AP PHYSICS

GIANCOLI

LESSON 6-1, WORK DONE BY A CONSTANT FORCE

LESSON 6-2, WORK DONE BY A VARYING FORCE

Big Idea(s):

- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding(s):

- Interactions with other objects or systems can change the total energy of a system.
- The energy of a system is conserved.

Essential Knowledge(s):

- Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.
  - If the force is constant during a given displacement, then the work done is the product of the displacement and the component of the force parallel or antiparallel to the displacement.
  - Work (change in energy) can be found from the area under a graph of the magnitude of the force component parallel to the displacement versus displacement.

Essential Knowledge(s):

- A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
  - The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.

Essential Knowledge(s):

- Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance; this energy transfer is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. [A piston filled with gas getting compressed or expanded is treated in Physics 2 as a part of thermodynamics.]

Learning Objective(s):

- The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.
- The student is able to design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.

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- The student is able to design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.
- The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.

Learning Objective(s):

- The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).
- The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

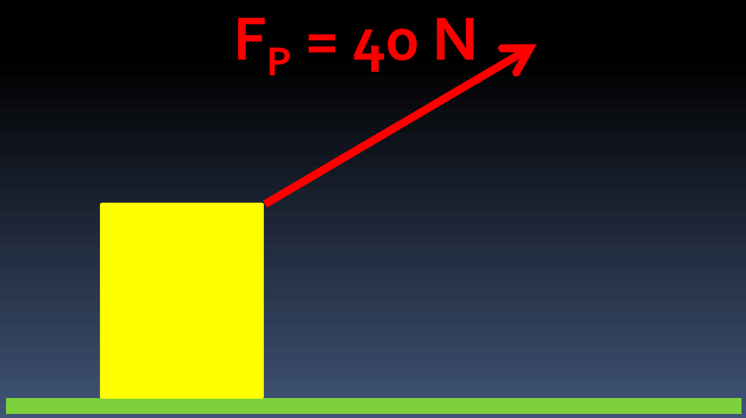
Introductory Video: Work

Work

- General meanings for the term in everyday life
- Very specific meaning in physics

Work

- ***The work done on an object by a constant force (constant in magnitude <u>and</u> direction) is defined to be the product of the magnitude of the displacement and the component of the force parallel to the displacement***



$$W = F_{\parallel} d$$

$$W = Fd\cos\theta$$

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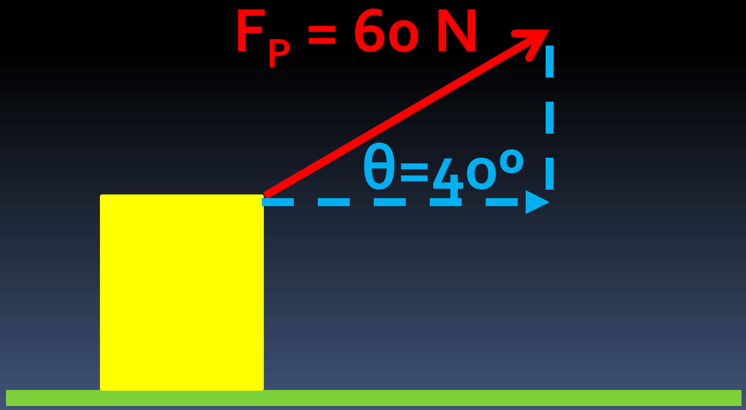

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$$W = (F \cos\theta) d$$

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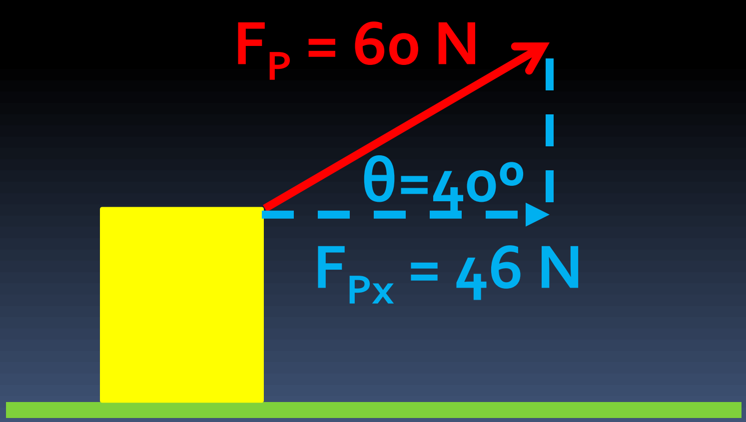

$$W = \left(F\cos\theta\right)d$$

$$W = \left(60\,N\right)\left(\cos 40^\circ\right)d$$

$$W = \left(46\,N\right)d$$

Work

- Work is a scalar quantity, only magnitude
- Unit of measure for work is the joule (J)
  - $1J = 1N \cdot m = 1\ kg\ m^2/s^2$
  - $W = Fd = (m \times a) \times d$
  - $(kg)\ (m/s^2)\ (m) = kg\ m^2/s^2$

$$W = F_{\|} d$$

$$W = Fd \cos\theta$$

Work

- ***Can you exert a force without doing work?***

$$W = F_{||} d$$

$$W = F d \cos\theta$$

Work

- ***Can you exert a force without doing work?***
  - A book sitting on a table: force of gravity and normal force, but no displacement

$$W = F_{\|} d$$

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Work

- ***Can you exert a force without doing work?***
  - A book sitting on a table: force of gravity and normal force, but no displacement
  - Carrying a stack of books across the room?

$$W = F_{||}d$$

$$W = Fd\cos\theta$$

Work

- ***Can you exert a force without doing work?***
  - A book sitting on a table: force of gravity and normal force, but no displacement
  - Carrying a stack of books across the room
    - No work done on the books by your arms because the applied force is normal to the displacement
    - However, your feet do work on the floor and friction does work on your feet

$$W = F_{\parallel} d$$

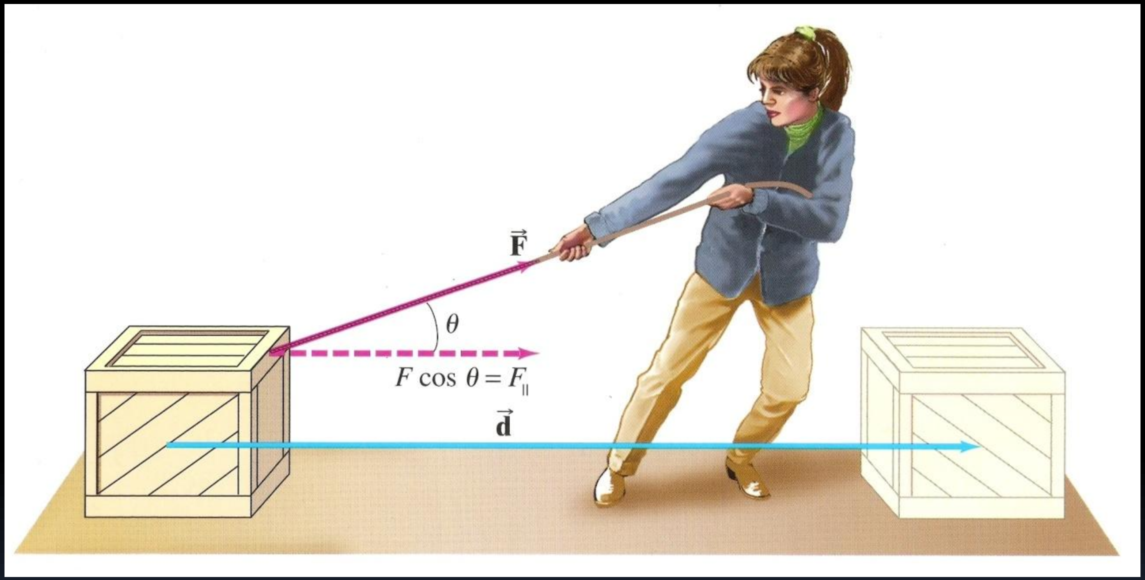
$$W = Fd\cos\theta$$

Work

- ***What forces are applied here and what work is being done?***

$$W = F_{\parallel} d$$

$$W = Fd\cos\theta$$



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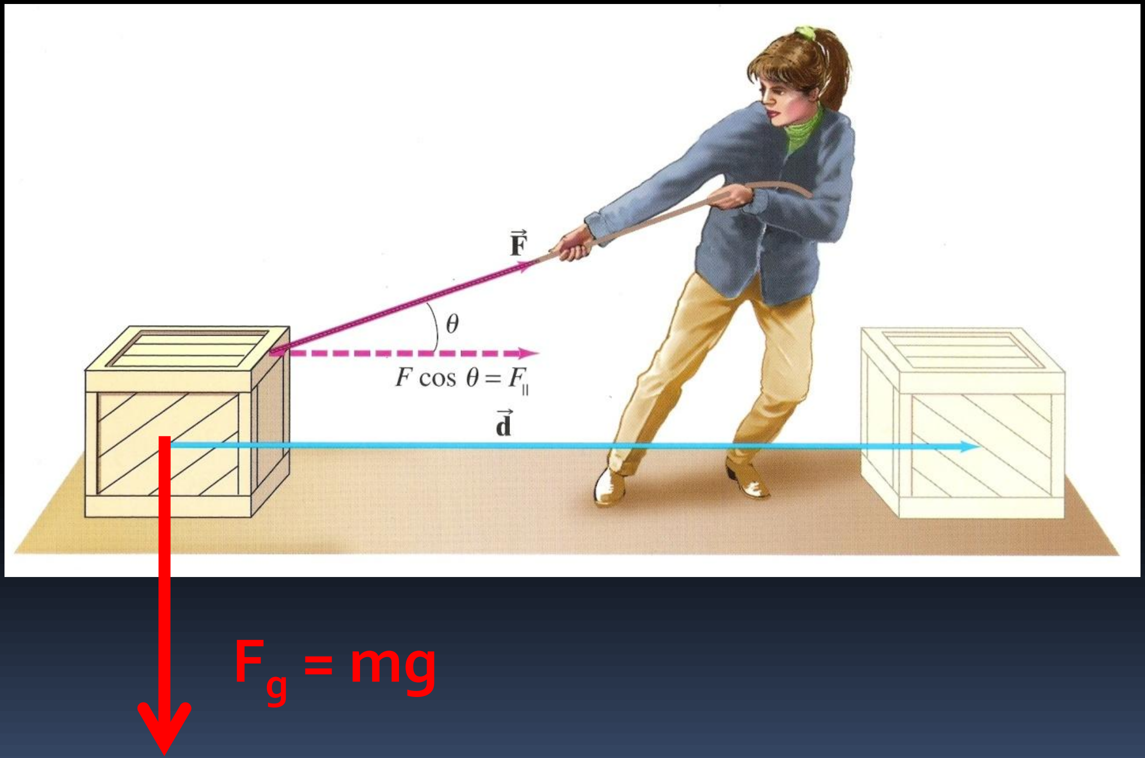
$$Work\,?$$



Work

- ***What forces are applied here and what work is being done?***

$$W = F_{\parallel} d$$

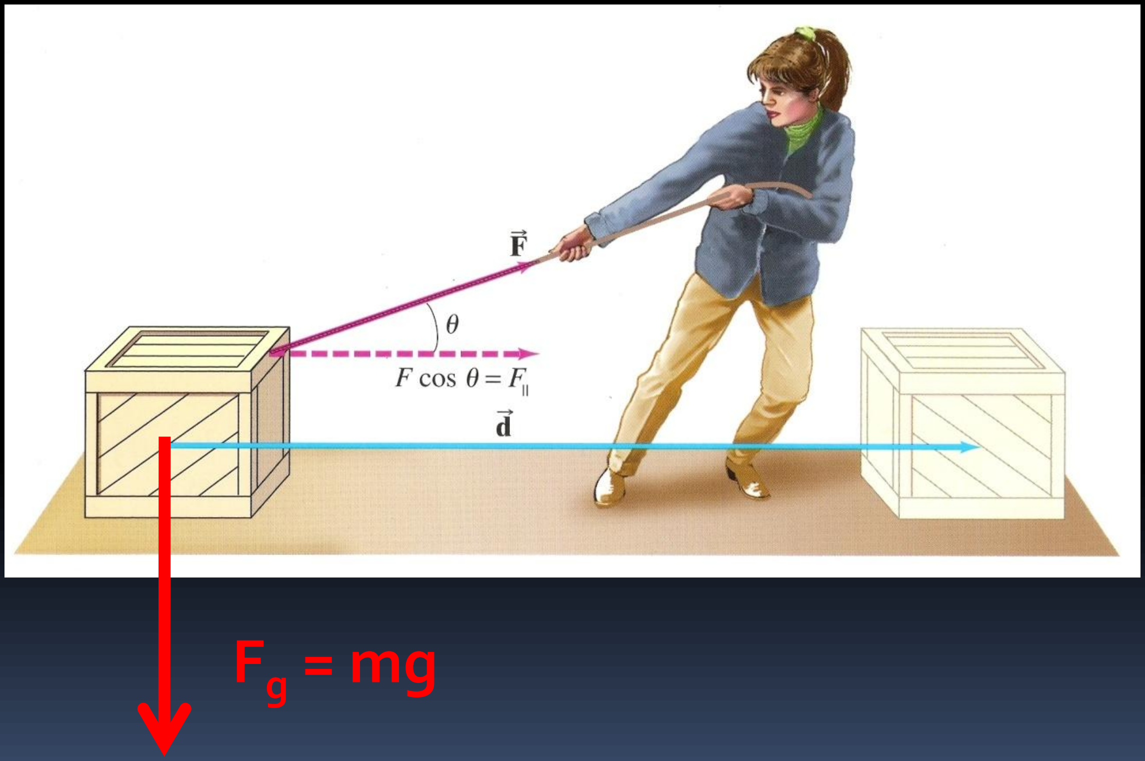
$$W = Fd\cos\theta$$

$$\theta = 90^{\circ}$$

$$\cos 90^{\circ} = 0$$

$$and,$$

$$d_y = 0$$



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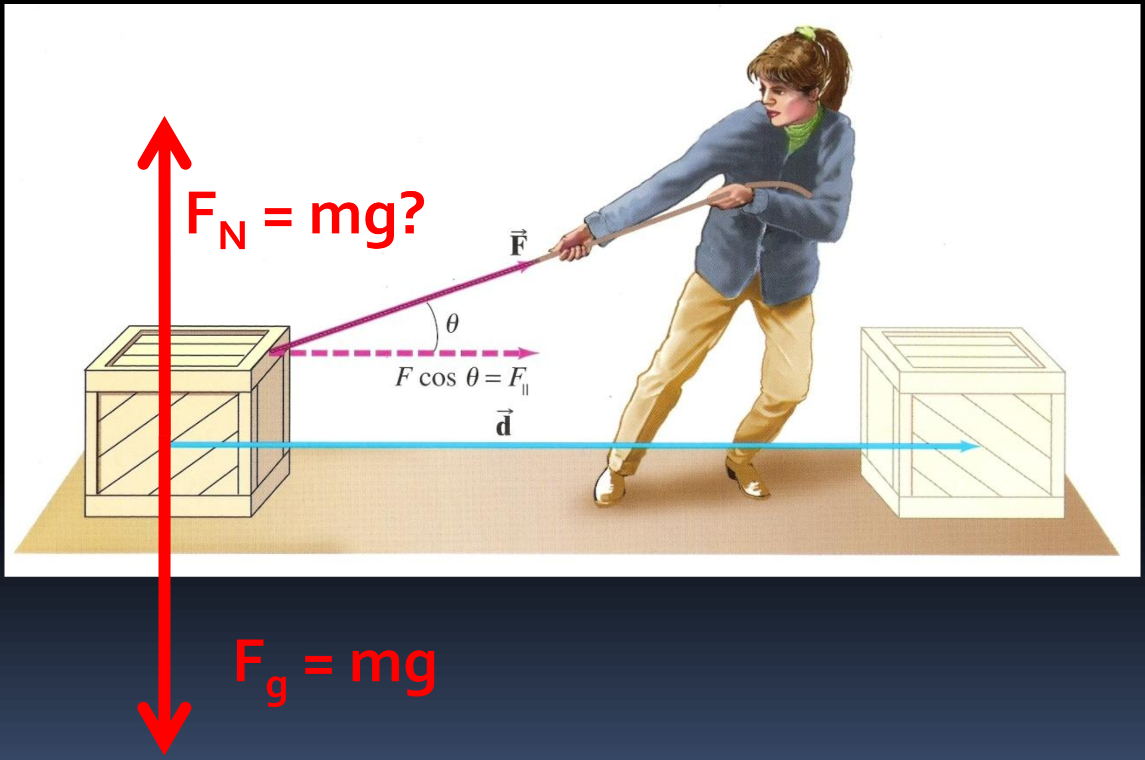


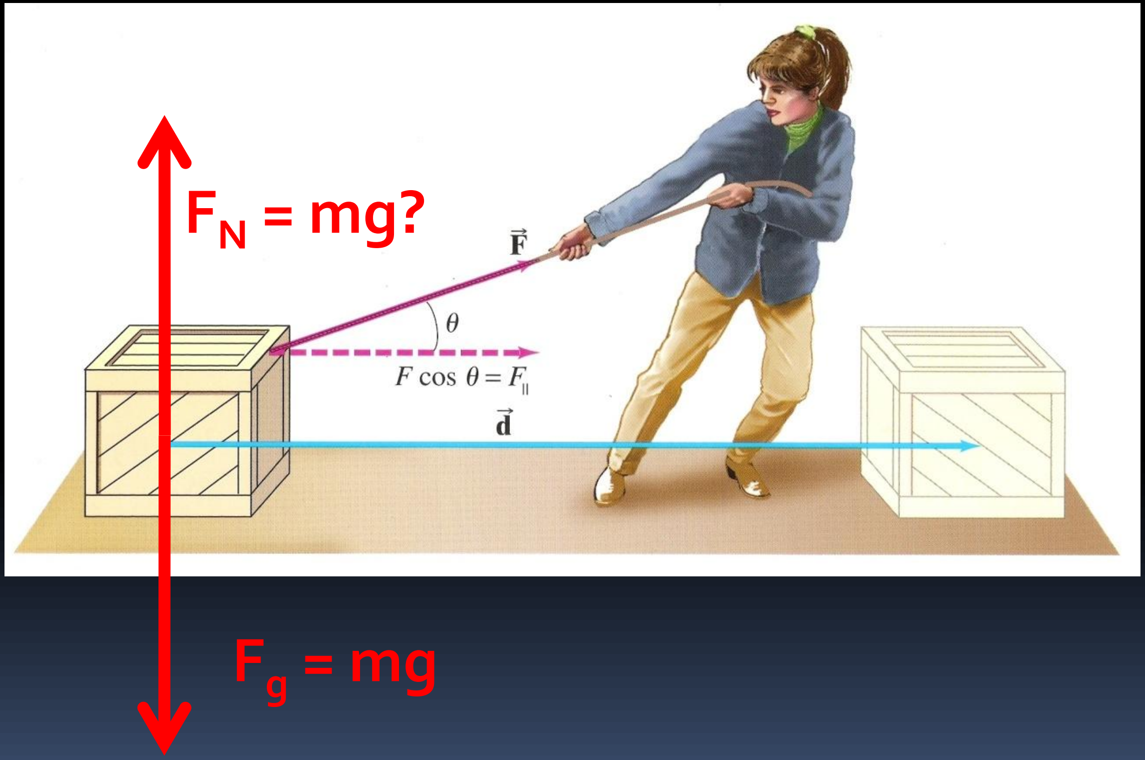
Work

- ***What forces are applied here and what work is being done?***

$$W = F_{\|} d$$

$$W = F d \cos\theta$$

$$F_N = mg?$$



Work

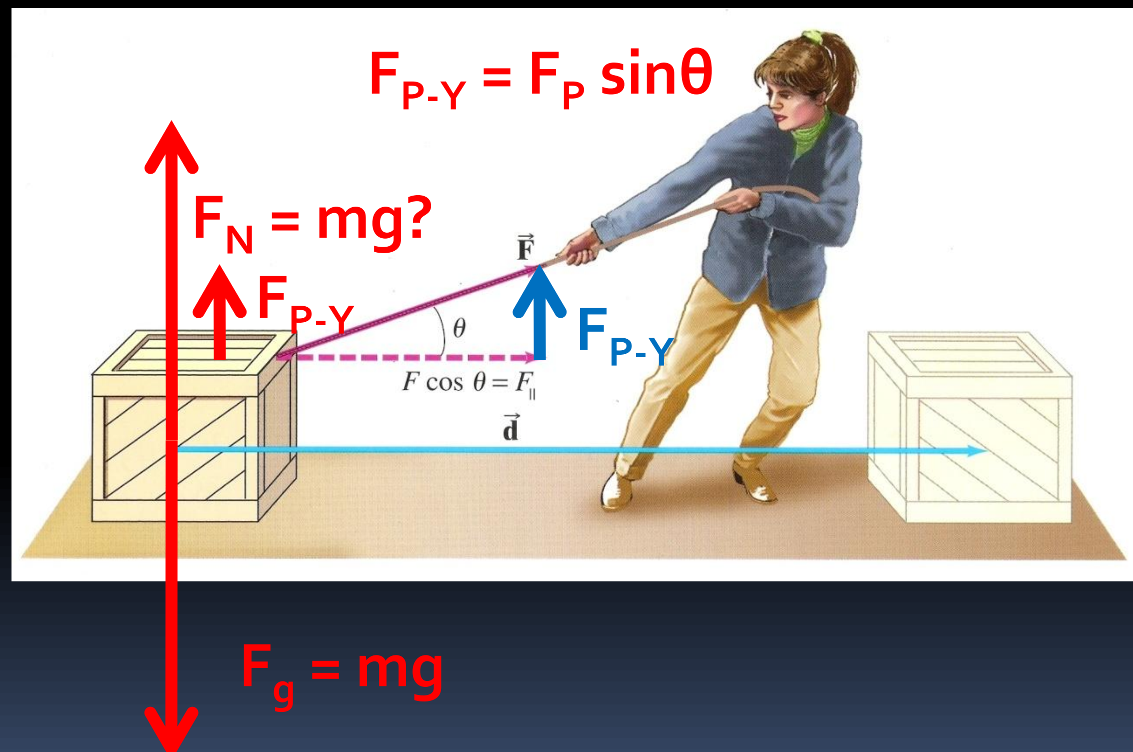
- ***What forces are applied here and what work is being done?***

$$W = F_{\parallel} d$$

$$W = Fd\cos\theta$$

$$F_N + F_{P-Y} = mg$$

$$F_N = mg - F_{P-Y}$$



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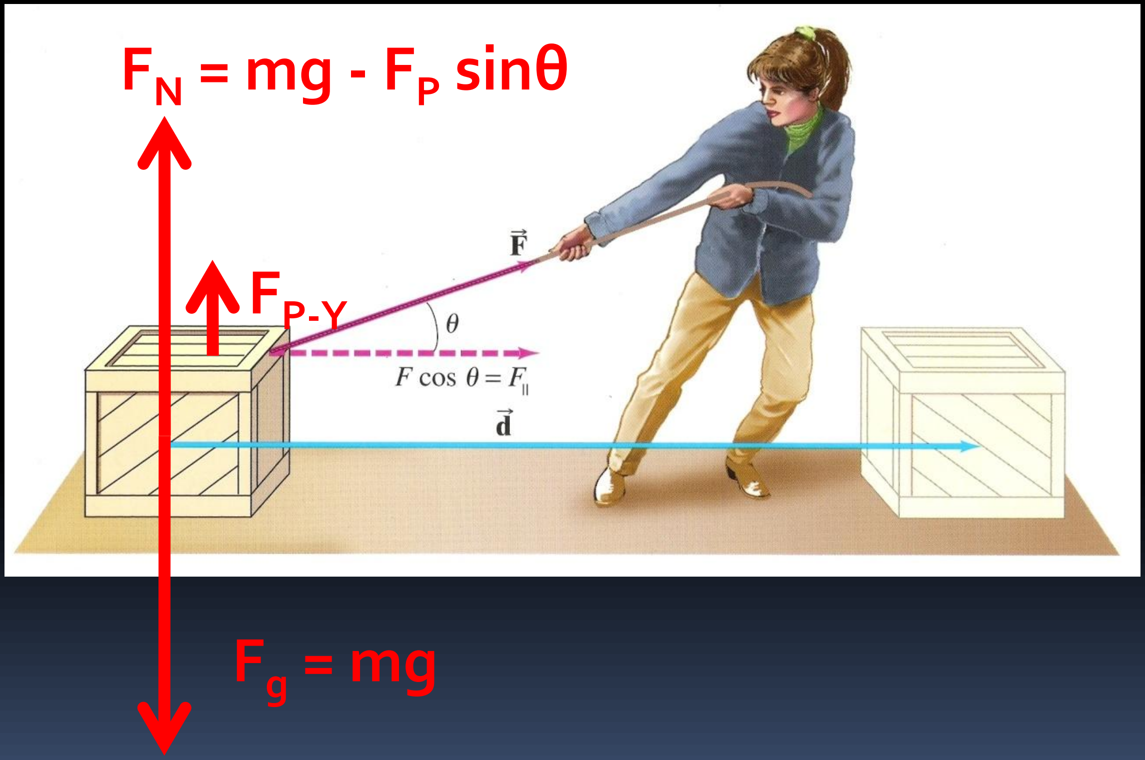

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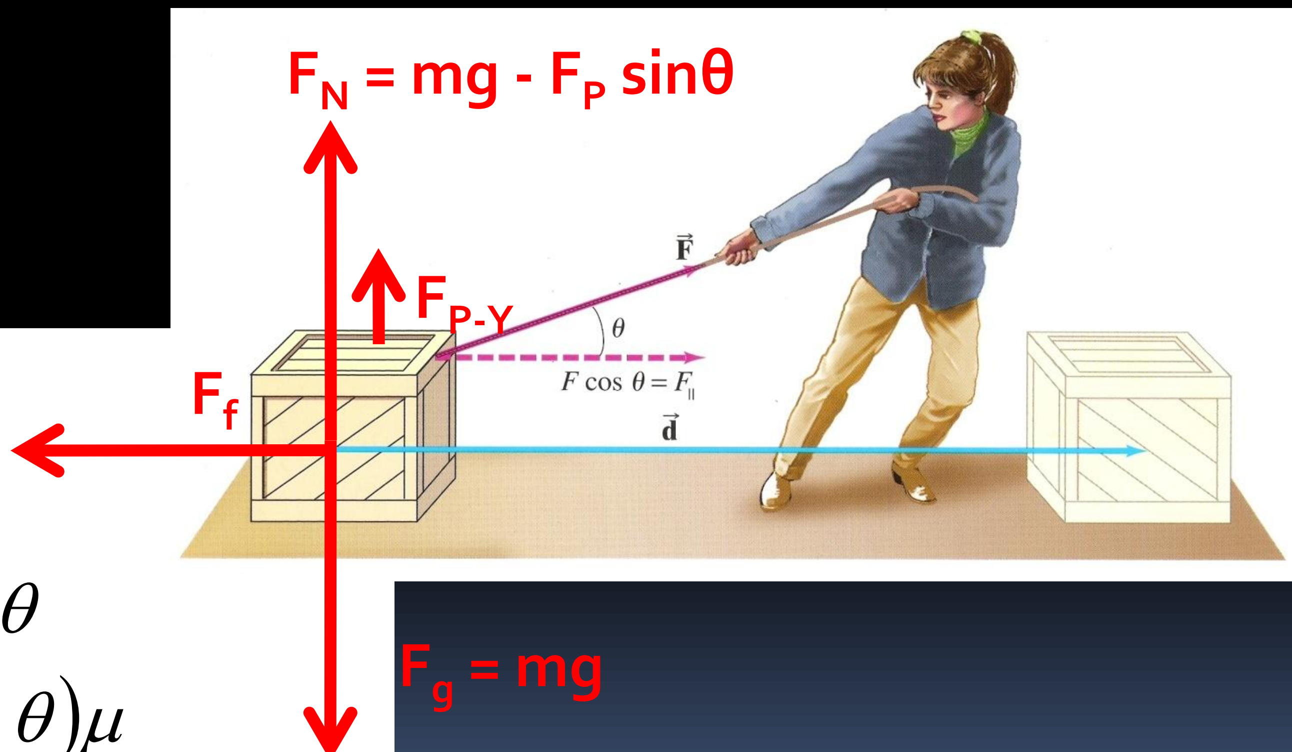

$$W = F_{\parallel} d$$

$$F_f = F_N \mu$$

$$F_N = mg - F_P \sin\theta$$

$$F_f = (mg - F_P \sin\theta)\mu$$

$$W = F_f d = [(mg - F_P \sin\theta)\mu] d$$

Work

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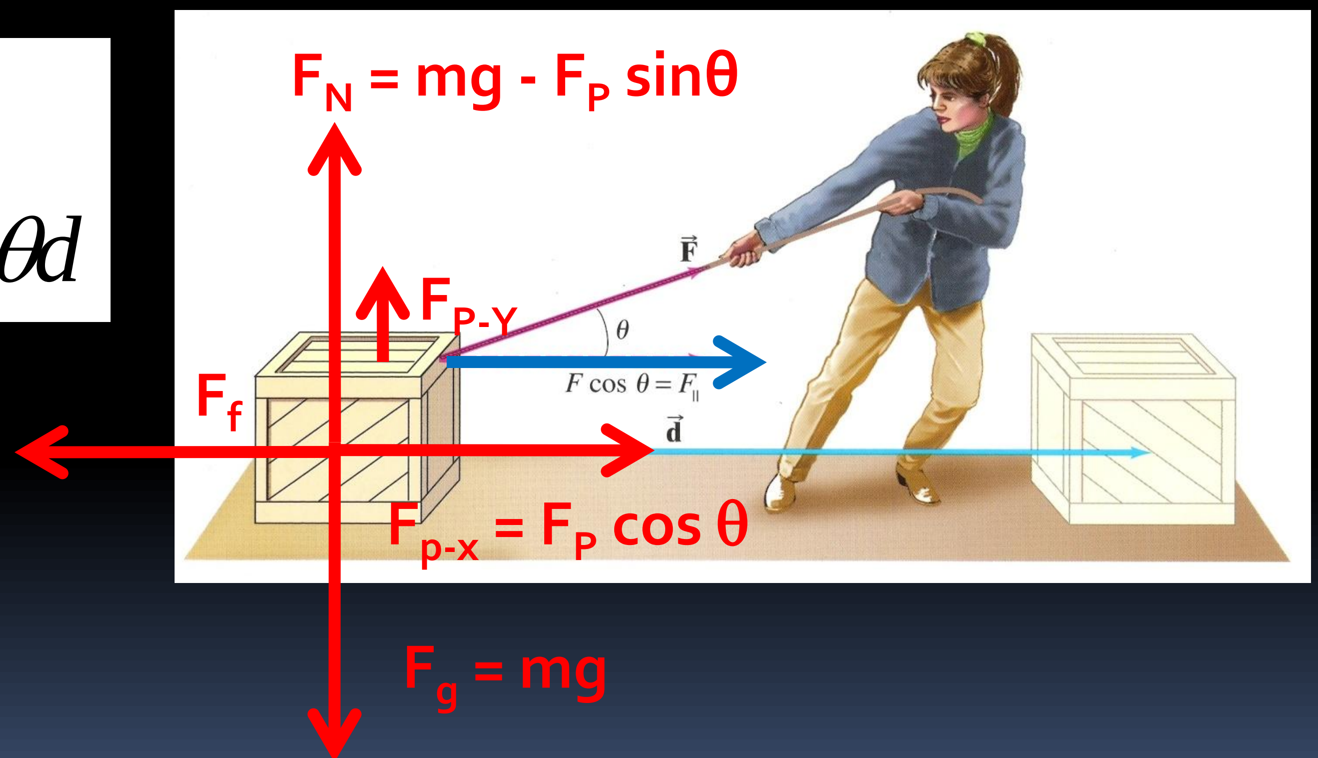
$$W = F_{\parallel} d$$

$$W_P = F_P \cos\theta d$$



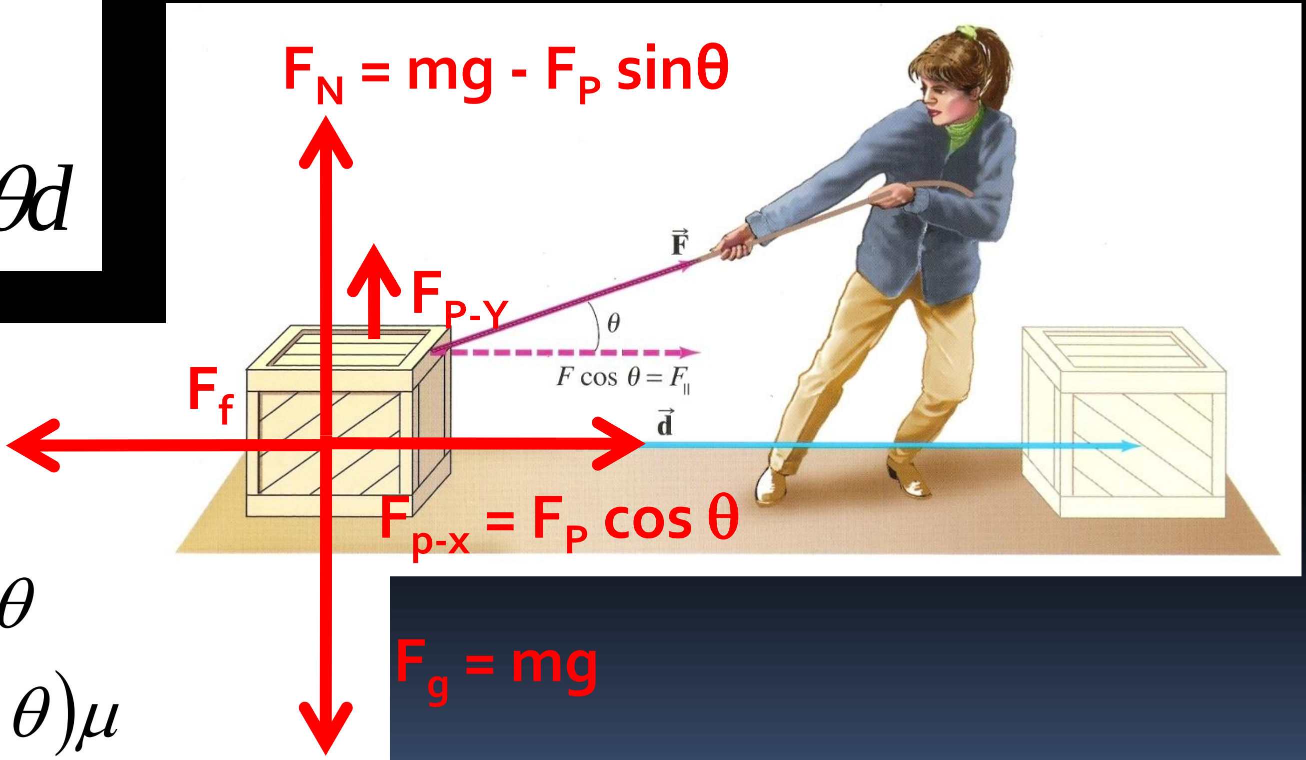
Work

- ***What forces are applied here and what work is being done?***

$$W_{Net} = F_P d\cos\theta - (mg - F_P\sin\theta)\mu d$$

$$W = F_{\parallel} d$$

$$W_P = F_P\cos\theta d$$



$$W = F_{\parallel} d$$

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$$F_N = mg - F_P\sin\theta$$

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$$W = F_f d = [(mg - F_P\sin\theta)\mu]d$$

Work

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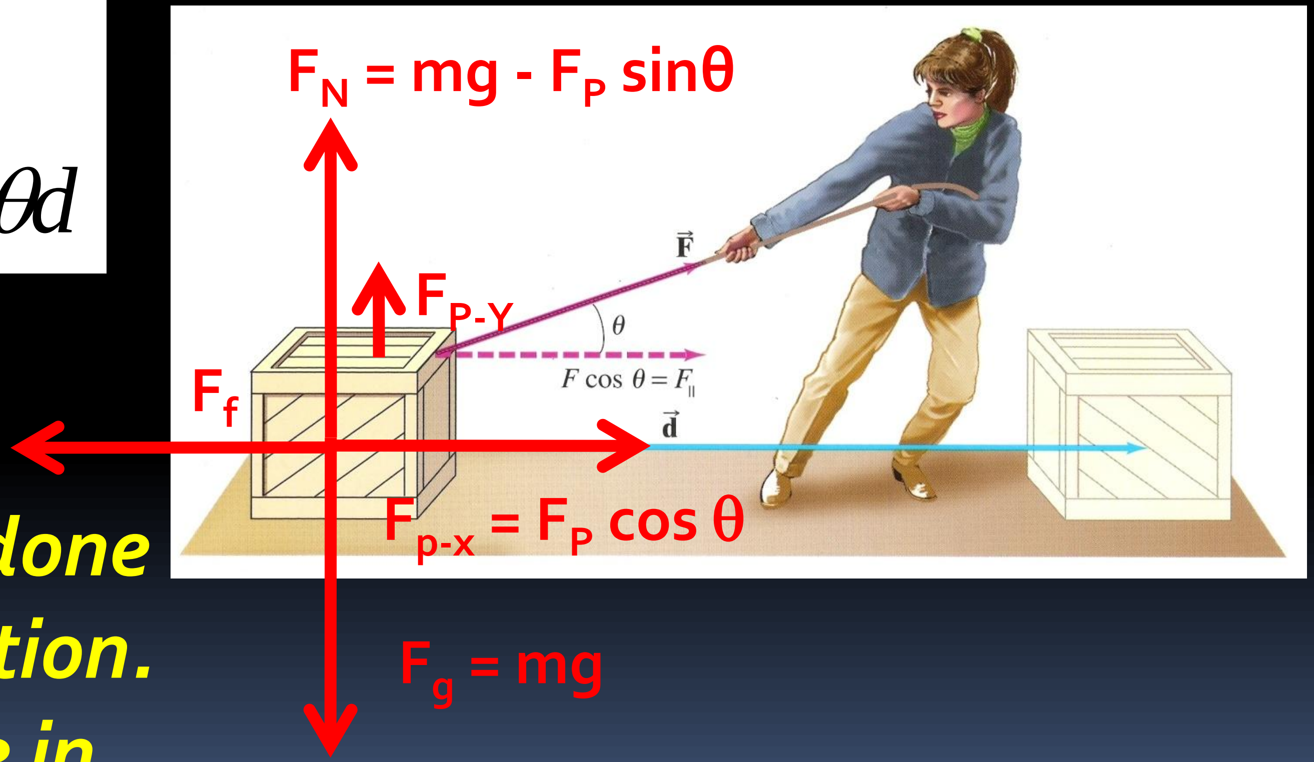
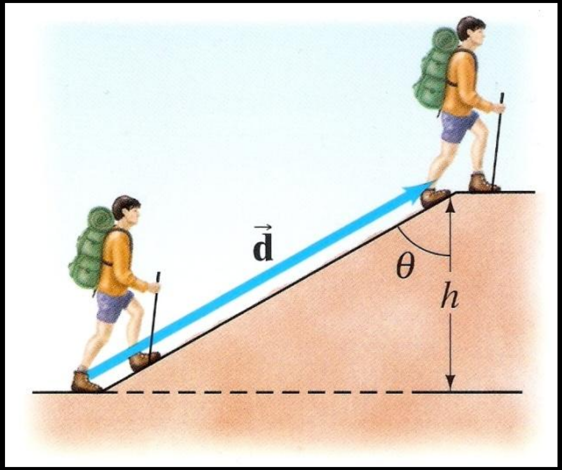
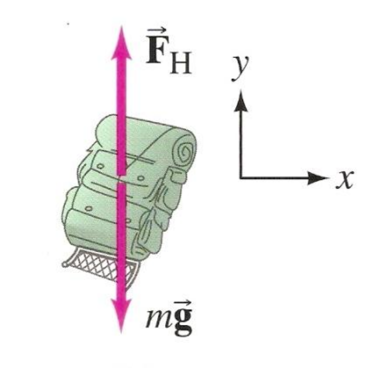


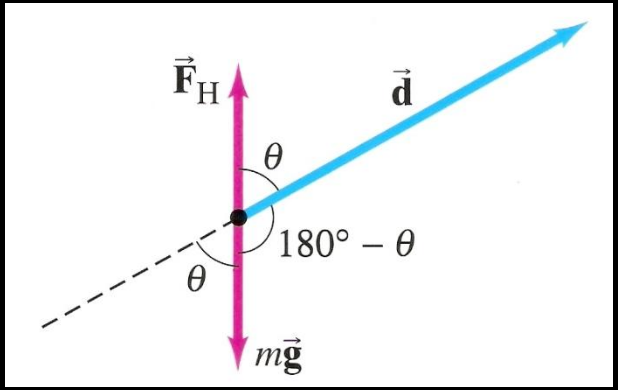
Work is only done in the x-direction. No work done in y-direction

Work

- ***What forces are applied here and what work is being done?***







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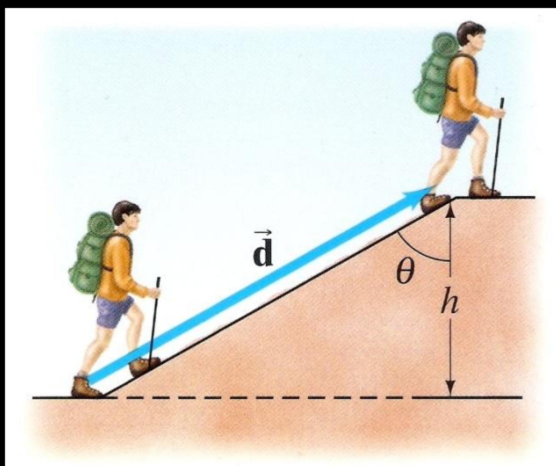

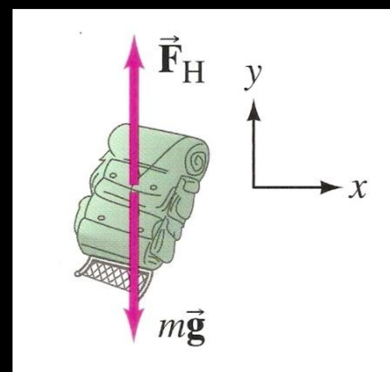

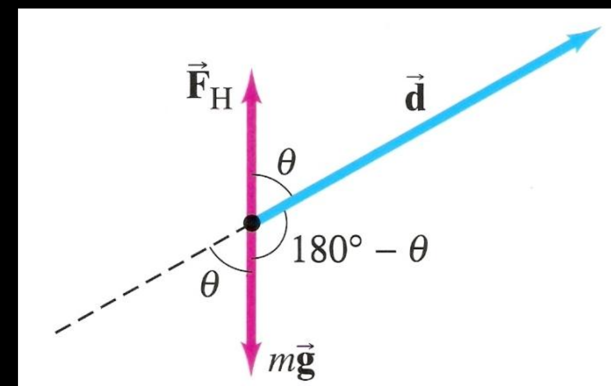

$$\Sigma F_y = ma$$

$$F_H - mg = 0$$

$$F_H = mg$$

Hiker

Work

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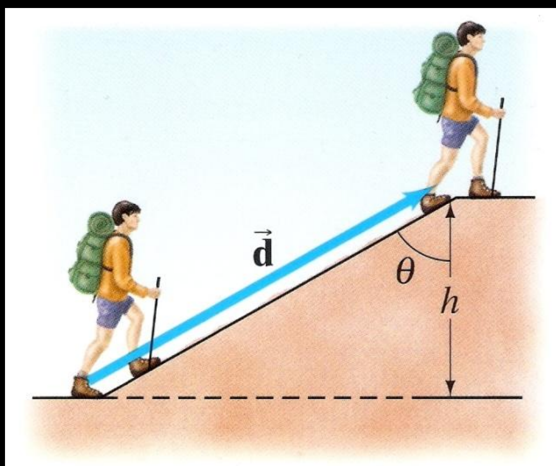

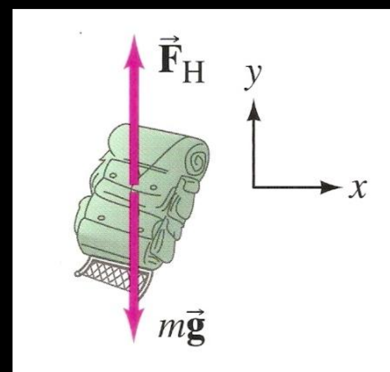

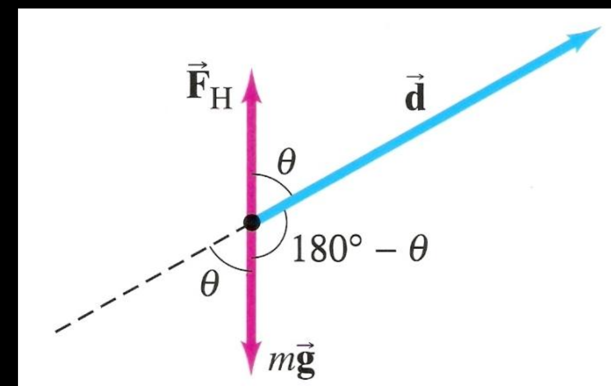

$$\Sigma F_y = ma$$

$$F_H - mg = 0$$

$$F_H = mg$$

$$W_H = F_H d \cos\theta$$

$$d \cos\theta = h$$

$$W_H = mgh$$

Hiker

Work

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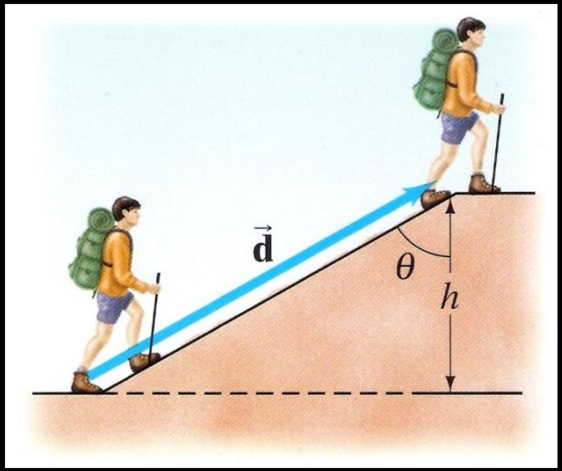
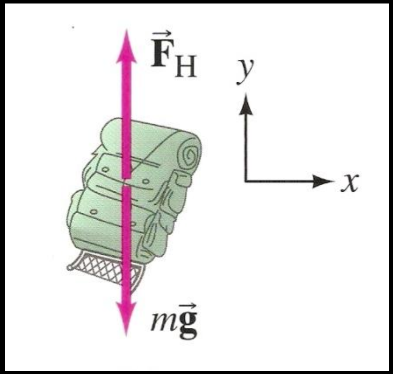
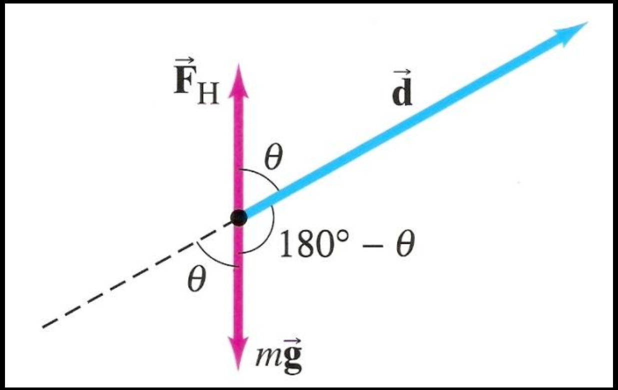






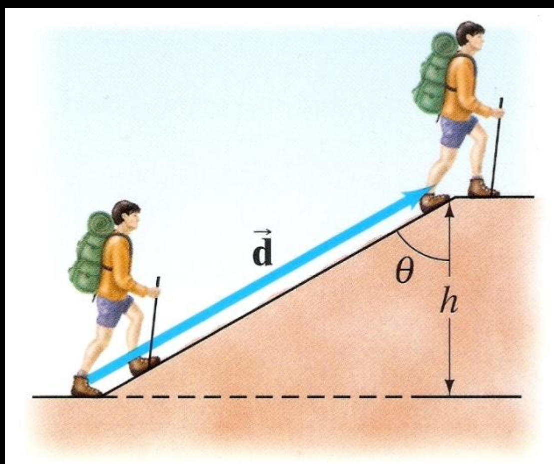
$$\Sigma F_y = ma$$
$$F_H - mg = 0$$
$$F_H = mg$$

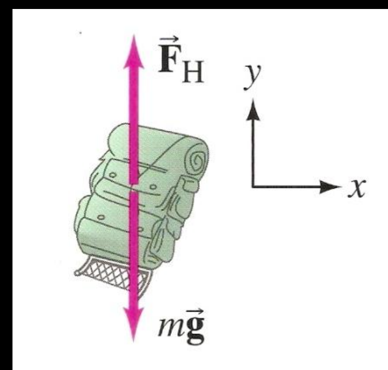
Gravity

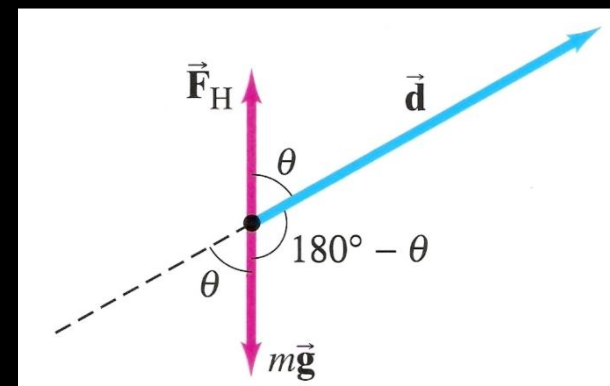
$$W_g = F_g d\cos(180-\theta)$$
$$\cos 180 - \cos\theta$$
$$0 - \cos\theta$$

Work

- ***What forces are applied here and what work is being done?*** **Note: $W_{net} = W_{Hiker} - W_{gravity} = 0$**







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$$W_H = F_H d \cos\theta$$
$$d\cos\theta = h$$
$$W_H = mgh$$

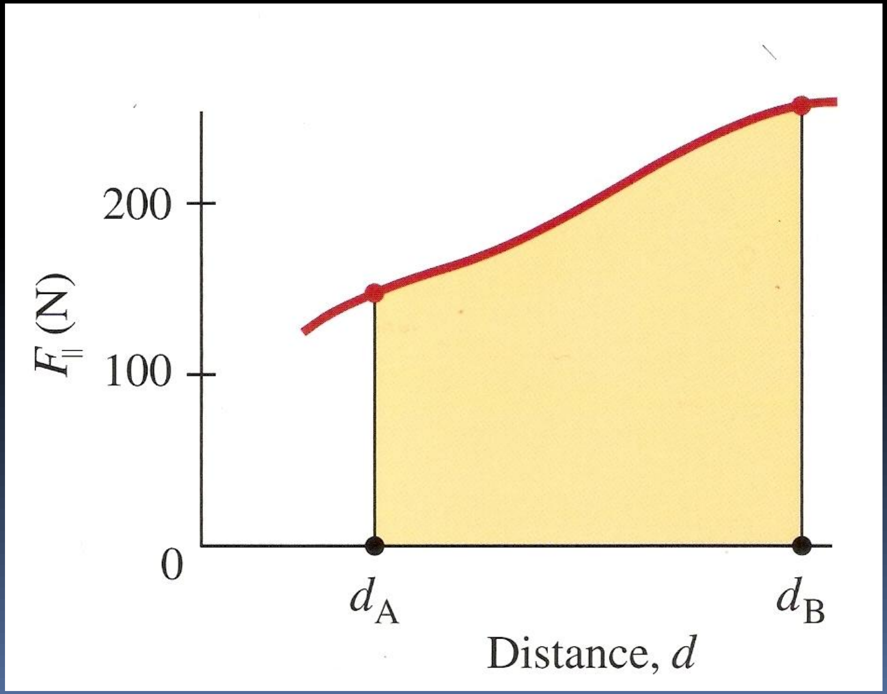
$$W_g = F_g d(-\cos\theta)$$
$$d\cos\theta = h$$
$$W_g = -mgh$$

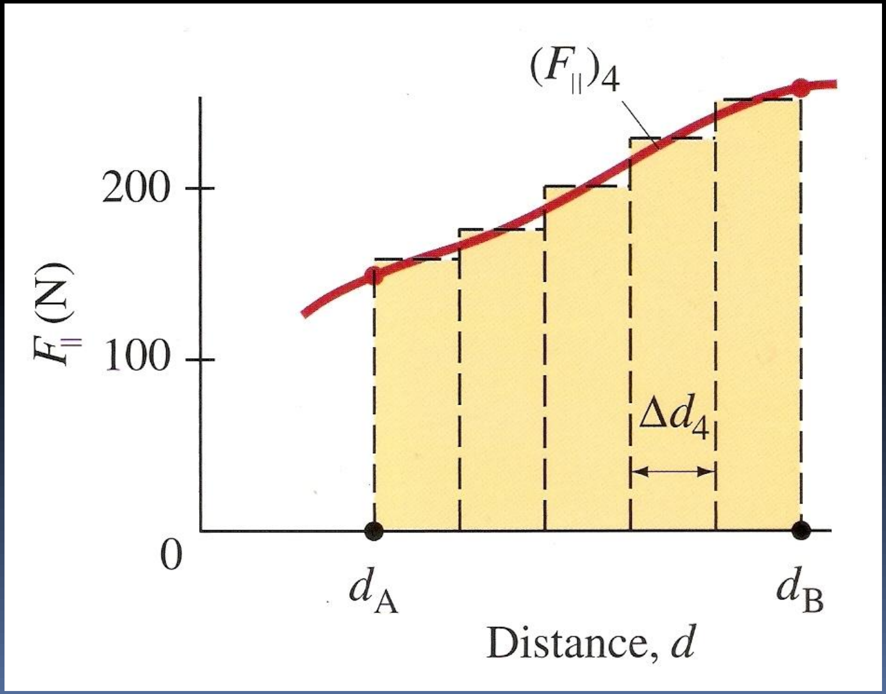
Work Done By A Varying Force

- Examples:
  - Rocket overcoming steadily decreasing gravity force as it moves away from earth
  - Force of a spring increases as its length increases
  - Force used to pull a cart up an uneven hill

Work Done By A Varying Force

- Work can be determined graphically
- The area under a force-distance graph is equal to work





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- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.

QUESTIONS?

Homework

#1-14