PHYS 1441 – Section 001
Lecture #7

Monday, June 9, 2008

Dr. Jaehoon Yu

- Exam problem solving
- Equilibrium Applications of Newton's Laws of Motion
- Non-equilibrium Applications of Newton's Laws
- Uniform Circular Motion
- Centripetal Acceleration and Force
- Banked and Unbanked Road
- Satellite Motion

Today's homework is homework #5, due 9pm, Friday, June 13!!

Announcements

- Quiz tomorrow, Tuesday, June 10
  - Covers: CH4.4 – what we learn today
- You will receive 100% for problems #11 - 13 in HW#3 since the computer answers are incorrect but I strongly suggest you to do these problems.
- Term 1 Results
  - Class Average: 64.4/102
    - Equivalent to 63/100
  - Top score: 95/102
- Homework: 30%, Final exam: 25%, Term exam: 20%, Lab: 15% and Quiz:10%
- Second term exam
  - 8 – 10am, Tuesday, June 17, in SH103
  - Covers CH4.1 – What we finish next Thursday, June 12
  - Practice test will be posted on the class web page
    - No answer keys will be posted
  - Dr. Satyanand will conduct a help session 8 – 10am, Monday, June 16 in class

Reminder: Special Project

- Using the fact that $g=9.80m/s^2$ on the Earth's surface, find the average density of the Earth
  - Use only the values of the constant of universal gravitation and the radius of the Earth, in addition to the value of the gravitational acceleration g given in this problem
- 20 point extra credit
- Due: Thursday, June 12
- You must show your OWN, detailed work to obtain any credit!!

Translational Equilibrium

An object is in its translational equilibrium when it has zero net acceleration.

$$\sum \vec{F} = m\vec{a} = 0$$

Conditions for Translational Equilibrium

$$\sum F_x = ma_x = 0 \qquad \sum F_y = ma_y = 0$$

If an object is not moving at all, the object is in its static equilibrium.

Is an object is moving at a constant velocity in its equilibrium? Yes

Why? Because its acceleration is 0.

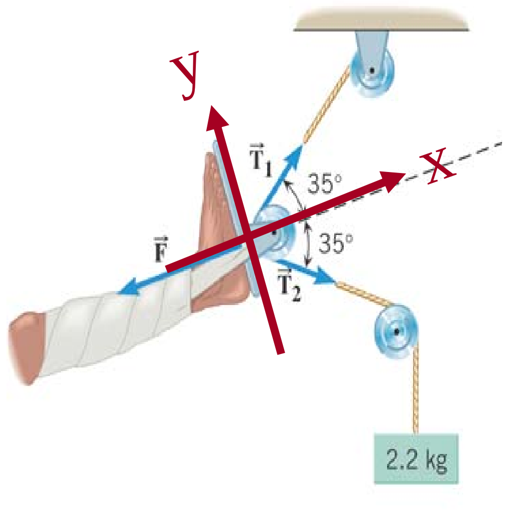
Strategy for Solving Force Problems

- Select an object(s) to which the equations of equilibrium are to be applied.
- Identify all the forces acting only on the selected object
- Draw a free-body diagram for each object chosen above. Include only forces acting on the object, not the forces the object exerts on its environment.
- Choose a set of *x* and *y* axes for each object and resolve all forces in the free-body diagram into components that point along these axes.
- Apply the equations and solve for the unknown quantities

$\Rightarrow$ No matter which object we choose to draw the free body diagram on, the results should be the same, as long as they are in the same motion

Ex. 11 Traction for the Foot

The weight of the 2.2 kg object creates a tension in the rope that passes around the pulleys. Therefore, tension forces T_1 and T_2 are applied to the pulley on the foot. The foot pulley is kept in equilibrium because the foot also applies a force F to it. This force arises in reaction to the pulling effect of the forces T_1 and T_2. Ignoring the weight of the foot, find the magnitude of the force F.



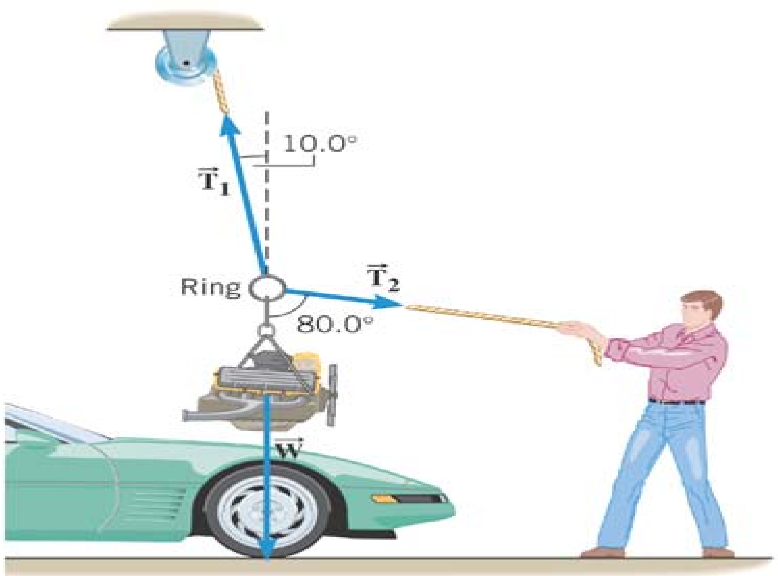
(*a*)

$$\sum F_y = +T_1 \sin 35^{\circ\circ} - T_2 \sin 35^\circ = 0$$

$$\sum F_x = +T_1 \cos 35^\circ + T_2 \cos 35^\circ - F = 0$$

Ex. 12 Replacing an Engine

An automobile engine has a weight (or gravitational force) W, whose magnitude is W=3150N. This engine is being positioned above an engine compartment, as shown in the figure. To position the engine, a worker is using a rope. Find the tension T_1 in the support cabling and the tension T_2 in the positioning rope.



(a)

First, analyze the forces in x and y

Force	*x component*	*y component*
$\vec{\mathbf{T}}_1$	$-T_1 \sin 10.0^{\text{o}}$	$+T_1 \cos 10.0^{\text{o}}$
$\vec{\mathbf{T}}_2$	$+T_2 \sin 80.0^{\text{o}}$	$-T_2 \cos 80.0^{\text{o}}$
$\vec{\mathbf{W}}$	0	$-W$

$$W = 3150 \text{ N}$$

Now compute each force component

$$\sum F_x = -T_1 \sin 10.0^{\circ} + T_2 \sin 80.0^{\circ} = 0$$

$$\sum F_y = +T_1 \cos 10.0^{\circ} - T_2 \cos 80.0^{\circ} - W = 0$$

The first equation gives $T_1 = \left(\frac{\sin 80.0^{\circ}}{\sin 10.0^{\circ}} \right) T_2$

Substitution into the second equation above gives

$$\left(\frac{\sin 80.0^{\circ}}{\sin 10.0^{\circ}} \right) T_2 \cos 10.0^{\circ} - T_2 \cos 80.0^{\circ} - W = 0$$

$$T_2 = \frac{W}{\left(\frac{\sin 80.0^{o}}{\sin 10.0^{o}}\right)\cos 10.0^{o} - \cos 80.0^{o}} =$$

$$\frac{3150N}{\left(\frac{\sin 80.0^{o}}{\sin 10.0^{o}}\right)\cos 10.0^{o} - \cos 80.0^{o}} = 582N$$

$$T_2 = 582 \text{ N}$$

$$T_1 = \left(\frac{\sin 80.0^{o}}{\sin 10.0^{o}}\right) T_2$$

$$T_1 = 3.30 \times 10^{3} \text{ N}$$

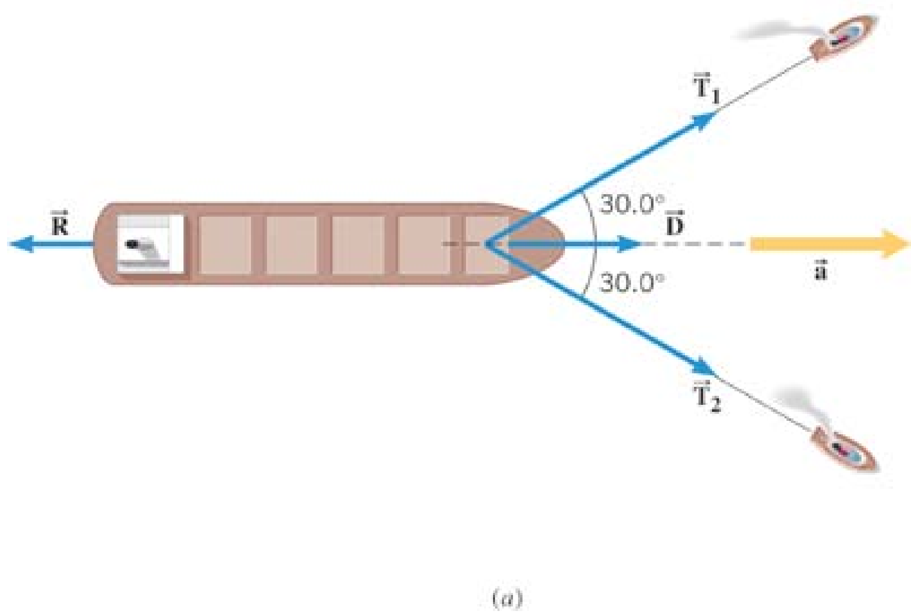
Is an accelerating object in its equilibrium? NO

$$\sum \vec{F} = m\vec{a} \neq 0$$

$$\sum F_x = ma_x \neq 0 \quad \sum F_y = ma_y \neq 0$$

Ex. 14 Towing a Supertanker

A supertanker of mass m=1.50x10^{8}kg is being towed by two tugboats. The tension in the towing cables apply the forces T_1 and T_2 at equal angles of 30^{o} with respect to the tanker's axis. In addition, the tanker's engines produce a forward drive force D, whose magnitude is D=75.0x10^{3}N. Moreover, the water applies an opposing force R, whose magnitude is R=40.0x10^{3}N. The tanker moves forward with an acceleration that points along the tanker's axis and has a magnitude of 2.00x10^{-3}m/s^{2}. Fine the magnitude of T_1 and T_2.



The acceleration is along the *x* axis so $a_y = 0$

Figure out X and Y components

Force	*x* component	*y* component
$\vec{\mathbf{T}}_1$	$+T_1 \cos 30.0^o$	$+T_1 \sin 30.0^o$
$\vec{\mathbf{T}}_2$	$+T_2 \cos 30.0^o$	$-T_2 \sin 30.0^o$
$\vec{\mathbf{D}}$	$+D$	0
$\vec{\mathbf{R}}$	$-R$	0

$$\sum F_y = +T_1 \sin 30.0^o - T_2 \sin 30.0 = 0$$

$$T_1 \sin 30.0^o = T_2 \sin 30.0 \quad \Rightarrow T_1 = T_2 = T$$

$$\sum F_x = +T_1 \cos 30.0^o + T_2 \cos 30.0 + D - R$$

$$= ma_x$$

Since $T_1=T_2=T$

$$2T \cos 30.0^o = ma_x + R - D$$

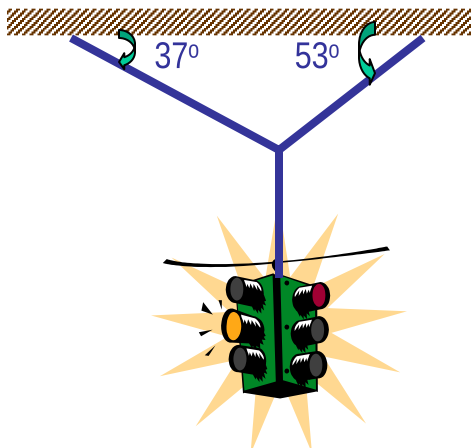
Solving for T

$$T = \frac{ma_x + R - D}{2\cos 30.0^o} = \frac{1.50\times10^0 \cdot 2.00\times10^{-3} + 40.0\times10^3 - 75.0\times10^3}{2\cos 30.0^o} =$$

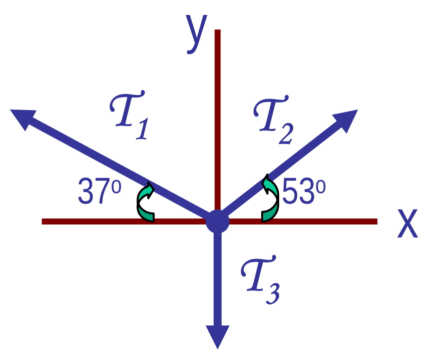
$$= 1.53\times10^5 \text{ N}$$

Example for Using Newton's Laws

A traffic light weighing 125 N hangs from a cable tied to two other cables fastened to a support. The upper cables make angles of 37.0° and 53.0° with the horizontal. Find the tension in the three cables.



Free-body Diagram



$$\vec{F} = \vec{T}_1 + \vec{T}_2 + \vec{T}_3 = m\vec{a} = 0$$ Newton's 2nd law

x-comp. of net force

$$F_x = \sum_{i=1}^{i=3} T_{ix} = 0 \quad -T_1\cos\left(37^\circ\right) + T_2\cos\left(53^\circ\right) = 0 \;\therefore T_1 = \frac{\cos\left(53^\circ\right)}{\cos\left(37^\circ\right)} T_2 = 0.754 T_2$$

y-comp. of net force

$$F_y = \sum_{i=1}^{i=3} T_{iy} = 0$$

$$T_1\sin\left(37^\circ\right) + T_2\sin\left(53^\circ\right) - mg = 0$$

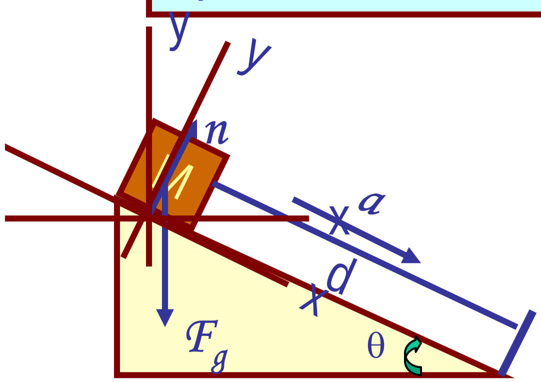
$$T_2\left[\sin\left(53^\circ\right) + 0.754\times\sin\left(37^\circ\right)\right] = 1.25T_2 = 125N$$

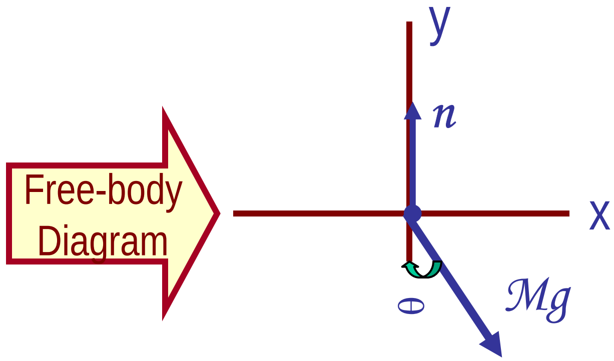
$$T_2 = 100N; \quad T_1 = 0.754T_2 = 75.4N$$

Example w/o Friction

A crate of mass M is placed on a frictionless inclined plane of angle θ.

a) Determine the acceleration of the crate after it is released.





$$\vec{F} = \vec{F}_g + \vec{n} = m\vec{a}$$

$$F_x = Ma_x = F_{gx} = Mg\sin\theta$$

$$a_x = g\sin\theta$$

$$F_y = Ma_y = n - F_{gy} = n - mg\cos\theta = 0$$

Supposed the crate was released at the top of the incline, and the length of the incline is d. How long does it take for the crate to reach the bottom and what is its speed at the bottom?

$$d = v_{ix}t + \frac{1}{2}a_x t^2 = \frac{1}{2}g\sin\theta\, t^2$$

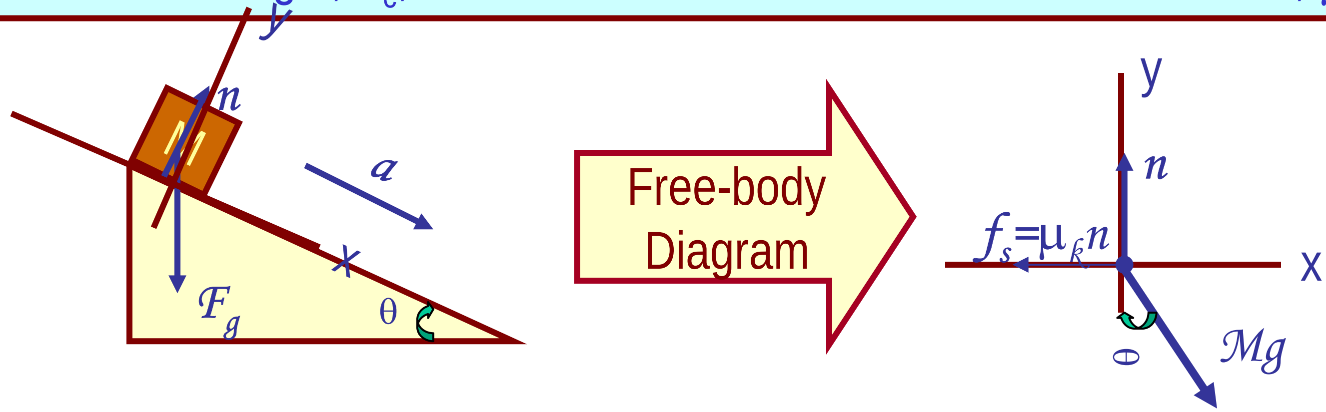
$$\therefore t = \sqrt{\frac{2d}{g\sin\theta}}$$

$$v_{xf} = v_{ix} + a_x t = g\sin\theta\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{2dg\sin\theta}$$

$$\therefore v_{xf} = \sqrt{2dg\sin\theta}$$

Example w/ Friction

Suppose a block is placed on a rough surface inclined relative to the horizontal. The inclination angle is increased till the block starts to move. Show that by measuring this critical angle, θ_c, one can determine coefficient of static friction, μ_s.



Net force $\vec{F} = M\vec{a} = \vec{F}_g + \vec{n} + \vec{f}_s$

x comp. $F_x = F_{gx} - f_s = Mg\sin\theta - f_s = 0 \qquad f_s = \mu_s n = Mg\sin\theta_c$

y comp. $F_y = Ma_y = n - F_{gy} = n - Mg\cos\theta_c = 0 \qquad n = F_{gy} = Mg\cos\theta_c$

$$\mu_s = \frac{Mg\sin\theta_c}{n} = \frac{Mg\sin\theta_c}{Mg\cos\theta_c} = \tan\theta_c$$