Announcement

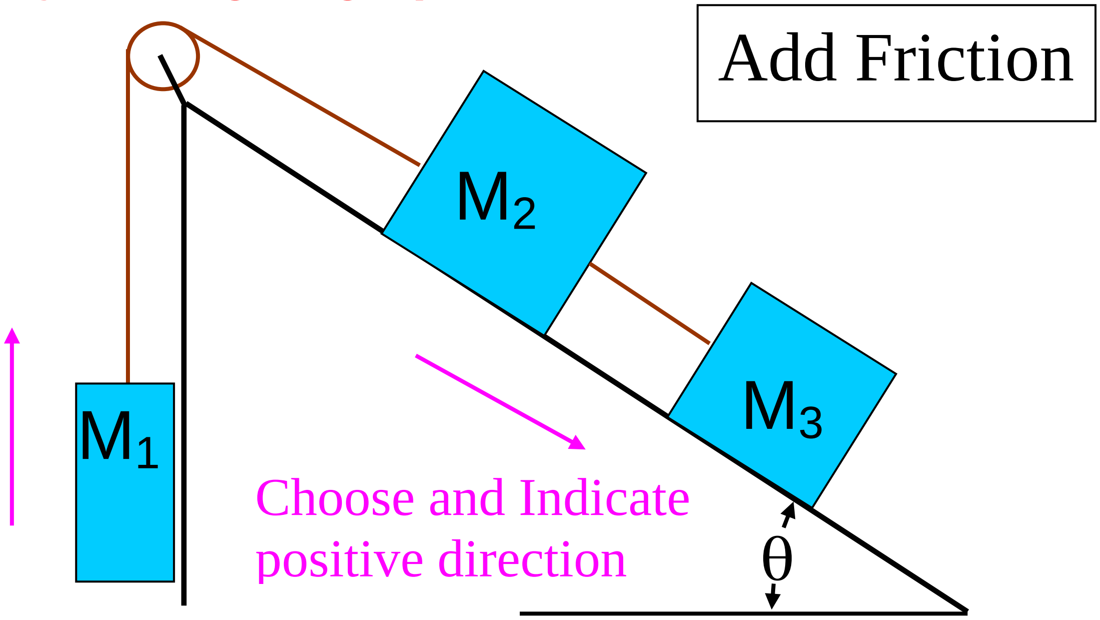
First hour exam is this coming Friday.

Exam policy is explained on the class website:
http://faculty.washington.edu/storm/121C/

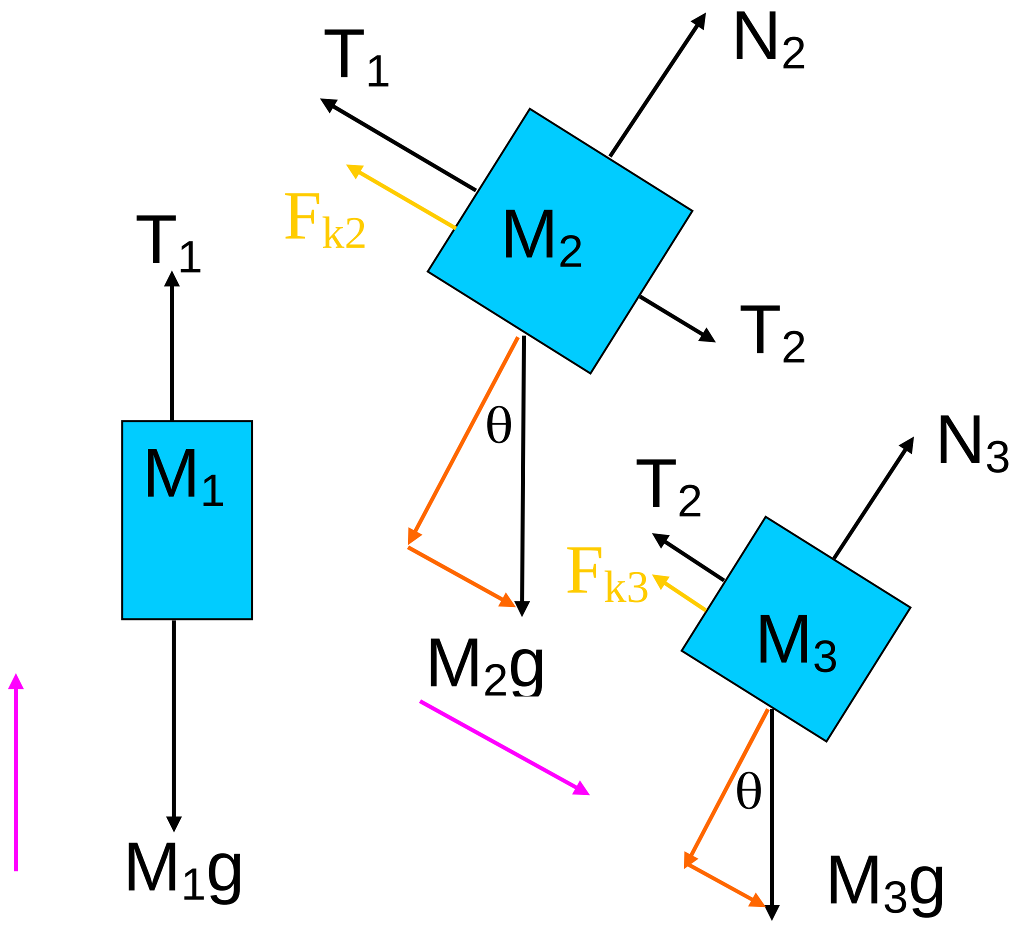
I will tell you more on Wed.

Continue with 3 masses on incline

To include friction, must say which way it goes.
Say M_1 is going up



Kinetic friction points opposite direction of motion (which we make be in the + direction)



Kinetic friction points opposite direction of motion (which we make be in the + direction)

$F_{k2} = -\mu_k N_2 = -\mu_k M_2 g \cos(\theta)$

$F_{k3} = -\mu_k N_3 = -\mu_k M_3 g \cos(\theta)$

Put into equations we had last time

1. $F_{1,net} = T_1 - M_1 g = M_1 a$

2. $F_{2,net} = T_2 - T_1 + M_2 g \sin(\theta) - \mu_k M_2 g \cos(\theta) = M_2 a$

3. $F_{3,net} = -T_2 + M_3 g \sin(\theta) - \mu_k M_3 g \cos(\theta) = M_3 a$

Still three equations, three unknowns.

Again, add them together, T's drop out:

$$-M_1 g + M_2 g\sin(\theta) - \mu_k M_2 g\cos(\theta) + M_3 g\sin(\theta) - \mu_k M_3 g\cos(\theta) = (M_1 + M_2 + M_3)\, a$$

Solve for a:

$$a = \frac{-M_1 + (M_2 + M_3)[\sin(\theta) - \mu_k\cos(\theta)]}{M_1 + M_2 + M_3} g$$

If *a* is positive (*v* is, but *a* may be either + or --) it is reduced by friction. If *a* is negative, it is increased. When (if) *v* reverses, the sign of the friction term will reverse.

Friction is "putting on the breaks" – provides deceleration. Increases magnitude of *a* when *a* is opposite to *v*, and decreases magnitude of *a* when *a* is in the direction of *v*.

Chapter 5 Section 2 Drag

$F_d = b\, v^n$

for air, many fluids $n=2$

b depends on shape, size and so on.

Consider wind:

1. The mass of air that hits a flat surface in a second is proportional to the wind speed.
2. The acceleration to stop it moving is proportional to the wind speed also.
3. F=ma then is proportional to square of wind speed.

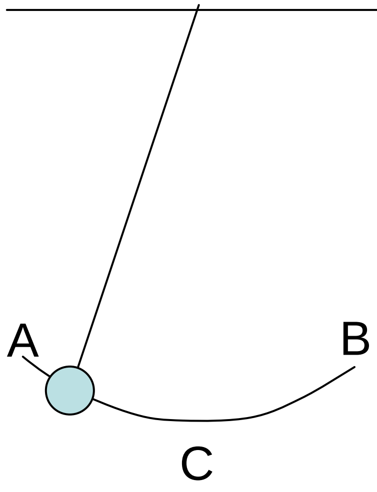
Terminal speed – when v is big enough that

$F_d = mg$

then no more acceleration, and v stays that value

Examples implications for windstorms, hurricanes.

A pendulum swings from A to B (and back and forth). Which statement about the acceleration is true?



A. Centripetal *a* is biggest (in magnitude) at A and B and tangential *a* is biggest at C.
B. Both tangential and centripetal *a* are biggest at C.
C. Both tangential and centripetal *a* are biggest at A and B .
D. Tangential *a* is biggest at A and B and centripetal *a* is biggest at C.
E. The acceleration is only centripetal everywhere.

Section 3 – Motion along a curved path

We already know about tangential and centripetal acceleration.

Examples:

1. **Draw Free Body Diagram with actual forces**
2. **Use coordinate axes with centripetal and tangential directions, and find components of forces on those axes. Get net F_c and F_t**
3. **Figure out a_c and a_t from m and F_c and F_t**
4. **Use $a_c = v^2/r$ and $a_t = dv/dt$**

Demo

Chapter 5 section 5 (skip 4) Center of Mass

Demo Motivation (last part of the section in the book!!)

Consider a system of several parts, with mass and position m_i and $\vec{r}_i$ for the ith one.
Newton's 2nd law applied to the system says

$$\sum_i m_i \vec{a}_i = \sum_i \vec{F}_i = \sum_i \vec{F}_{i,\text{int}} + \sum_i \vec{F}_{i,\text{ext}}$$

where $\vec{F}_i$ is the net force on the ith part.

We can divide $\vec{F}_i$ into internal and external parts. Newton's 3rd law says the internal forces come in pairs and cancel. So $\sum_i \vec{F}_{i,\text{int}} = 0$ and

$$\sum_i m_i \vec{a}_i = \sum_i \vec{F}_{i,\text{ext}}$$

Since $\vec{a}_i = \frac{d\vec{v}_i}{dt} = \frac{d^2\vec{r}_i}{dt^2}$ **and the derivative of a sum is the sum of the derivatives, and the m_i are constant**

$$\sum_i \vec{F}_{i,\text{ext}} = \sum_i m_i \vec{a}_i = \sum_i m_i \frac{d^2\vec{r}_i}{dt^2} = \frac{d^2}{dt^2} \sum_i m_i \vec{r}_i$$

Which suggests $\sum_i m_i \vec{r}_i$ is useful.

With $M = \sum_i m_i$ being the total mass, we define the center of mass position $\vec{r}_{cm}$ by

$$M\vec{r}_{\text{cm}} = \sum_i m_i \vec{r}_i$$

The equation we had

$$\sum_i \vec{F}_{i,\text{ext}} = \sum_i m_i \vec{a}_i = \sum_i m_i \frac{d^2\vec{r}_i}{dt^2} = \frac{d^2}{dt^2}\sum_i m_i \vec{r}_i$$

then becomes (because *M* is a constant)

$$\sum_i \vec{F}_{i,\text{ext}} = \frac{d^2}{dt^2}\sum_i m_i \vec{r}_i = M\frac{d^2}{dt^2}\vec{r}_{\text{cm}} = M\vec{a}_{\text{cm}}$$

Which says the motion of the center of mass depends on the sum of the external forces (only).

Next will be the beginning of the section – calculating center of mass positions for various systems.