Annoucements

1. Second hour exam – Wed. Oct. 16, 2002 at 10:00-10:55 AM

   Bring: Clear head

   Calculator

   Equation sheet

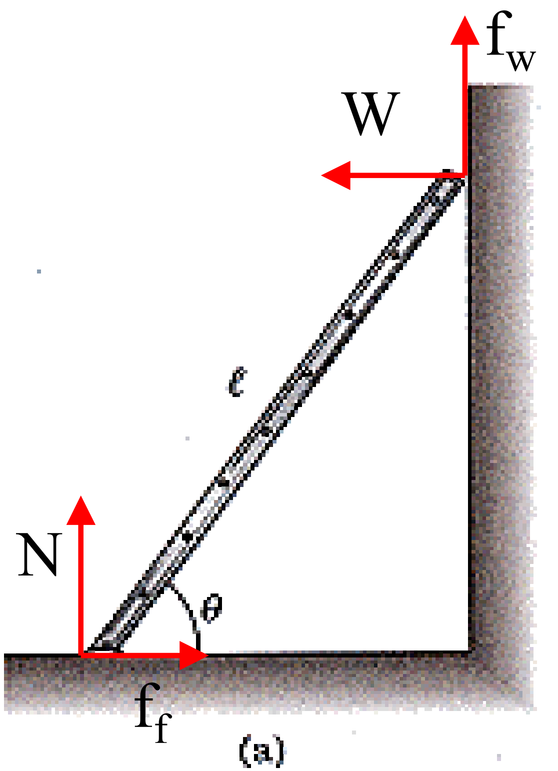
   Assigned seating

   (Will not collect HW notebooks.)

2. Extra practice sessions

   Monday (today) at 5:30 PM

   Tuesday at 5:30 PM?



12-48. A uniform ladder weighing 200 N is leaning against a wall. The ladder slips when θ= 60.0°. Assuming that the coefficients of static friction at the wall and the ground are the same, obtain a value for μ_s.

5 unknowns: W, N, f_f, f_w, μ_s

Answer: $\mu_s^2 + 2\tan\theta\,\mu_s - 1 = 0$

Problem solving steps

1. Visualize problem – labeling variables.
2. Determine which basic physical principles apply.
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (at least as many knowns as unknowns; some information may be redundant).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).

Review:

Notion of potential energy for conservative force $\mathbf{F_C}$:

$$U(\mathbf{r}) = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} \mathbf{F}_C \cdot d\mathbf{r}' = -W_C(\mathbf{r}_{ref} \to \mathbf{r})$$

$$W_{total}^{i\to f} = W_C^{i\to f} + W_{NC}^{i\to f} = U(\mathbf{r}_i) - U(\mathbf{r}_f) + W_{NC}^{i\to f} = K_f - K_i$$

$$K_f + U(\mathbf{r}_f) = K_i + U(\mathbf{r}_i) + W_{NC}^{i\to f}$$

Notion of linear momentum $\mathbf{p} = m\mathbf{v}$

In terms of Newton's second law:

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = \frac{d(m\mathbf{v})}{dt} \equiv \frac{d\mathbf{p}}{dt}$$

Linear momentum and Newton's second law:

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}$$

Consequences:

1. If $\mathbf{F} = 0$ ➔ $\frac{d\mathbf{p}}{dt} = 0$ ➔ $\mathbf{p} = \text{constant}$

2. Notion of impulse: $d\mathbf{p} = \mathbf{F}dt$

$$\int_i^f d\mathbf{p} = \Delta\mathbf{p}_{i\rightarrow f} = \int_i^f \mathbf{F}dt$$

Physics of composite systems

$$\sum_i \mathbf{F}_i = \sum_i \frac{d\mathbf{p}_i}{dt}$$

If $\quad \sum_i \mathbf{F}_i = 0; \Rightarrow \sum_i \frac{d\mathbf{p}_i}{dt} = 0; \Rightarrow \sum_i \mathbf{p}_i \quad = \text{(constant)}$

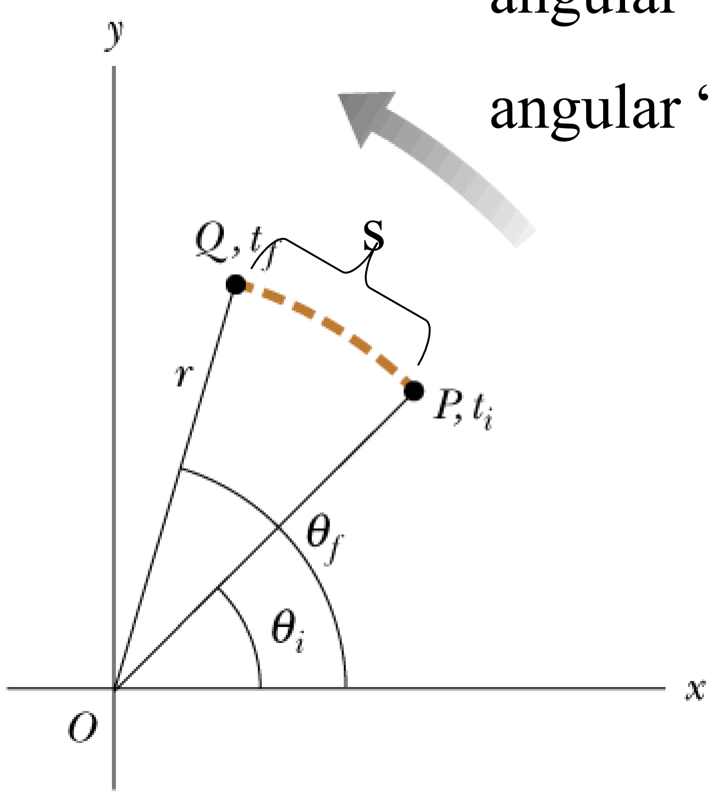
Define center-of-mass velocity: $\mathbf{v}_{\mathrm{CM}} \equiv \dfrac{\sum_i m_i \mathbf{v}_i}{\sum_i m_i} \equiv \dfrac{\sum_i m_i \mathbf{v}_i}{M}$

center-of-mass displacement: $\mathbf{r}_{\mathrm{CM}} \equiv \dfrac{\sum_i m_i \mathbf{r}_i}{\sum_i m_i}$

Note that: $\sum_i \mathbf{F}_i \equiv \mathbf{F}_{total} = M \dfrac{d\mathbf{v}_{\mathrm{CM}}}{dt}$

Angular motion

Serway, Physics for Scientists and Engineers, 5/e
Figure 10.2



Harcourt, Inc.

angular "displacement" → $\theta(t)$

angular "velocity" → $\omega(t) = \frac{d\theta}{dt}$

angular "acceleration" → $\alpha(t) = \frac{d\omega}{dt}$

"natural" unit == 1 radian

Relation to linear variables:

$s_\theta = r\,(\theta_f - \theta_i)$

$v_\theta = r\,\omega$

$a_\theta = r\,\alpha$

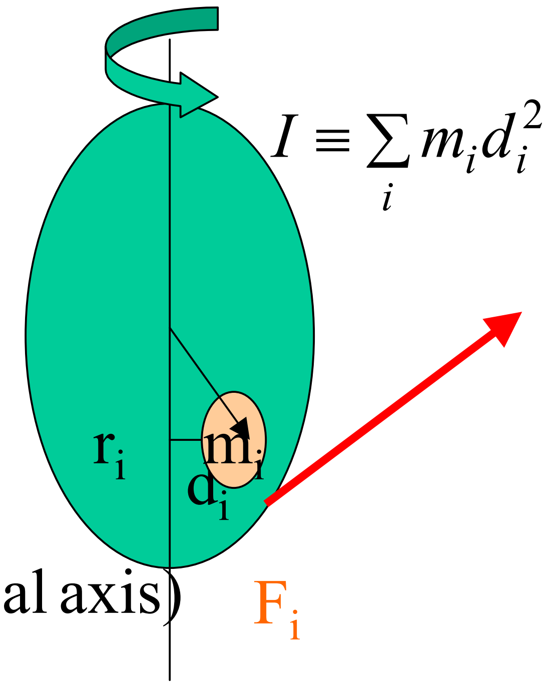
Newton's second law applied to center-of-mass motion

$$\sum_i \mathbf{F}_i = \sum_i m_i \frac{d\mathbf{v}_i}{dt} \Rightarrow \mathbf{F}_{total} = M \frac{d\mathbf{v}_{CM}}{dt}$$

Newton's second law applied to rotational motion

$$\mathbf{F}_i = m_i \frac{d\mathbf{v}_i}{dt} \Rightarrow \mathbf{r}_i \times \mathbf{F}_i = \mathbf{r}_i \times m_i \frac{d\mathbf{v}_i}{dt}$$

$$I \equiv \sum_i m_i d_i^2$$



$$\boldsymbol{\tau}_i = \mathbf{r}_i \times \mathbf{F}_i$$

$$\mathbf{v}_i = \boldsymbol{\omega} \times \mathbf{r}_i$$

$$\Rightarrow \boldsymbol{\tau}_i = m_i \mathbf{r}_i \times \frac{d(\boldsymbol{\omega} \times \mathbf{r}_i)}{dt}$$

$$\Rightarrow \boldsymbol{\tau}_{total} = I \frac{d\boldsymbol{\omega}}{dt} = I\boldsymbol{\alpha}$$ (for rotating about principal axis)

Torque and angular momentum

Define angular momentum: $\mathbf{L} \equiv \mathbf{r} \times \mathbf{p}$

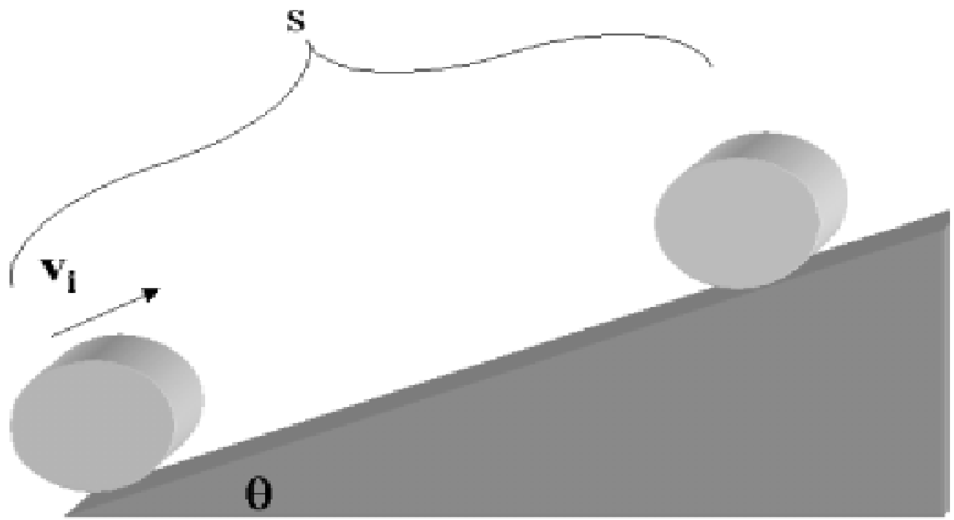
For composite object: $L = I\omega$

Newton's law for torque:

$$\boldsymbol{\tau}_{total} = I\frac{d\boldsymbol{\omega}}{dt} = \frac{d\mathbf{L}}{dt} \quad \Rightarrow \text{If } \boldsymbol{\tau}_{\text{total}} = 0 \quad \text{then } \mathbf{L} = \text{constant}$$

Mechanical equilibrium

$$\sum_i \mathbf{F}_i = 0; \qquad \sum_i \boldsymbol{\tau}_i = 0$$

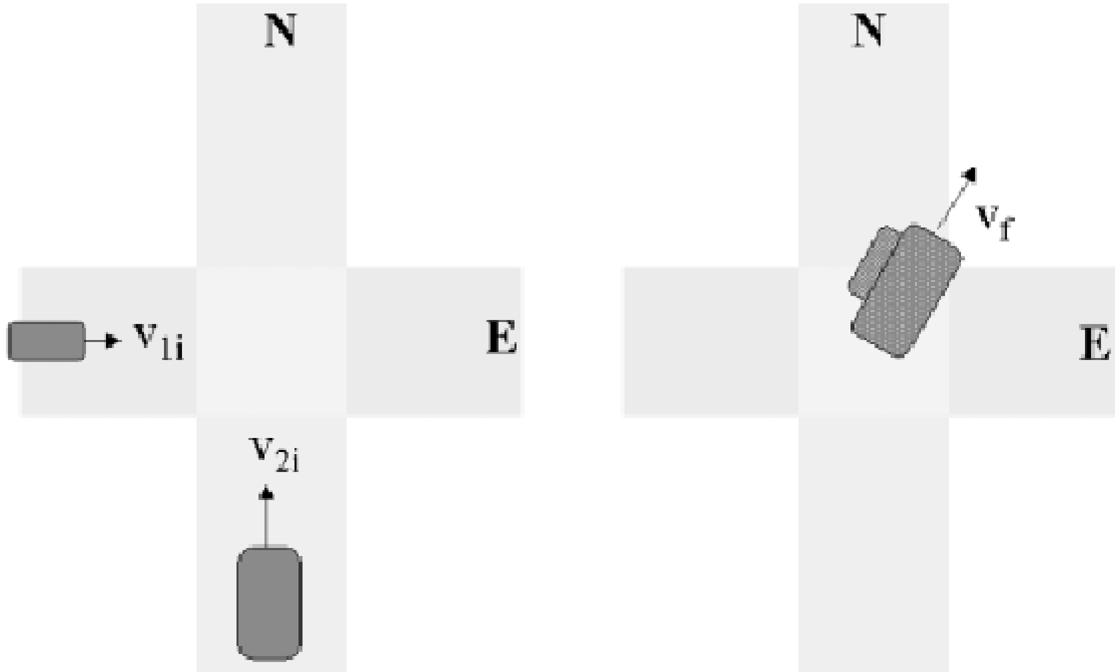


In this figure, the inclined plane is assumed to be stationary with $\theta = 22^o$. The object, having a mass $M = 2$ kg starts at the bottom of the incline with an initial speed of $v_i = 3m/s$ and moves up the incline to a maximum distance s, before moving back down. The value of s will be different for different questions below. For some of the questions below you will need to know that the object has a cylindrical shape with a radius of 0.4 m with a *non-uniform* mass distribution so that the moment of inertia is $I = 0.23$ kg·m^2.

1. Consider the inclined plane shown in the figure above. For this question, assume that surface of the incline is *frictionless* and that the object moving up the incline *slides without rolling* . What is the distance s for this case?

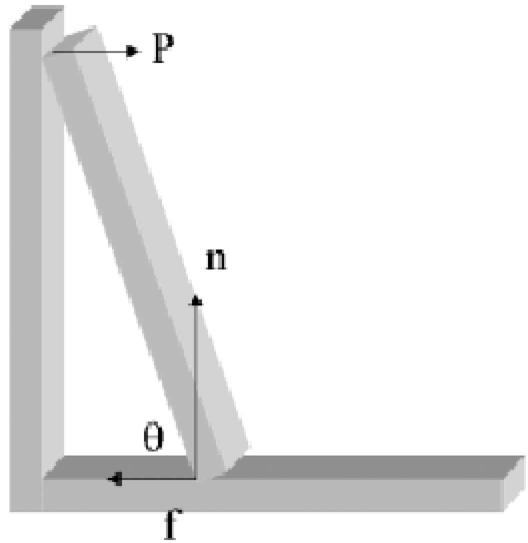
2. Again consider the inclined plane shown in the figure above. For this question, assume that the object moves up the incline again by *sliding without rolling*, but now the coefficient of kinetic friction between the two surfaces is $\mu_k = 0.2$. What is the distance s for this case?

3. Finally again consider the inclined plane shown in the figure above. For this question, assume that the object now moves up the incline by *rolling without slipping*. What is the distance s for this case?



Before After

4. The figure above shows a collision of two vehicles. Vehicle #1 is initially moving **east** with a mass $m_1 = 1200kg$ and an initial velocity of $\mathbf{v_{1i}} = 10m/s\hat{\mathbf{E}}$. Vehicle #2 is initially moving **north** with a mass $m_2 = 2600kg$ and an initial velocity of $\mathbf{v_{2i}} = 2m/s\hat{\mathbf{N}}$. Immediately after the collision, the two vehicles stick together moving with a velocity $\mathbf{v_f}$. Use the notion of conservation of momentum to estimate the **east** and **north** components of the final velocity vector $\mathbf{v_f}$. Discuss the validity of conservation of momentum in a similar actual collision.



7. The figure above shows a plank made of uniform material with a total weight of 500 N and length $\ell = 6m$, supported by the floor and leaning against the wall with an angle $\theta = 50^o$. Assuming that the system is in stable equilibrium, determine the normal force **n**, static friction force **f** provided by the floor, and the wall normal force **P**. (Neglect any possible friction force provided by wall.)