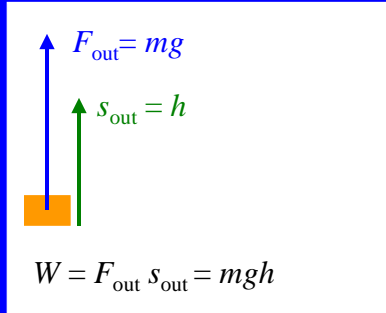


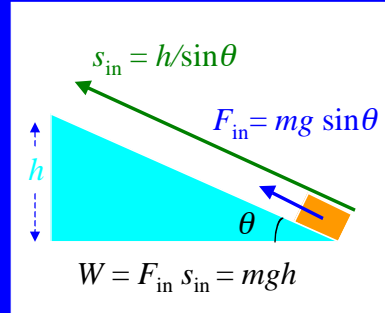
Work and Energy

Work Done and Machines

- Work done $W = F s$ for \mathbf{F} parallel to \mathbf{s} . Sometimes one can provide the work but not the force. In this case, a machine can help
- $W = F_{in} s_{in} = F_{out} s_{out}$ for an ideal machine. Can have $F_{in} \ll F_{out}$ if $s_{in} \gg s_{out}$. E. g., a ramp:



- Lifting up a weight directly requires a larger force.



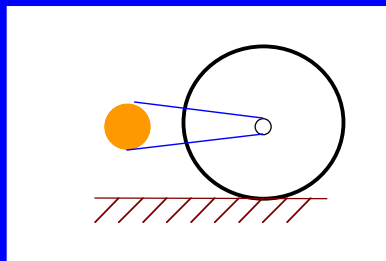
- Pushing up a weight along a ramp requires a lesser force.

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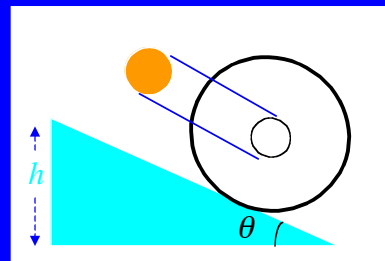
Work and Energy

Work Done and Machines

- Work done $W = F s$ for \mathbf{F} parallel to \mathbf{s} . Sometimes one can obtain higher output speed with larger the force from a machine.
- $W = F_{in} s_{in} = F_{out} s_{out}$ for an ideal machine. Can have $s_{out} \gg s_{in}$ if $F_{in} \gg F_{out}$. E. g., overdrive in a bicycle:



- Overdrive with a large s_{out}/s_{in} for speed on a level road.



- Reducing s_{out}/s_{in} with low gear with going up a hill to increase driving force.

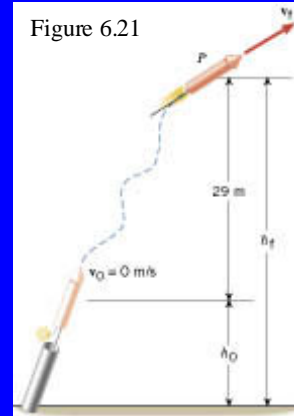
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Work and Energy

Non-Conservative-Forces and the Work-Energy Theorem

- Total mechanical energy: $E = KE + PE$
- Work done by non-conservative $W_{nc} = (KE_f + PE_f) - (KE_0 + PE_0) = E_f - E_0 \neq 0$, or

$$W_{nc} = \left(\frac{1}{2}mv_f^2 + mgh_f\right) - \left(\frac{1}{2}mv_0^2 + mgh_0\right) \neq 0$$
- Can use this to calculate W_{nc} if other quantities are known (Example 11).
- Can calculate v_f if W_{nc} is given (Example 12).



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Work and Energy

Power

- Average Power is a scalar defined by work done divided by the time required to perform the work, or,

$$\bar{P} = \frac{\text{work}}{\text{time}} = \frac{W}{t}$$

 , or $W = \bar{P} t$.
- SI unit: watt ($W = J/s$)
- By the Work-Energy Theorem:

$$W = KE_f - KE_0 = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

 ,

$$\bar{P} = \frac{\text{change in energy}}{\text{time}} = \frac{\Delta KE}{t}$$
- By $W = F s \cos\theta = F s_F$,

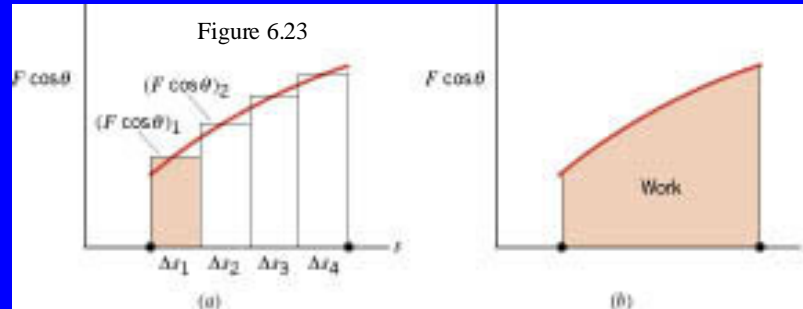
$$\bar{P} = \frac{W}{t} = F \frac{s_F}{t} = F \bar{v}_F = F \bar{v}$$
- Can be extended to instantaneous power by using instantaneous velocity.
- E. g., human metabolic rate $\sim 100 \text{ W}$ to 1000 W (Table 6.4).

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Work and Energy

Work Done by a Variable Force

- Work done $W =$ area under the $F \cos \theta$ vs. s curve.



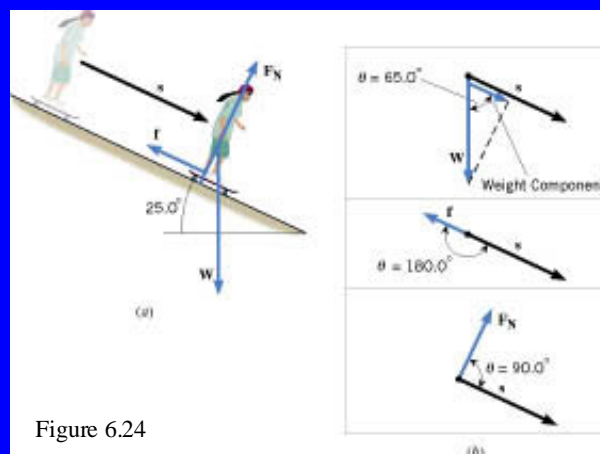
- W still equals to change of energy.

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Work and Energy

Example 15

- Work done by the three forces.

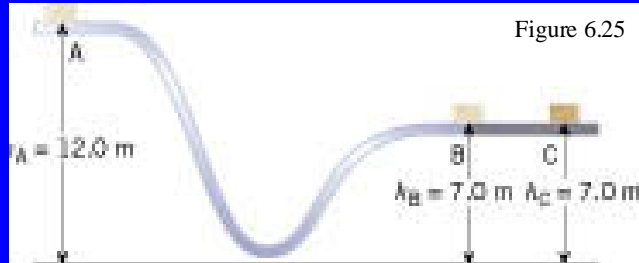


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Work and Energy

Example 16

- Conservation of energy and work done by frictional force.

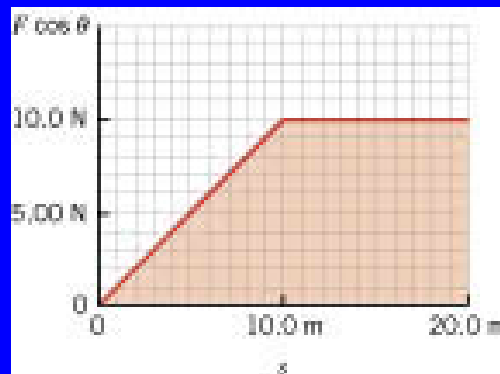


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Work and Energy

Problem 67

- Work done by a variable force.



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