AP Physics I

Energy – Work-Energy Theorem

Today…Monday

- Review Dynamics Test
- Review Mini-quiz
- Work-Energy Theory
- Mechanical Energy Intro

Work-Energy Theorem

- There are many different types of energy and energy can be converted among these.
- When a force does work on a system, the work done changes the system's energy.
- If work increases motion, increase in kinetic energy.
- If work increases the object's height, increase in gravitational potential energy.
- If work compresses a spring, increase in elastic potential energy.
- If work is against friction, however, where does the energy go?
- In this case, the energy isn't lost, but instead increases the rate at which molecules in the object vibrate, increasing the object's temperature, or internal energy.

Work-Energy Theorem

- The understanding that the work done on a system by an external force changes the energy of the system is known as the Work-Energy Theorem.
- If an external force does positive work on the system, the system's total energy increases.
- If system does work, system's total energy decreases.
- This combines Kinematics with Newton’s Second Law.

What does this mean?

In a one-dimensional situation where one force is used to accelerate, we can get the relationship between net work and speed given by:

$$Wnet = KE_{Final} - KE_{initial}$$

$$Wnet = \frac{1}{2}mv^2 - \frac{1}{2}mv_0{}^2$$

Deriving Work-Energy Theorem

If F_a & displacement are going same way:

$$W_{net} = Fd$$

Substituting $F_{net}=ma$ from Newton's 2nd law gives

$$W_{net} = mad$$

Using $v^2 = v_0^2 + 2a_x(x - x_0)$ → $a = \dfrac{v_f^2 - v_0^2}{2d}$

Substitute that into proceeding equation give us:

$$W_{net} = m\left(\frac{v_f^2 - v_0^2}{2d}\right)d$$

Rearrange… $W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$

Class Problem

A chef pushes a 10kg pastry cart from rest a distance of 5m with a constant horizontal force of 10N. Assuming a frictionless surface determine the cart's change in kinetic energy and its final velocity.

Find work done by chef – is equal to cart's change in KE

$$W = Fd\cos\theta = (10N)(5m)\cos 0 = 50J$$

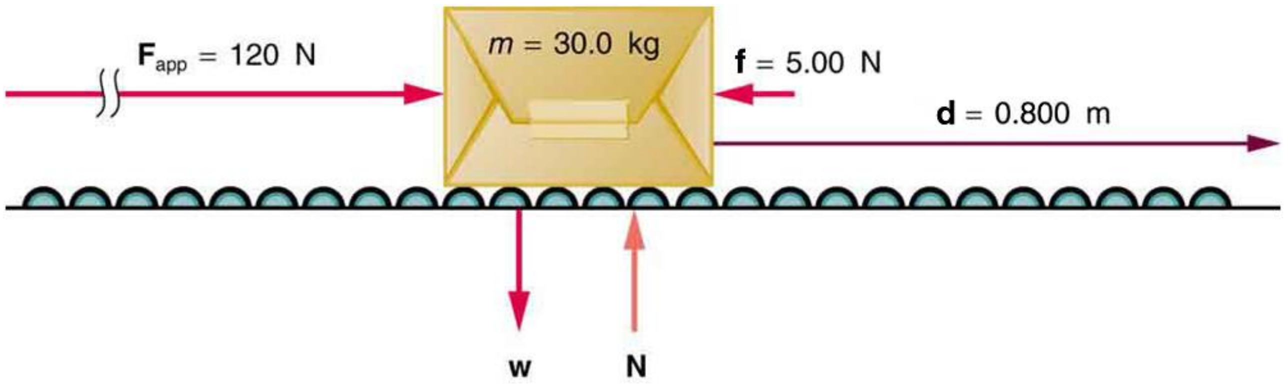
Solve for cart's final velocity

$$W = KE = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2k}{m}} = \sqrt{\frac{2(50J)}{10kg}} = 3.2m/s^2$$

Class Problem in 3 Parts

Suppose that you push on the 30.0-kg package in Figure 7.4 with a constant force of 120 N through a distance of 0.800 m, and that the opposing friction force averages 5.00 N.

(a) Calculate the net work done on the package. (b) Solve the same problem as in part (a), this time by finding the work done by each force that contributes to the net force.



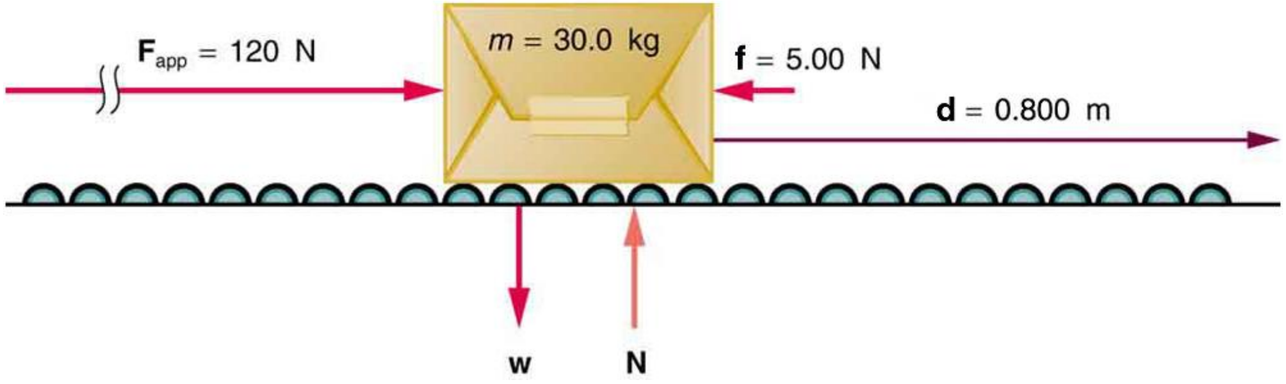
Solution for a

Push on 30.0-kg package with constant force of 120 N through a distance of 0.800 m, with opposing friction force of 5.00 N.

(a) Calculate the net work done on the package.

The net force is the push force minus friction, or Fnet= 120 N – 5.00 N = 115 N. Thus the net work is

$$\begin{aligned} W_{\text{net}} &= F_{\text{net}} d = (115\ \text{N})(0.800\ \text{m}) \\ &= 92.0\ \text{N} \cdot \text{m} = 92.0\ \text{J}. \end{aligned}$$



Solution for b

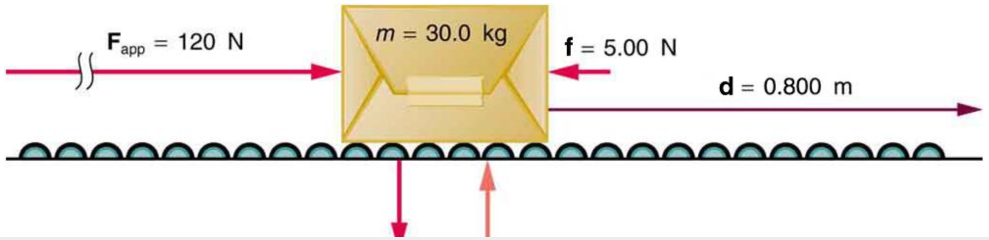
Push on 30.0-kg package with constant force of 120 N through a distance of 0.800 m, with opposing friction force of 5.00 N.

(b) Solve by finding the work done by each force that contributes to the net force.

$$\begin{aligned} W_{\mathrm{app}} &= F_{\mathrm{app}} d \cos(0º) = F_{\mathrm{app}} d \\ &= (120\ \mathrm{N})(0.800\ \mathrm{m}) \\ &= 96.0\ \mathrm{J} \end{aligned}$$

$$\begin{aligned} W_{\mathrm{fr}} &= F_{\mathrm{fr}} d \cos(180º) = -F_{\mathrm{fr}} d \\ &= -(5.00\ \mathrm{N})(0.800\ \mathrm{m}) \\ &= -4.00\ \mathrm{J.} \end{aligned}$$

$$\begin{aligned} W_{\mathrm{gr}} &= 0, \\ W_{\mathrm{N}} &= 0, \\ W_{\mathrm{app}} &= 96.0\ \mathrm{J}, \\ W_{\mathrm{fr}} &= -4.00\ \mathrm{J.} \end{aligned}$$



$$W_{\mathrm{total}} = W_{\mathrm{gr}} + W_{\mathrm{N}} + W_{\mathrm{app}} + W_{\mathrm{fr}} = 92.0\ \mathrm{J.}$$

Now Find Speed

Here the work-energy theorem can be used, because we have just calculated the net work, W_{net}, and the initial KE, $\frac{1}{2}mv_0{}^2$.

Then, can find the final KE, $\frac{1}{2}mv^2$, and final speed v.

Work-Energy Theorem Equation:

$$W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mv$$

$$v = \sqrt{\frac{2(95.75\ \mathrm{J})}{m}} = \sqrt{\frac{191.5\ \mathrm{kg\cdot m^2/s}}{30.0\ \mathrm{kg}}}$$

$$= 2.53\ \mathrm{m/s.}$$

Solve for $\frac{1}{2}mv^2$ gives:

$$\frac{1}{2}mv^2 = W_{net} + \frac{1}{2}mv_0{}^2$$

$$\frac{1}{2}mv^2 = 92J + 3.75J = 95.75J$$

Homework

- Work-Energy Theorem Problems
- Read/watch intro to Conservation of Mechanical Energy. Possible sources:
  - Flipping Physics
  - OpenStax
  - Aplus Physics
- Write 2-4 sentences, maybe a formula. Put it in this Google Form.