Phys 111: Lecture 11

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Homework Wk #6 Due Thursday 10/03/19

Today's Topics

1. Work & Energy
2. Kinetic Energy
3. Potential Energy

Answers We Don't Have Yet

Applications of Work & Energy

1. Relating applied forces directly to displacements and velocities
2. Quantifying limitations of motion due to applied forces
3. Determining how to do the same work with less force

How might we rank or quantify displacements which are caused by forces?

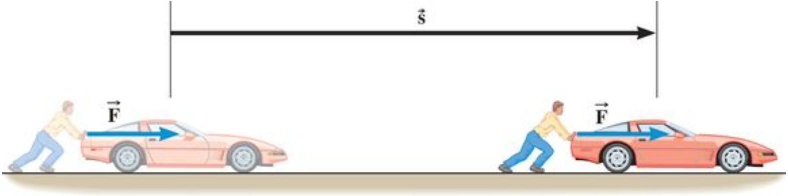

Figure: 11.1 Quantifying how much work tasks take.

Some Everyday Scenarios

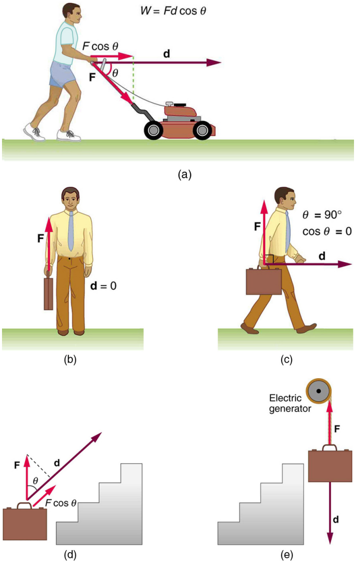

Figure: 11.2 Motivation for Work

Work: Work done on an object by a force ($\vec{\mathbf{F}}$) is the net contribution of that applied force to the net displacement ($\vec{\mathbf{s}}$) of the object.

$$\text{Work} = (\text{Force}) \text{ x } (\text{Mag. of Displacement}) \text{ x } (\text{Alignment Fraction})$$

$$W = Fs(cos\theta)$$

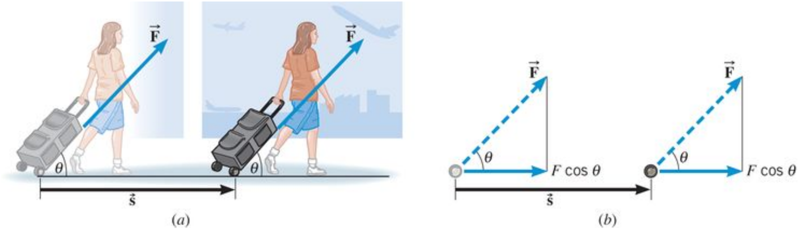

Figure: 11.3 Specific Work Example

OPSTX Problem 7.1 How much work does a supermarket checkout attendant do on a can of soup he pushes 0.600 m horizontally with a force of 5.00 N? Express your answer in joules

OPSTX Problem 7.6 How much work is done by the boy pulling his sister a displacement of 30.0 m horizontally in a wagon as shown in Figure 11.4? Assume no friction acts on the wagon.

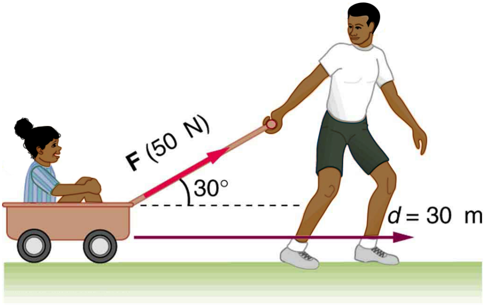

Figure: 11.4 OPSTX Problem 7.1 Work

Exercise #1 Answers

OPSTX Problem 7.1 $s = 0.600\ m$, $F = 5.00\ N$, $\theta = 0^\circ$.

$$W = Fscos(\theta) = (5.00\ N)(0.600\ m)cos(0^\circ) = 3.00\ J$$

OPSTX Problem 7.6 $s = 30.0\ m$, $F = 50.0\ N$, $\theta = 30^\circ$.

$$W = Fscos(\theta) = (50.0\ N)(30.0\ m)cos(30^\circ) = 1300\ J$$

Recall the Physics summarized with the equations:

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

$$v_f^2 = v_o^2 + 2as$$

and think about the space probe Deep Space 1:

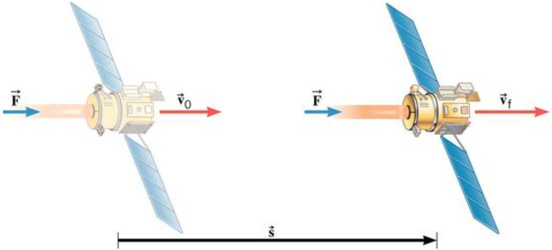

Figure: 11.5 Ion propulsion drive example

Mixing Work, Forces, & Kinematics

$$W = Fs = (ma)s$$

$$as = \frac{1}{2}\left(v_f^2 - v_o^2\right)$$

$$\downarrow$$

$$W = \frac{1}{2}m\left(v_f^2 - v_o^2\right)$$

What's a $\frac{1}{2}mv^2$?

Kinetic Energy (KE) is the energy associated with the translational/linear motion of an object. KE is quantified with the equation $\frac{1}{2}mv^2$.

Work-Energy Theorem

Net Work on a System causes Change in Kinetic Energy

or

Net Work = Change in Kinetic Energy

$$W = \Delta KE$$

$$W = \frac{1}{2}m\left(v_f^2 - v_o^2\right)$$

C&J 6.2.13 A fighter jet is launched from an aircraft carrier with the aid of its own engines and a steam-powered catapult. The thrust of its engines is $2.3 \times 10^5\ N$. In being launched from rest it moves through a distance of $87\ m$ and has a kinetic energy of $4.5 \times 10^7\ J$ at lift-off. What is the work done on the jet by the catapult?

Exercise #2 Answer

C&J 6.2.13 $F_{je} = 2.3 \times 10^5\ N$, $s = 87\ m$, $KE_o = 0$, $KE_f = 4.5 \times 10^7\ J$.

Note: $PE_o = PE_f$

$$KE_o + PE_o + W_{je} + W_{jc} = KE_f + PE_f$$

$$W_{jc} = KE_f - KE_o - W_{je}$$

$$W_{jc} = 2.50 \times 10^7\ J$$

Conservation of Energy

Energy is the ability to do Work.

Law of Conservation of Energy

Energy can neither be created nor destroyed, but can only be converted from one form to another.

Types of Energy

1. Kinetic
2. Potential

Gravitational Work

Let's think about the force due to gravity

$$F_G = m\frac{GM}{r^2} \quad \rightarrow \quad F_g = mg$$

$$\text{Work} = |\text{Force}| \times |\text{Displacement}| \times \cos\theta$$

$$W_g = F_g|\Delta s|cos\theta$$

$$W_g = (mg)(s)cos\theta$$

Turns out $scos\theta = \Delta y = \pm h$ **so we can write**

$$W_g = -mgh$$

Concept Check Does energy depend on position as well or does it only depend on velocity?

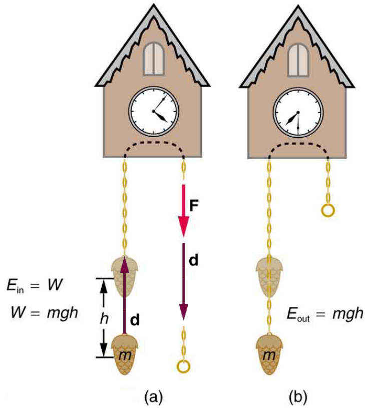

Figure: 11.6 Gravitational work & potential energy

Remember that we are trying to reformulate **all** of our previous material so yes! Energy depends on position, inertia, and velocity and many other things.

Gravitational Potential Energy

$$PE_g = mgy$$

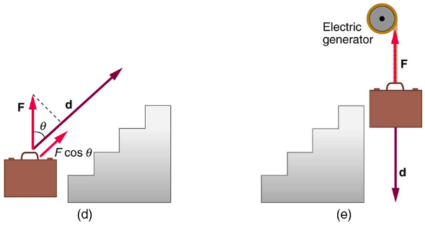

Figure: 11.7 Gravitational potential energy

Total Energy of a System

The total energy (E) of a system is the sum of all of the kinetic energy (KE) and all of the potential energy (PE) of said system.

$$\text{Total Energy} = \text{Kinetic Energy} + \text{Potential Energy}$$

$$E = \sum KE + \sum PE$$

Conservative Forces

A conservative force is any force where the total work done by the force is not dependent on the displacement of the ojbect. We say the work is path independent. Ex. Gravity, Elastic Springs, Electric.

Conservation Laws

$$\text{Quantity Before} = \text{Quantity After}$$
or
$$\text{Quantity Before} + \text{Interaction Changes} = \text{Quantity After}$$

Only Conservative Forces Acting

$$\text{Energy Before} = \text{Energy After}$$

$$E_o = E_f$$

Non-conservative Forces Acting

$$\text{Energy Before} + \text{Non-conservative Work} = \text{Energy After}$$

$$E_o + W_{nc} = E_f$$

$$W_{nc} = E_f - E_o = \Delta E_{tot}$$

Exercise #4

C&J 6.4.35 A $55.0\ kg$ skateboarder starts out with a speed of $1.80\ m/s$. He does $+80.0\ J$ of work on himself by pushing with his feet against the ground. In addition, friction does $-265\ J$ of work on him. In both cases, the forces doing the work are nonconservative. The final speed of the skateboarder is $6.00\ m/s$.

a. Calculate the change ($\Delta PE = PE_f - PE_o$) in the gravitational potential energy.
b. How much has the vertical height of the skater changed, and is the skater above or below the starting point?

C&J 6.4.35 $m = 55.0\ kg$, $v_o = 1.80\ m/s$, $W_{nc} = (+80.0 - 265.0)\ J$ on him, and $v_f = 6.00\ m/s$. Note that +y is up and -y is down.

a. $\Delta PE = -1085\ J$. The skater must be below starting point.
b. $\Delta y = -1.97\ m$. The skater is below his starting point.

Problem Solving with Energy

1. Determine the *system of interest* and *identify knowns, unknowns, and goals*. A sketch will help.
2. Examine all the forces involved and determine whether you know or are given the potential energy from the work done by the forces.
3. If you know all of the forces are conservative, then you can apply conservation of mechanical energy:

$$KE_o + PE_o = KE_f + PE_f$$

4. If you know some of the forces are nonconservative, then the conservation of energy law in its most general form must be used.

$$KE_o + PE_o + W_{nc} = KE_f + PE_f$$

5. Before solving, eliminate terms wherever possible to simplify the algebra. Ex. Set initial or final height to be zero.
6. *Check the answer to see if it is reasonable.* Check for $\pm$ signs and if speeds or heights are too large or too small.

Transformation of Energy

Energy can neither be created nor destroyed, but can only be converted from one form to another.

Forms of Kinetic Energy

1. Mechanical - Motion of any kind
2. Electrical - Energy from flow of electrons
3. Thermal - Heat or internal vibration of molecules
4. Radiant - electromagnetic energy of light
5. Sound - Movement of energy from compression waves

Forms of Potential Energy

1. Chemical - Energy stored in chemical bonds between atoms/molecules
2. Nuclear - Energy stored in nuclei of atoms
3. Gravitational - Energy from Relative Positions or Heights
4. Elastic - Energy stored from applied mechanical forces

The End

Thanks for your time and attention!
Any questions?

C&J 6.2.16 Starting from rest, a $1.9 \times 10^4\ kg$ flea springs straight upward. While the flea is pushing off from the ground, the ground exerts an average upward force of $0.38\ N$ on it. This force does $+2.4 \times 10^4\ J$ of work on the flea.

a. What is the flea's speed when it leaves the ground?

b. How far upward does the flea move while it is pushing off? Ignore both air resistance and the flea's weight.

Additional Practice #1 Answer

C&J 6.2.16 $v_o = 0$, $m = 1.9 \times 10^4\ kg$, $F_N = 0.38\ N$, $W_N = +2.4 \times 10^4\ J$. Set $y_o = 0$, and $PE_o = 0$.

a. The flea's speed when it leaves the ground is $v_f = 1.6\ m/s$.

b. The flea moves $h = 8.0 \times 10^{-4}\ m = 0.80\ mm$ upward while it is pushing off.

C&J 6.4.29 A $75.0\ kg$ skier rides a $2830\ m$ long lift to the top of a mountain. The lift makes an angle of 14.6° with the horizontal. What is the change in the skier's gravitational potential energy?

C&J 6.4.29 $m = 75.0\ kg$, $s = 2830\ m$, $\theta = 14.6°$, $KE_o = KE_f$. Set $y_o = 0$.

$$\Delta PE_g = PE_f - PE_i$$

$$\Delta PE_g = mg(y_f - y_o)$$

$$\Delta PE_g = mgy_f$$

$$\Delta PE_g = (75.0\ kg)(10.0\ m/s^2)(2830\ m)(sin 14.6°)$$

$$\Delta PE_g = 5.35 \times 10^5\ J$$