless
-- It is usually less than 1.0 (but it can be bigger)
-- It is specific and unique for any two surfaces
-- $\mu_{STATIC} > \mu_{KINETIC}$

Before an object is moving

after the object is moving

$$F_{max} = \mu_s F_N$$

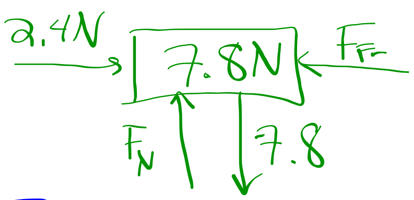
EXAMPLE 1



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.

①



$$\Sigma F_x = 2.4N + F_{Fr} = m\cancel{a_x}^{0} = 0$$

$$\boxed{F_{Fr} = -2.4N}$$

$$\Sigma F_Y = F_N - 7.8 = m\cancel{a_y}^{0} = 0$$

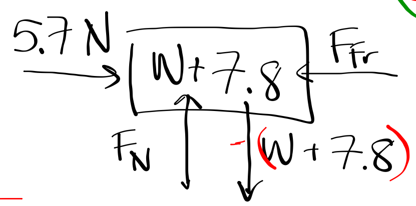
$$\boxed{F_N = 7.8N}$$

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

$$2.4N = \mu 7.8N$$

$$\mu = 0.31$$

②



$$\Sigma F_Y = F_N - (W+7.8) = m\cancel{a_y}^{0} = 0$$

$$F_N = W + 7.8$$

$$\Sigma F_x = 5.7N + F_{Fr} = m\cancel{a_x}^{0} = 0$$

$$5.7N + F_{Fr} = 0$$

$$F_{Fr} = -5.7N = \mu F_N$$

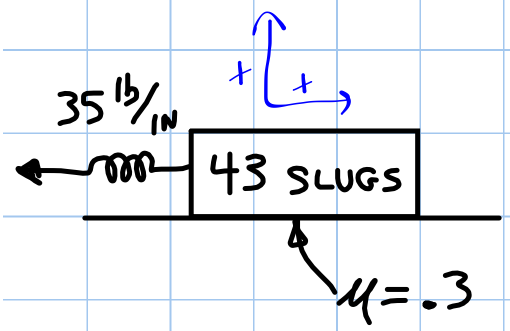
$$5.7 = 0.31 F_N$$

$$F_N = \boxed{18.4N}$$

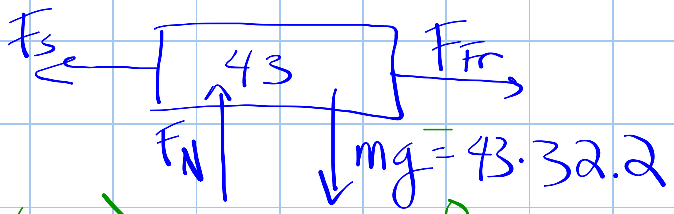
$$18.4N = W + 7.8N$$

$$W = 10.6N$$

Example 2



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



$$\sum F_Y = (-43)(32.2) + F_N = m\cancel{a_y}^{\,0} = 0$$

$$F_N = 1384.6\,N$$

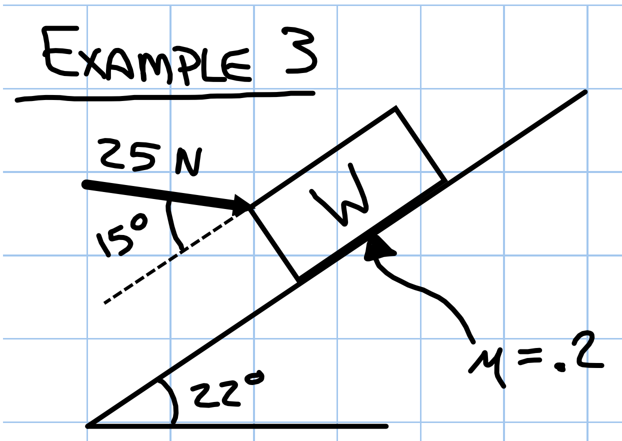
$$\sum F_x = F_s + F_{Fr} = m\cancel{a_x}^{\,0} = 0$$

$$kx \leftarrow F_s = -F_{Fr} \rightarrow \mu F_N$$

$$(35)x = -(.3)(1384.6)$$

$$x = -11.9 \text{ in}$$

Stretched 11.9 in

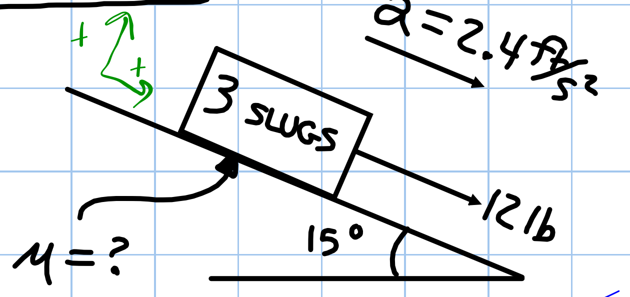


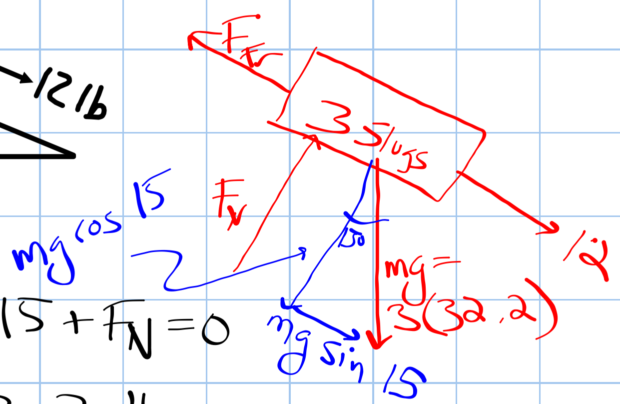
What is W if the object moves up the incline at constant speed? (W is a weight)

Example 4

$a = 2.4\ ft/s^2$

What must μ be?





$\sum F_y = (3)(32.2)\cos 15 + F_N = 0$

$F_N = 93.3\ lbs$

$\sum F_x = F_{Fr} + 12 + 3(32.2)(\sin 15) = ma_x = (3)(2.4)$

$F_{Fr} + 12 + 25 = 7.2$

$F_{Fr} = -29.8$

$F_{Fr} = \mu F_N$

$29.8 = \mu\, 93.3$

$\mu = 0.32$

1. Try h/w (due Tuesday)
2. Skim reading (due Tuesday)
3. Read lab, make diagrams, be prepared (due FRIDAY!)