Lecture 16
(Work, Energy and Power)

Physics 160-01 Fall 2012

Douglas Fields

Problem 6.27

6.27. Stopping Distance. A car is traveling on a level road with speed v_0 at the instant when the brakes lock, so that the tires slide rather than roll. (a) Use the work–energy theorem to calculate the minimum stopping distance of the car in terms of v_0, g, and the coefficient of kinetic friction μ_k between the tires and the road. (b) By what factor would the minimum stopping distance change if (i) the coefficient of kinetic friction were doubled, or (ii) the initial speed were doubled, or (iii) both the coefficient of kinetic friction and the initial speed were doubled?

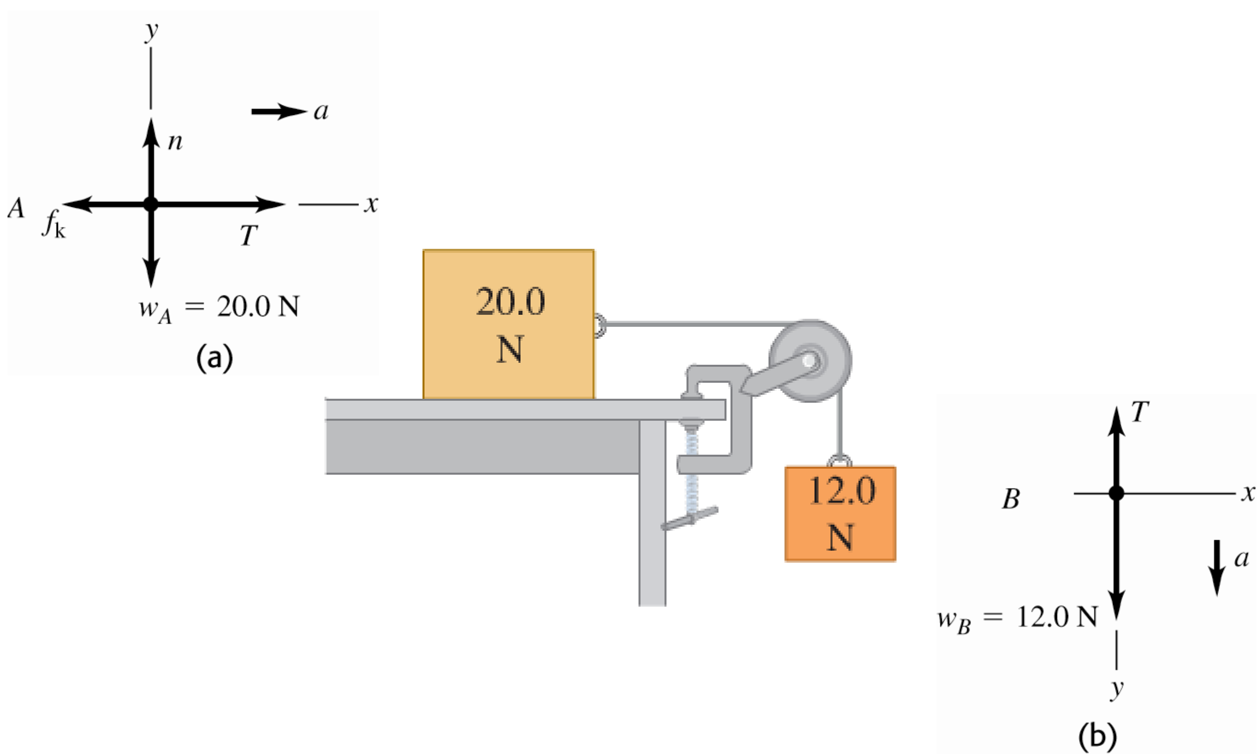
Work-Energy Theorem

$$W_{TOTAL!!} = \Delta KE$$

- For instance, in raising a book from the ground up to a height h, you must consider both the work that I do, plus the work that gravity does!

Problem 6.60

6.60. Consider the blocks in Exercise 6.7 as they move 75.0 cm. Find the total work done on each one (a) if there is no friction between the table and the 20.0-N block, and (b) if $\mu_s = 0.500$ and $\mu_k = 0.325$ between the table and the 20.0-N block.



CPS Question 16-1

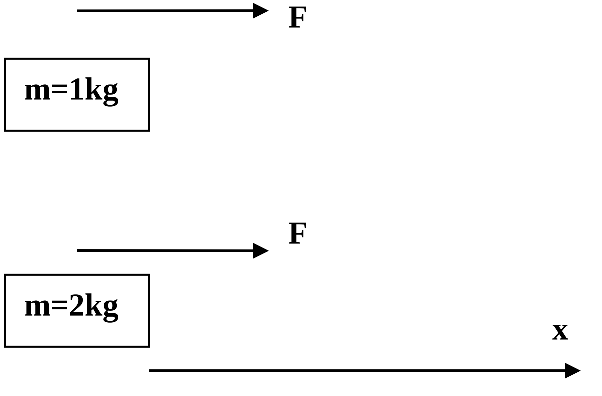
- **Two masses experience the same net force, F, over the same distance, x. Describe the difference in the kinetic energy between the two masses at the end of the path.**

A) The heavier mass has more kinetic energy.

B) The lighter mass has more kinetic energy.

C) They have the same kinetic energy.

D) Not enough information to solve.

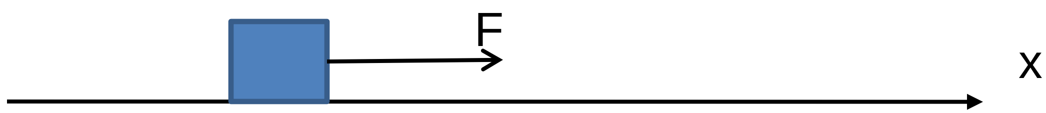


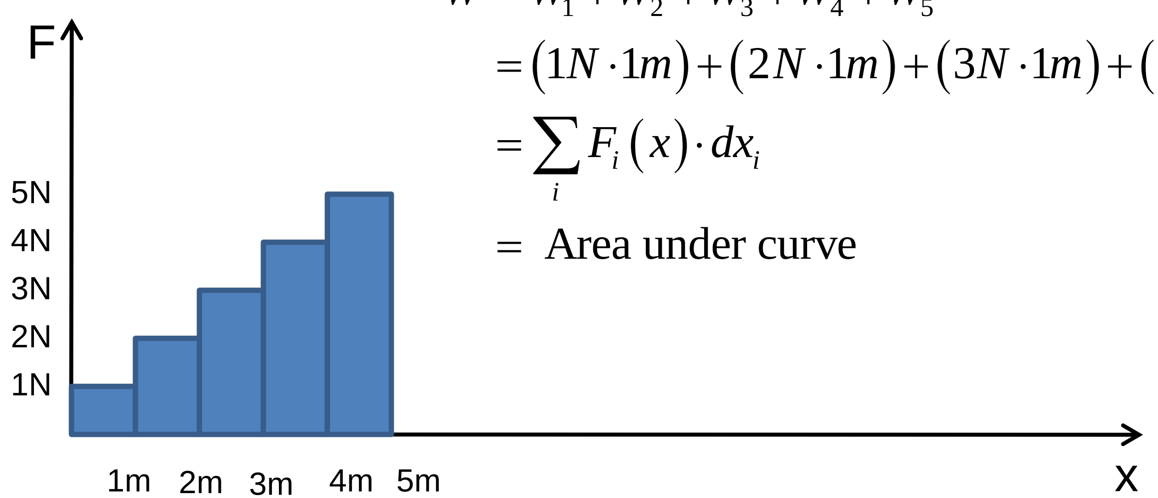
Problem 6.62

6.62. A 5.00-kg package slides 1.50 m down a long ramp that is inclined at 12.0° below the horizontal. The coefficient of kinetic friction between the package and the ramp is $\mu_k = 0.310$. Calculate (a) the work done on the package by friction; (b) the work done on the package by gravity; (c) the work done on the package by the normal force; (d) the total work done on the package. (e) If the package has a speed of 2.20 m/s at the top of the ramp, what is its speed after sliding 1.50 m down the ramp?

Non-uniform forces

- Let’s say we have a box on a horizontal, frictionless surface. A horizontal 1N force is applied for 1m, then a 2N force applied for another meter, then a 3N force, etc. After 5 meters, what is the total work on the box?

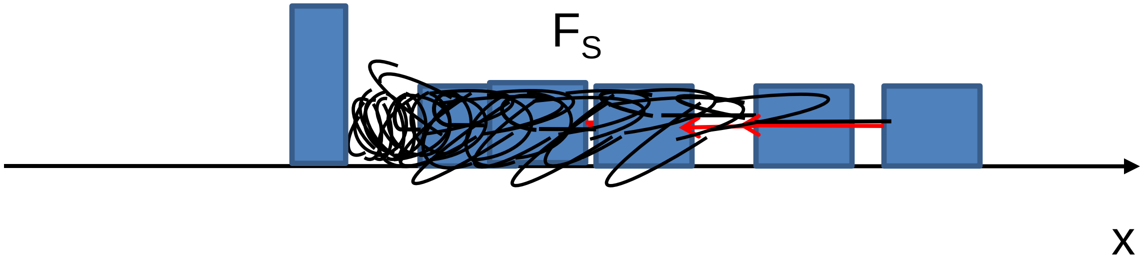


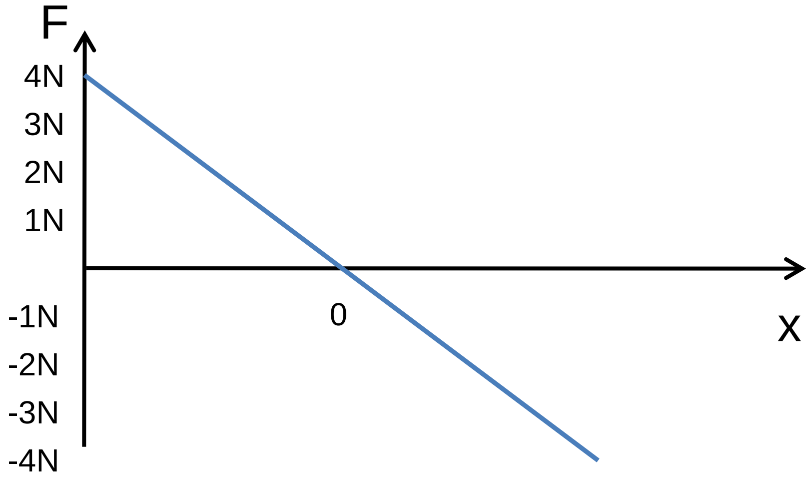


$$
\begin{aligned}
W &= W_1 + W_2 + W_3 + W_4 + W_5 \\
&= (1N \cdot 1m) + (2N \cdot 1m) + (3N \cdot 1m) + (4N \cdot 1m) + (5N \cdot 1m) \\
&= \sum_i F_i(x) \cdot dx_i \\
&= \text{ Area under curve}
\end{aligned}
$$

Spring forces

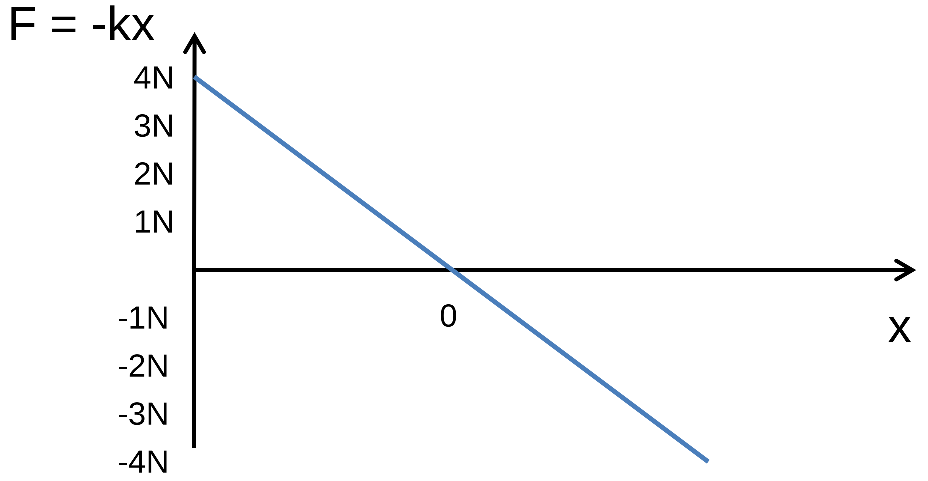
- Now, let's assume the force changes gradually, instead of in steps. This is what happens in the case of a force applied by a spring: $F(x) = -kx$





Work by Springs

- The work done is then just: $W = \int_i^f \vec{F}_S \cdot d\vec{x}$

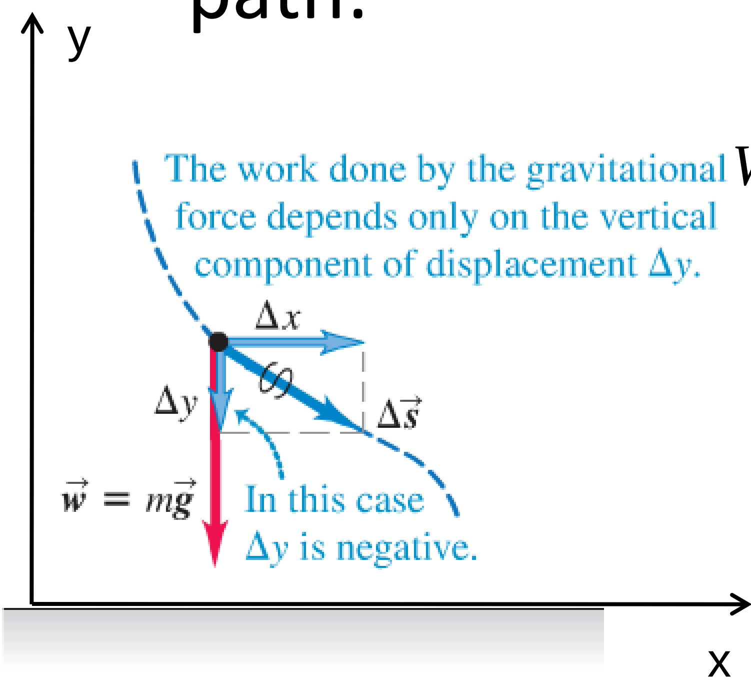


$$W_S = \frac{1}{2}kx^2$$

Sign determined by the
dot product (+ when pushing in same
direction as motion, - when opposite)

Gravitational Work

- Let’s examine the gravitational work done on an object when it moves along some arbitrary path:



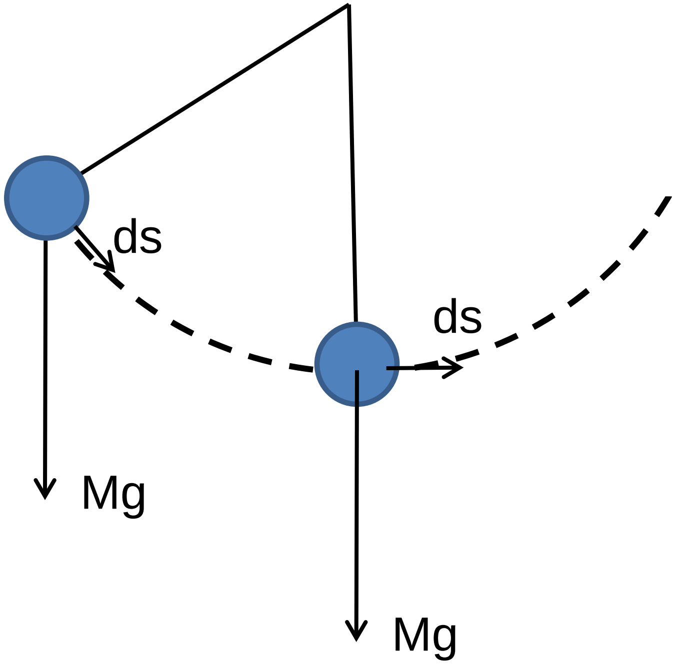
$$W_{Gravity} = \int_{initial}^{final} \vec{F}_{Gravity} \cdot d\vec{s} = \int_{initial}^{final} \left(-mg\hat{j}\right)\cdot\left(dx\hat{i} + dy\hat{j}\right)$$

$$= -\left(\int_{initial}^{final} mg\hat{j}\cdot dx\hat{i} + \int_{initial}^{final} mg\hat{j}\cdot dy\hat{j} \right)$$

$$= 0 - mg \int_{initial}^{final} dy\left(\hat{j}\cdot\hat{j}\right) = -mg\left(y_{final} - y_{initial}\right)$$

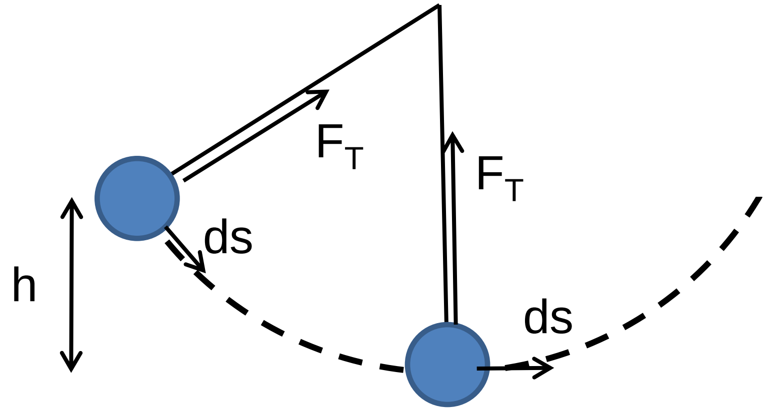
$$= -mg\Delta y$$

Work (by gravity) on a Pendulum



CPS Question 16-2

- **How much work does the cable holding the bowling ball do from the top of the arc to the bottom?**



A) +mgh

B) -mgh

C) 0

D) Not enough information to solve.

Work-Energy Theorem

$$W_{TOTAL} = W_{Gravity} + W_{Elastic} + W_{Other} = \Delta KE$$

- Now, we have just broken the total work on an object up into three terms, the first two being from forces that we understand:

$$W_{Gravity} = \int_{initial}^{final} \vec{F}_{Gravity} \cdot d\vec{s} = mg\left(y_f - y_i\right)$$

$$W_{Elastic} = \int_{initial}^{final} \vec{F}_{Elastic} \cdot d\vec{s} = \frac{1}{2}kx^2$$

Sign determined by the dot product (+ when pushing in same direction as motion, - when opposite)

Power

- Power is Energy transferred/used per unit time period.
- Unit is Watts = Joules/second.
- If something is doing work, then their power is:

$$P = \frac{W}{time} = \frac{\vec{F} \cdot \vec{d}}{time} = \vec{F} \cdot \frac{\vec{d}}{time} = \vec{F} \cdot \vec{v}$$