Energy and Work

1

Work

- Definition
  - force applied over a distance
  - distance must be in the same direction as the force
  - SI Unit of Joules
- Equation

$$\boxed{\begin{array}{l}\text{Work} = \text{Force x Distance} \\ W = F_{net} d\end{array}}$$

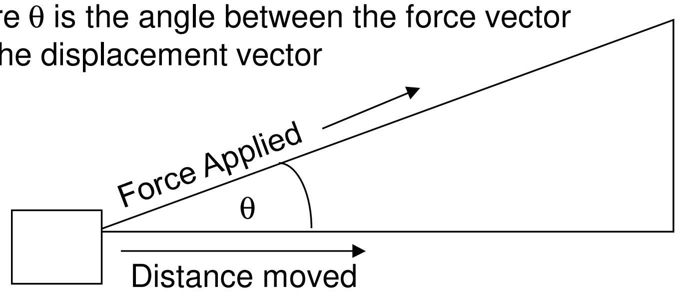
2

Work and Direction of Force

- Work is only done if the force is exerted in the direction of motion.
- Force applied at an angle:

$$W = (F_A \cos\theta)d$$

Where θ is the angle between the force vector and the displacement vector



3

Work on Pendulums

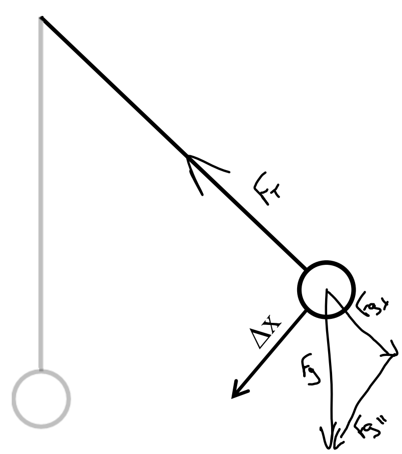
- Draw all of the forces acting on the pendulum.

What force causes the motion?

$F_{g\parallel}$ CAUSES THE MOTION

THERFORE IT IS THE FORCE THAT

DOES WORK ON THE PENDULUM.



4

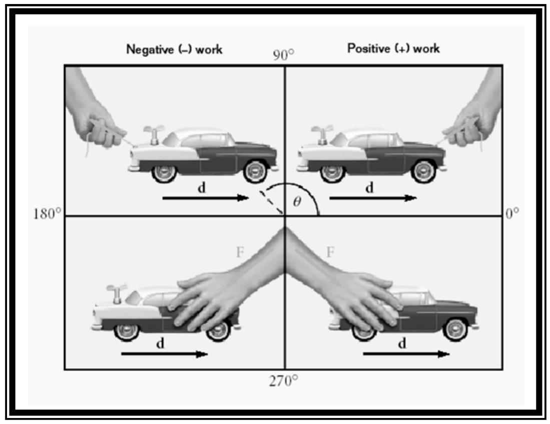
The Sign of Work

- When is the work negative?

  When Δx is in the opposite direction of the force.

- What common force that we have studied does negative work?

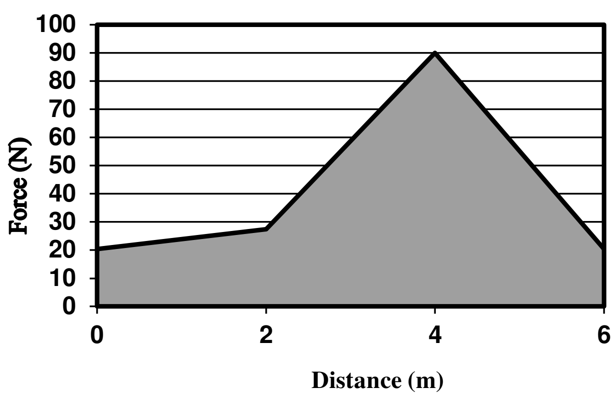
  Friction



5

Varying Forces

- Work can be found by finding the <u>area</u> under a Force vs. Distance graph



6

Varying Forces - Springs

- Any object that has an elastic property can have elastic potential energy.
- The force felt is directly proportional to the distance the object is stretched.
- This proportionality is dependent on the object itself, defined as the force constant, k.

$$\boxed{\begin{aligned} F_{spring} &= k\Delta x \quad (Hooke's\ Law) \\ W_{spring} &= \frac{1}{2}k\Delta x^2 \end{aligned}}$$

7

Sample Problem

- A 200.0 g mass is hung from a spring with a spring constant of 33.6 N/m. How far will the spring stretch from its original position? How much work is done in stretching the spring?

$F_{NET} = 0 = F_s - F_g$

$F_s = F_g$

$k\Delta x = mg$

$33.6(\Delta x) = (.2)(9.8)$

$\Delta x = .058\,m$

$W = \frac{1}{2}k\Delta x^2$

$= \frac{1}{2}(33.6)(.058)^2$

$W = .0565\,J$

8

Energy

- Definition
  - The ability to do work
- Relation of energy and work
  - When you work, you are transferring energy to the object that you are working on.
- Unit of Measure
  - Joule (J)

9

Mechanical Energy

- (Gravitational) Potential Energy
  - energy of vertical position

$$\boxed{U_g = mgh}$$

- Kinetic Energy
  - Object's energy due to velocity

$$\boxed{K = \frac{1}{2}mv^2}$$

- Potential Energy in a spring
  - energy of a spring based on the amount of compression or stretch

$$\boxed{U_{spring} = \frac{1}{2}k\Delta x^2}$$

10

Work-Energy Theorem

- The net work done on an object is equal to the change in its energy

$$W = \Delta K$$
$$W = K_{final} - K_{initial}$$

11

Law of Conservation of Energy

- Within a closed and isolated system, energy can change form; but the total amount of energy is constant.
- Energy cannot be created or destroyed, but it can change form.

$$E_i = E_f$$

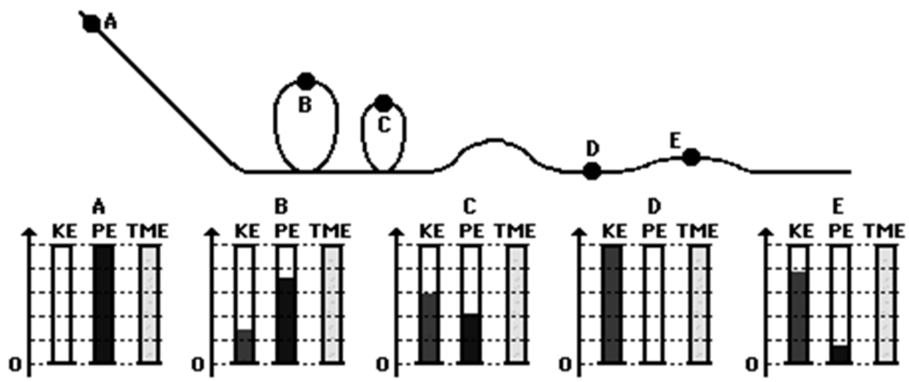
$$W_i + U_{g_i} + U_{s_i} + K_i = W_f + U_{g_f} + U_{s_f} + K_f$$

$$(Fd + mgh + \frac{1}{2}kx^2 + \frac{1}{2}mv^2)_{initial} = (Fd + mgh + \frac{1}{2}kx^2 + \frac{1}{2}mv^2)_{final}$$

12

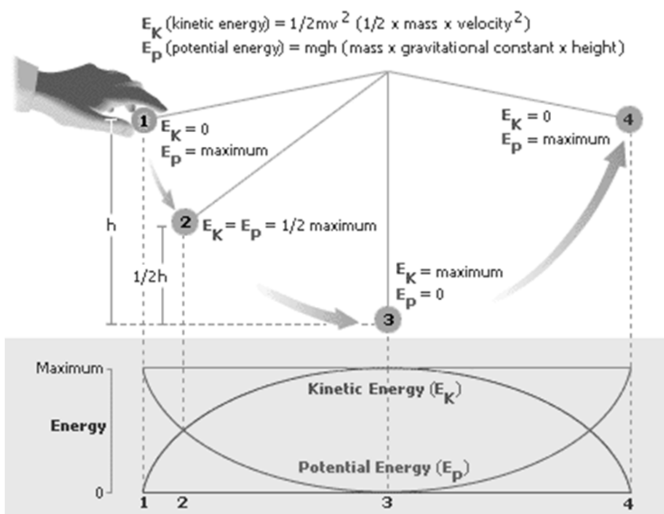
Graphing Energy

- Total Mechanical Energy (TME) is the same, but the amount of each type of energy can change.



13

Graphing Energy of a Pendulum



14

Classifying Forces

- Conservative
  - those forces that conform the law of conservation of energy
  - Ex: Gravitational, Elastic
- Dissipative
  - forces that produce deviations from the law of conservation of energy
  - produce forms of energy other than mechanical. Ex: friction

15

Sample Problem

- If a 15.0 kg slides down a 2.35 m incline, what is the velocity of the block when it leaves the incline? (Assume no friction)

$E_i = E_f$

$\cancel{\tfrac{1}{2}mv_i^2}^{\,0} + mgh_i = \tfrac{1}{2}mv_f^2 + \cancel{mgh_f}^{\,0}$

$(15\,kg)(9.8)(2.35) = \tfrac{1}{2}(15\,kg)(v^2)$

$345.45 = 7.5\,v^2$

$46.06 = v^2$

$v = 6.79\ m/s$

16

Sample Problem 2

- A spring (k = 850 N/m) is compressed 0.4 m. Calculate the speed it can impart to a 500 g ball.

$W = \Delta K$

$\frac{1}{2}k\Delta x^2 = \frac{1}{2}mv_f^2 - \cancel{\frac{1}{2}mv_i^2}^{\,0}$

$\frac{1}{2}(850)(.4)^2 = \frac{1}{2}(.5\,kg)v^2$

$68 = .25v^2$

$272 = v^2$

$v = 16.5\ m/s$

OR

$E_i = E_f$

$\cancel{U} + \cancel{U_g} + \underline{U_s} + \cancel{K} = \cancel{U} + \cancel{U_g} + \cancel{U_s} + \underline{K}$

$U_s = K$

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

$\frac{1}{2}(850)(.4)^2 = \frac{1}{2}(.5)v^2$

$68 = .25v^2$

$272 = v^2$

$v = 16.5\ m/s$

17

Sample Problem 3

- A baseball (m = 140 g) traveling at 30 m/s moves a fielder's glove backward 35 cm when the ball is caught. Calculate the average force exerted by the ball on the glove.

$W = \Delta KE$

$Fd = \cancel{\frac{1}{2}mv_f^2}^{\,0} - \frac{1}{2}mv_i^2$

$F(.35m) = -\frac{1}{2}(.140)(30)^2$

$.35F = -63$

$F = -180N$

or

$E_i = E_f$

$\cancel{U} + \cancel{U_g} + \cancel{U_s} + \underline{K} = \underline{W} + \cancel{U_g} + \cancel{U_s} + \cancel{U}$

$K = W$

$\frac{1}{2}mv^2 = Fd$

$\frac{1}{2}(.140)(30)^2 = F(.35)$

$63 = .35F$

$F = 180N \Rightarrow$ FORCE NEEDS TO BE (–) TO STOP BALL

$-180N$

18

Sample Problem 4

- A bus slams on brakes to avoid an accident. The tread marks of the tires are 25 m long. If μ_k = 0.7, what was the speed before applying brakes?

$W = \Delta K$

Friction $Fd = \cancel{\tfrac{1}{2}mv_f^2} - \tfrac{1}{2}mv_i^2$

$\mu F_N(25) = \tfrac{1}{2}mv_i^2$

$\mu \cancel{m}g(25) = \tfrac{1}{2}\cancel{m}v_i^2$

$.7(9.8)(25) = \tfrac{1}{2}v_i^2$

$171.5 = \tfrac{1}{2}(v_i^2)$

$343 = v_i^2$

$v_i = 18.5\ m/s$

or

$E_i = E_f$

$\cancel{U_e} + \cancel{U_g} + \cancel{U_s} + K = W + \cancel{U_g} + \cancel{U_s} + \cancel{K}$

$K = W$

$\tfrac{1}{2}mv^2 = F_F d$

$\tfrac{1}{2}mv^2 = \mu F_N d$

$\tfrac{1}{2}\cancel{m}v^2 = \mu \cancel{m}gd$

$v^2 = 2\mu gd$

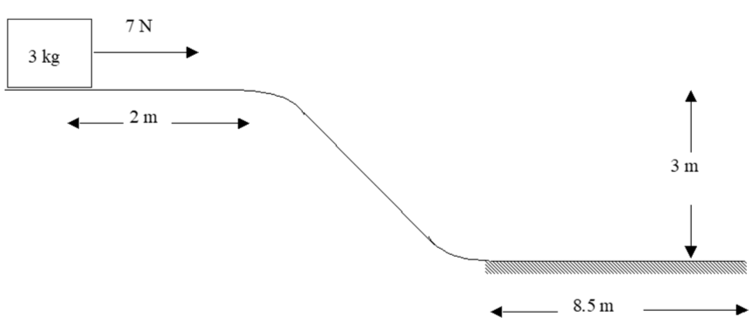
$v = \sqrt{2\mu gd} = \sqrt{2(.7)(9.8)25}$

$v = 18.5\ m/s$

19

Sample Problem 5

- A 3 kg mass is pushed along a horizontal surface by a constant 7 N force for 2 m, then released and allowed to slide down a 3 m high frictionless ramp. Calculate the coefficient of friction between the two surfaces at the bottom of the ramp if the block stops 8.5 m after entering the final horizontal section.



$E_i = E_i$

$W_{Push} + U_g = W_F$

$Fd + mgh = F_F d$

$(7)(2m) + (3)(9.8)(3) = \mu F_N(d)$

$102.2 = \mu mgd$

$102.2 = \mu(3)(9.8)8.5$

$102.2 = \mu(249.9)$

$\mu = .41$

20