**PHY 231 HW7 More F=ma**  
**View Basic/Answers**

**HW7 More F=ma Begin Date:** 2/25/2015 6:00:00 PM -- **Due Date:** 3/6/2015 11:59:00 PM **End Date:** 3/6/2015 11:59:00 PM

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**Problem 1:**

A crate is placed on flatbed truck but is not tied down. The truck accelerates in the positive x-direction (to the right, as shown) too fast and the crate falls off the back of the truck. There is friction between the truck bed and the crate.

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**Part (a)** When the crate falls off, in what direction is it moving relative to the ground?

- 1) To the right (positive x-direction).
- 2) To the left (negative x-direction).
- 3) It is not moving with respect to the ground.

**Part (b)** A friction force acts on the crate. Which of the following statements is true?

- The friction force is in the same direction as the motion of the crate relative to the ground.
- The friction force is in the opposite direction of the motion of the crate relative to the ground. (Friction always opposes motion).
- The friction force is perpendicular to the motion of the crate.

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**Problem 2:**

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Problem 3:

A semi is traveling down the highway at a velocity of \( v = 28.5 \text{ m/s} \). The driver observes a wreck ahead, locks his brakes, and begins to slide. The truck has mass \( m \) and a coefficient of kinetic friction between the tires and the road of \( \mu_k = 0.017 \).

Randomized Variables

\( v = 28.5 \text{ m/s} \)
\( \mu_k = 0.017 \)

Part (a) Write an expression for the sum of the forces in the x-direction for the truck while braking.

**Expression**

\[ \Sigma F_x = \]

Select from the variables below to write your expression. Note that all variables may not be required.
\( \cos(\alpha), \cos(\phi), \cos(\theta), \sin(\alpha), \sin(\phi), \sin(\theta), \alpha, \beta, \mu_k, \theta, a, d, g, h, i, j, k, m, P, S, t \)

Part (b) Using the results from Part (a), input an expression for the truck's acceleration, \( a_f \), while braking.

**Expression**

\[ a_f = \]

Select from the variables below to write your expression. Note that all variables may not be required.
\( a, \beta, \mu_k, \theta, a, d, g, h, i, j, k, m, P, S, t \)

Part (c) What is the magnitude of the acceleration in m/s\(^2\)?

**Numeric** A numeric value is expected and not an expression.

\[ |a_f| = \]

Part (d) How far does the truck travel, \( d \) in meters, before stopping?

**Numeric** A numeric value is expected and not an expression.

\[ d = \]

a) Only acting by friction, so \( \Sigma F_x = -\mu_k mg \)

b) Newton's 2nd law, \( \Sigma F_x = ma \rightarrow -\mu_k mg = ma \), \[ a_f = -\mu_k g \]

c) \[ a_f = 0.167 \text{ m/s}^2 \]

d) Kinematic equation, \( V_f^2 - V_i^2 = 2a \Delta x \rightarrow 0 - V^2 = 2(\mu_k g) d \rightarrow d = \frac{V^2}{2\mu_k g} \]

\[ d = 24.35 \text{ m} \]
A spring with a spring constant of $k = 180 \text{ N/m}$ is initially compressed by a block a distance $d = 0.32 \text{ m}$. The block is oriented horizontally and has a mass of $m = 6 \text{ kg}$.

**Randomized Variables**

\[
\begin{align*}
  k & = 180 \text{ N/m} \\
  d & = 0.32 \text{ m} \\
  m & = 6 \text{ kg}
\end{align*}
\]

**Part (a)** Assuming the block is moving to the right, input an expression for the sum of the forces in the x-direction in the configuration shown above, using the variables provided.

**Expression** :

\[ \sum F_x = \text{expression} \]

Select from the variables below to write your expression. Note that all variables may not be required.

- $a$, $\beta$, $\mu_k$, $\theta$, $d$, $g$, $i$, $j$, $k$, $m$, $P$, $S$, $t$

**Part (b)** Using $\mu_s$ to represent the coefficient of static friction, how large would $\mu_s$ need to be to keep the block from moving?

**Numeric** : A numeric value is expected and not an expression.

$\mu_s = \text{numeric}$

**Part (c)** Assuming the block has just begun to move and the coefficient of kinetic friction is $\mu_k = 0.2$, what is the block's acceleration in $\text{m/s}^2$?

**Numeric** : A numeric value is expected and not an expression.

$a = \text{numeric}$

\[ \begin{align*}
  \text{a)} & \quad \text{Assuming the block is moving (to the right), at the moment shown in the figure, the forces are} \\
  \qquad & \quad \sum F_x = kd - \mu_k mg \\
  \text{b)} & \quad \sum F_x = kd - F_s = 0 \rightarrow kd = F_s \leq M_s Mg \quad , \quad M_s \geq \frac{kd}{mg} \\
  \qquad & \quad \text{At maximum, } M_s = 0.979 \\
  \text{c)} & \quad \text{From part a, } kd - \mu_k mg = ma \rightarrow a = \frac{kd}{m} - \mu_k g \quad , \quad a \approx 11.64 \text{ m/s}^2
\end{align*} \]
A block with a mass of \( m = 1 \text{ kg} \) rests on a wooden plank. The coefficient of static friction between the block and the plank is \( \mu_s = 0.6 \). One end of the board is attached to a hinge so that the other end can be lifted forming an angle, \( \theta \), with respect to the ground. Assume the x-axis is along the plank as shown in the figure.

**Randomized Variables**

\[ \mu_s = 0.6 \]
\[ m = 1 \text{ kg} \]

**Part (a)** Please select the correct free body diagram given \( F_g \) is the force due to gravity, \( F_s \) is the static friction force and \( F_N \) is the normal force. Assume the block is at rest.

**SchematicChoice** :

![Free body diagrams](image)

**Part (b)** Assuming the x-direction is along the plank as shown, find an expression for the magnitude of the force of gravity in the y-direction, \( F_{gy} \), perpendicular to the plank in terms of given quantities and variables available in the palette.

**Expression** :

\[ F_{gy} = \ldots \]

Select from the variables below to write your expression. Note that all variables may not be required.

\[ \text{acot}(\mu_s), \ \text{atan}(\mu_s), \ \cos(\alpha), \ \cos(\phi), \ \cos(\theta), \ \sin(\alpha), \ \sin(\phi), \ \sin(\theta), \ \tan(\theta), \ \alpha, \ \beta, \ \mu_k, \ \mu_s, \ \theta, \ b, \ d, \ g, \ h, \ m, \ t \]

**Part (c)** Write an expression for the magnitude of the maximum friction force along the surface, \( F_s \), in terms of given quantities and variables available in the palette.

**Expression** :

\[ F_s = \ldots \]

Select from the variables below to write your expression. Note that all variables may not be required.

\[ \text{acot}(\mu_s), \ \text{atan}(\mu_s), \ \cos(\alpha), \ \cos(\phi), \ \cos(\theta), \ \sin(\alpha), \ \sin(\phi), \ \sin(\theta), \ \alpha, \ \mu_k, \ \mu_s, \ b, \ g, \ m, \ t \]

**Part (d)** Assuming the static friction is maximized, write an expression, using only the given parameters and variables available in the palette, for the sum of the forces along the plank, \( \Sigma F_x \).

**Expression** :

\[ \Sigma F_x = \ldots \]

Select from the variables below to write your expression. Note that all variables may not be required.

\[ \text{acot}(\mu_s), \ \text{atan}(\mu_s), \ \cos(\alpha), \ \cos(\phi), \ \cos(\theta), \ \sin(\alpha), \ \sin(\phi), \ \sin(\theta), \ \alpha, \ \mu_k, \ \mu_s, \ b, \ g, \ m, \ t \]

**Part (e)** Write an expression for the maximum angle, \( \theta_m \), that the board can make with respect to the horizontal before the block starts moving. (Write in terms of the given parameters and variables available in the palette.)

**Expression** :

\[ \theta_m = \ldots \]

Select from the variables below to write your expression. Note that all variables may not be required.

\[ \text{acot}(\mu_s), \ \text{atan}(\mu_s), \ \cos(\alpha), \ \cos(\phi), \ \cos(\theta), \ \sin(\alpha), \ \sin(\phi), \ \sin(\theta), \ \tan(\theta), \ \alpha, \ \mu_k, \ \mu_s, \ \theta, \ b, \ t \]

**Part (f)** Solve numerically for the maximum angle, \( \theta_m \), in degrees.

**Numeric** : A numeric value is expected and not an expression.

\[ \theta_m = \ldots \]
Problem 5:

A horizontal force, \( F_1 = 50 \) N, and a force, \( F_2 = 10.4 \) N acting at an angle of \( \theta \) to the horizontal, are applied to a block of mass \( m = 2.1 \) kg. The coefficient of kinetic friction between the block and the surface is \( \mu_k = 0.2 \).

**Randomized Variables**

- \( F_1 = 50 \) N
- \( F_2 = 10.4 \) N
- \( m = 2.1 \) kg

**Part (a)** Solve numerically for the magnitude of the normal force, \( F_N \) in Newtons, that acts on the block if \( \theta = 30^\circ \).

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<thead>
<tr>
<th>Numeric</th>
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<tr>
<td>( F_N = )</td>
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**Part (b)** Solve numerically for the magnitude of acceleration of the block, \( a \) in m/s\(^2\), if \( \theta = 30^\circ \).

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<tbody>
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<td>( a = )</td>
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\[ a = \]
Problem 6:

Consider the 65.0-kg ice skater being pushed by two others shown in the figure. Find the direction and magnitude of $\mathbf{F}_{\text{tot}}$, the total force exerted on her by the others, given that the magnitudes $F_1$ and $F_2$ are 26.4 N and 18.6 N, respectively. (b) What is her initial acceleration if she is initially stationary and wearing steel-bladed skates that point in the direction of $\mathbf{F}_{\text{tot}}$? (c) What is her acceleration assuming she is already moving in the direction of $\mathbf{F}_{\text{tot}}$? (Remember that friction always acts in the direction opposite that of motion or attempted motion between surfaces in contact.)
**Problem 7**

**Solution (a)**

\[ F_{\text{tot}} = \left( (F_1)^2 + (F_2)^2 \right)^{1/2} \]

\[ F_{\text{tot}} = \left[ (26.4 \text{ N})^2 + (18.6 \text{ N})^2 \right]^{1/2} = 32.29 \text{ N} - 32.3 \text{ N} \]

\[ \theta = \tan^{-1} \left( \frac{F_2}{F_1} \right) = \tan^{-1} \left( \frac{18.6 \text{ N}}{26.4 \text{ N}} \right) = 35.2^\circ \]

(b) \( f_{\text{max}} = \mu \cdot mg = 0.4(65.0 \text{ kg})(9.80 \text{ m/s}^2) = 254.8 \text{ N} \). \( f_{\text{max}} \approx F_{\text{tot}} \), therefore \( a = 0 \).

(c) \( F = F_{\text{tot}} - \mu_k mg = 32.29 \text{ N} - 0.02 \left( 65.0 \text{ kg} \right) \left( 9.80 \text{ m/s}^2 \right) \)

\[ F = 19.56 \text{ N} \text{ and } a = \frac{F}{m} = \frac{19.56 \text{ N}}{65.0 \text{ kg}} = 0.301 \text{ m/s}^2 \text{ in the direction of } \vec{F}_{\text{tot}} \]
Consider the 52.0-kg mountain climber in the figure. (a) Find the tension in the rope and the force that the mountain climber must exert with her feet on the vertical rock face to remain stationary. Assume that the force is exerted parallel to her legs. Also, assume negligible force exerted by her arms. (b) What is the minimum coefficient of friction between her shoes and the cliff?

Solution

(a) \( T \cos 31^\circ + F_{\text{legs} \, \sin 15^\circ} = mg \) and \( T \sin 31^\circ - F_{\text{legs} \, \cos 15^\circ} = T - 1.88F_{\text{legs}} \)

\[
F_{\text{legs}} = \frac{mg}{1.88 \cos 31^\circ + \sin 15^\circ} = \frac{(52.0 \text{ kg})(9.80 \text{ m/s}^2)}{1.88 \cos 31^\circ + \sin 15^\circ} = 272 \text{ N}
\]

\( T - 1.88F_{\text{legs}} = 1.88 \times 272 \text{ N} = 512 \text{ N} \)

(b) \( \mu_s N = F_{\text{legs} \, \sin 15^\circ} = \mu_s F_{\text{legs} \, \cos 15^\circ} \geq F_{\text{legs} \, \sin 15^\circ} \)

Therefore \( \mu_s \geq \tan 15^\circ = 0.268 \)

Problem 8:

A contestant in a winter sporting event pulls a 45 kg block of ice in the positive horizontal direction with a rope over his shoulders across a frozen lake as shown in the figure. Assume the coefficients of static and kinetic friction are \( \mu_s = 0.1 \) and \( \mu_k = 0.03 \).

Part (a) Calculate the minimum force \( F \) he must exert to get the block sliding in newtons.

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**Numeric** : A numeric value is expected and not an expression.

\[ F_{\text{min}} = \] _______________

**Part (b) What is its acceleration in m/s\(^2\) once it starts to move, if that force is maintained?**

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**Numeric** : A numeric value is expected and not an expression.

\[ a = \] _______________

**Solution**

(a) \( F - \mu_s N - \mu_k (mg - F \sin \theta) - F \cos \theta \)

\( F(\cos \theta + \mu_k \sin \theta) = \mu_s mg \)

\[
F = \frac{\mu_s mg}{\cos \theta + \mu_k \sin \theta} = \frac{(0.1)(45.0 \text{ kg})(9.80 \text{ m/s}^2)}{\cos 25^\circ + (0.1)\sin 25^\circ} = 46.49 \text{ N} = 46.5 \text{ N}
\]

(b) net \( F = ma = F \cos \theta - \mu_k N = F \cos \theta - \mu_k (mg - F \sin \theta) \), so that

\[
a = \frac{F(\cos \theta + \mu_k \sin \theta) - \mu_k mg}{m} = \frac{46.49 \text{ N}(\cos 25^\circ - 0.03 \sin 25^\circ) - 0.03(45.0 \text{ kg})(9.80 \text{ m/s}^2)}{45.0 \text{ kg}} = 0.629 \text{ m/s}^2 \]
Problem 9:

A 76.0-kg person is being pulled away from a burning building as shown in the figure. Calculate the tension in the two ropes if the person is momentarily motionless. Include a free-body diagram in your solution.

Solution

\[ T_1 \sin 15° = T_2 \cos 10° \]
\[ T_2 = 0.263T_1 \]
\[ T_2 \cos 15° + T_2 \sin 10° = mg \]
\[ T_2 \cos 15° + 0.263T_1 \sin 10° = (76.0 \text{ kg})(9.80 \text{ m/s}^2) \]
\[ 1.012T_1 = 744.8 \text{ N} \]
\[ T_1 = 735.9 \text{ N} = 736 \text{ N} \]
\[ T_2 = 0.263T_1 = 193.6 \text{ N} = 194 \text{ N} \]

Problem 10:
A block of mass $m = 260$ kg rests against a spring with a spring constant of $k = 900$ N/m on an inclined plane which makes an angle of $\theta$ degrees with the horizontal. Assume the spring has been compressed a distance $d$ from its neutral position.

**Randomized Variables**

- $m = 260$ kg
- $k = 900$ N/m

**Part (a)** Set your coordinates to have the x-axis along the surface of the plane, with up the plane as positive, and the y-axis normal to the plane, with out of the plane as positive. Write an expression for the normal force, $F_N$, in the y-direction.

**Expression**

$$F_N =$$

Select from the variables below to write your expression. Note that all variables may not be required.

- $\cos(\alpha)$, $\cos(\theta)$, $\sin(\alpha)$, $\sin(\theta)$, $\alpha$, $\beta$, $\mu_s$, $\theta$, $d$, $g$, $k$, $m$, $t$

**Part (b)** Assuming the coefficient of static friction is $\mu_s$, write an expression for the sum of the forces in the x-direction just before the block begins to slide.

**Expression**

$$\Sigma F_x =$$

Select from the variables below to write your expression. Note that all variables may not be required.

- $\cos(\alpha)$, $\cos(\theta)$, $\sin(\alpha)$, $\sin(\theta)$, $\alpha$, $\beta$, $\mu_s$, $\theta$, $d$, $g$, $k$, $m$, $t$

**Part (c)** Assuming the plane is frictionless, what is the minimum angle in degrees the incline plane can make before the block will move if the spring is compressed by 0.1 m?

**Numeric**: A numeric value is expected and not an expression.

$$\theta =$$

**Part (d)** Assuming $\theta = 45$ degrees and the surface is frictionless, how far will the spring be compressed, $d$ in meters?

**Numeric**: A numeric value is expected and not an expression.

$$d =$$

\[\Sigma F_y = F_N - mg \cos \theta = 0, \quad F_N = mg \cos \theta\]

$$\Sigma F_x = F_s - F_f - F_x = k \Delta - F_f - mg \sin \theta = 0$$

If $F_f$ takes its maximum value we have

$$\Sigma F_x = k \Delta - mg \cos \theta - mg \sin \theta$$

$$c) \quad \Sigma F_x = k \Delta - mg \sin \theta = 0 \quad \therefore \sin \theta = \frac{k \Delta}{mg} \quad \therefore \theta \approx 2.02^\circ$$

$$d) \quad k \Delta - mg \sin \theta = 0 \quad \therefore d = \frac{mg \sin \theta}{k} \quad \therefore d \approx 2.0 \text{ m}$$