Calculus-Based Physics-1: Mechanics (PHYS150-01): Week 6

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WEEK 5 REVIEW

Week 5 Review

1. Friction
    - Normal force and friction
    - Static, kinetic
2. Drag
    - Terminal velocity
3. Restoring Forces
    - Hooke's Law
    - Young's modulus
    - Shear modulus
    - Bulk modulus

WEEK 5 REVIEW PROBLEM

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A car rests on four shock absorbers, and each is like a spring with a spring constant $k = 1000 N/cm$. The car weighs 10000 N. By what distance is each spring compressed?

- A: 2.5 cm
- B: 10 cm
- C: 1 meter
- D: 0 cm

WEEK 6 SUMMARY

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1. Work has a scientifically precise definition
    - Units
    - As a product of force and displacement vectors
2. Kinetic Energy and the Work-Energy Theorem
3. Gravitational potential energy
    - Potential energy
    - *Simplifying otherwise complex calculations*
    - Potential energy near Earth's surface
    - ...in space
4. Definition of a **conservative force**
    - Relationship between conservative forces and potential energy
    - Conservation of energy for conservative forces

DEFINITIONS OF WORK

Physical Definition of Work

Let $\vec{F}$ be a force exerted on a system, which is displaced by a displacement $\vec{x}$. The **work** done on the system is $W = \vec{F} \cdot \vec{x}$

The units of work are N m = kg m/s^2, or *Joules*.

Extra credit opportunity: **Do you like beer**? Write a 10-page paper on the on the scientific challenge faced by James Prescott Joule, who began to formulate the modern view of energy in the 19th century, contrary to *caloric theory*. **Upon completion of this assignment I will change two homework scores to perfect scores.**

Let θ be the angle between the force and the displacement. Then this equation

$$W = \vec{F} \cdot \vec{x} \tag{1}$$

becomes

$$W = Fx \cos\theta \tag{2}$$

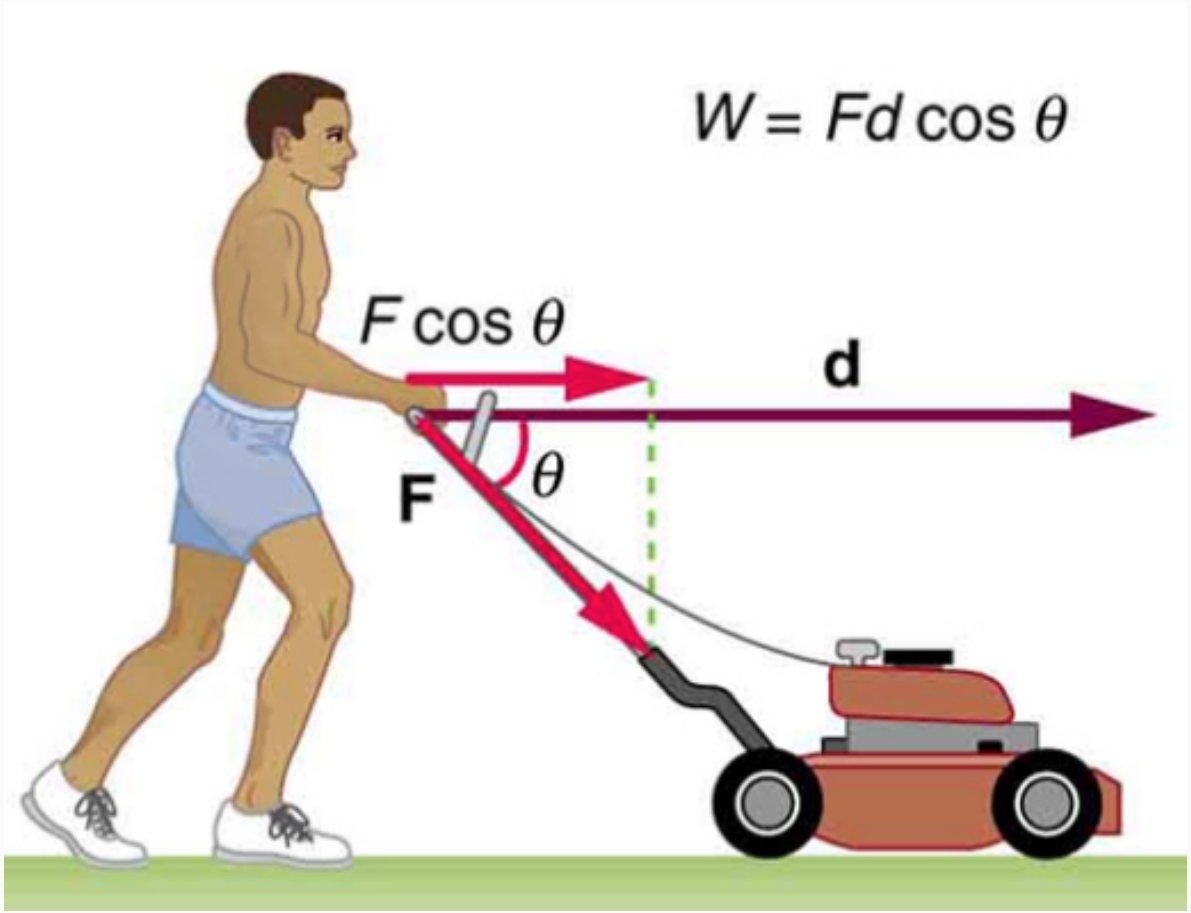

Figure 1: A case where $\theta \neq 0$.

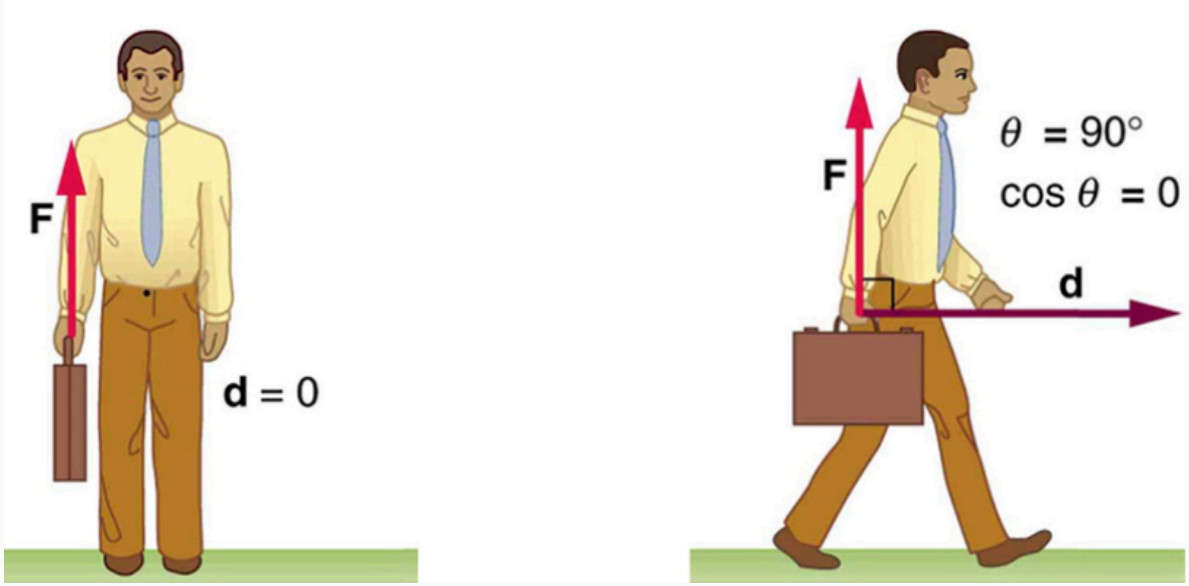

Figure 2: (Left): A case where $x = 0$, so $W = 0$. (Right): A case where $\theta = 90°$, so $W = 0$.

Just because an action requires *energy* doesn't mean we are performing *work*. It requires muscular energy to hold up a heavy briefcase but this is not what we mean by work. Work is about moving objects.

What about Newton's 3rd Law? If one system A exerts a force F_{AB} on a system B, then Newton's 3rd law states that system B exerts a force $-F_{\mathrm{AB}}$ on system A.

If the work done by A on B is $W = (F_{\mathrm{AB}})x\cos\theta$, then the work done by B on A is $W = -(F_{\mathrm{AB}})x\cos\theta$.

In Fig. 1, the work done by the man on the mower is positive, but the work done by the mower on the man is negative.

More units of energy:

Unit Name	Definition	Value
electron-volt (eV)	energy of 1 e^- through 1 V	1.60×10^{-19} J
1 Rydberg (Rd)	ionize 1 hydrogen atom	21.8×10^{-19} J
Joule	**1 N·m**	**1.0 J**
foot-pound	1 ft·lb	1.36 J
calorie	Raise 1 gram of water 1° C	4.184 J
British Thermal Unit	Raise 1 lb of ice to boil (°F)	1054.3 J
food calorie (kcal)	1000 calories	4184 J
kilowatt hours	1 kilowatt system for 1 hr	3.6×10^6 J
gasoline galon equiv.	burning a galon of gas	$\approx 120 \times 10^6$ J
$E = mc^2$, 1 mole of H^+	Rest mass (fusion/fission)	9×10^{13} J

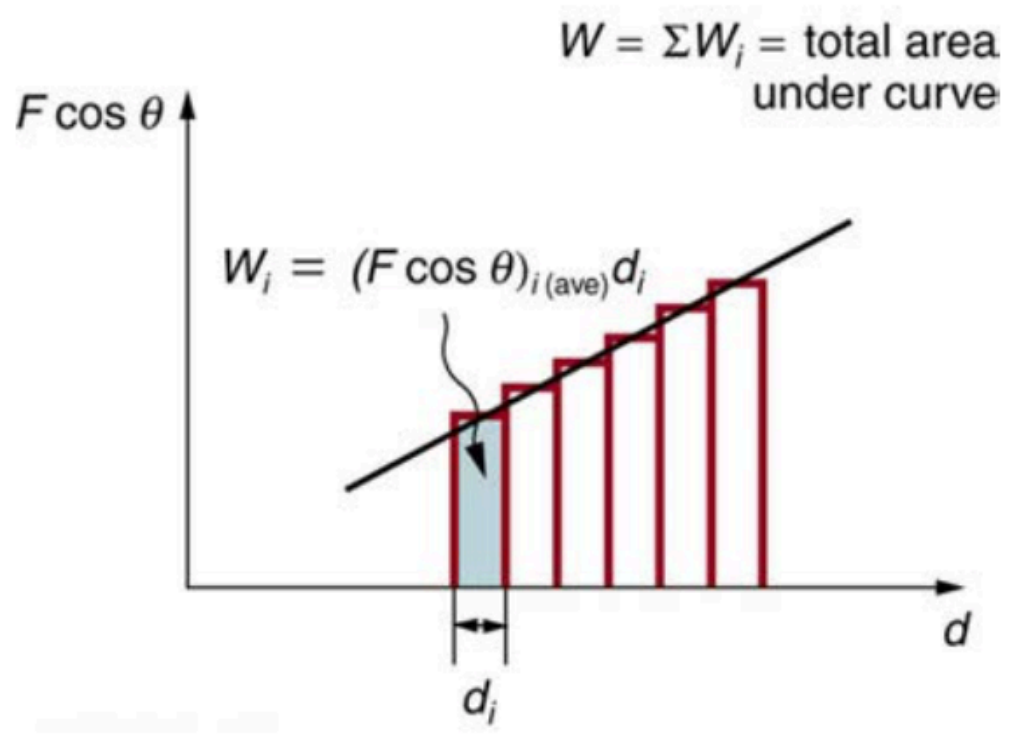

Figure 3: Breaking the displacement $\vec{x}$ into pieces, and summing them.

This interpretation naturally leads to the subject of *integration* in calculus.

WORK PRACTICE PROBLEMS

- Linear, against friction
- Gravitational, near Earth's surface
- Same, with kinematics

CONCLUSION

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ANSWERS

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- ...