Chapter 7

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ENERGY OF A SYSTEM

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Lecture 06

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Mechanical Power

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Power

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Power: is the time rate of energy transfer.

Average power: the time rate at which work is being done.

$$P_{avg} = \frac{W}{t} = \frac{E}{t}$$

The instantaneous power is defined as: the power at an instant.

$$P_{inst} = \frac{dW}{dt} = \frac{dE}{dt}$$

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Power

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A scalar quantity could be: positive, negative or zero.

The instantaneous power when Force is constant:

$$P = \vec{F} \cdot \vec{v} = F\ v\ cos\theta$$

This expression for power is valid for any means of energy transfer.

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Units of Power

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The SI unit of power is called the watt.

$$1\,W = 1\,J/s = 1\,kg\,.m^2/s^3$$

A unit of power in the US Customary system is horsepower.

$$1\,hp = 746\,W$$

Units of power can also be used to express units of work or energy.

$$1\,kWh = 1000W \times 3600s = 3.6 \times 10^6 J$$

Average Power

Saturday, 30 January, 2021 15:15

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.
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H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
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The loaded cab of an elevator has a mass of $3 \times 10^3\ kg$ and moves 210 m up the shaft in 23 s at constant speed. At what average rate does the force from the cable do work on the cab?

$$P = \frac{W}{t} = \frac{E}{t} = \frac{mgh}{t}$$

$$p = \frac{3 \times 10^3 \times 98 \times 210}{23} = 2 \cdot 7 \times 10^5 w$$

Instantaneous power

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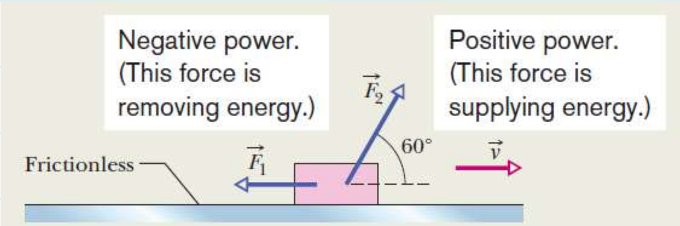
The figure shows constant forces $\vec{F}_1$ and $\vec{F}_2$ acting on a box as the box slides rightward across a frictionless floor. Force $\vec{F}_1$ is horizontal, with magnitude 2 N; force $\vec{F}_2$ is angled upward by 60° to the floor and has magnitude 4 N. The speed of the box at a certain instant is 3 m/s.

- What is the power due to each force acting on the box at that instant, and
- What is the net power?



Solution

We want an instantaneous power, not an average power, over a time period. Also, we know the box's velocity (rather than the work done on it).

We use $P = Fv\cos\theta$ for each force. For force $\vec{F}_1$, at angle $\theta_1 = 180°$ to velocity $\vec{v}$, we have:

$P_1 = F_1 v \cos\theta_1 = (2.0N)(3.0m/s)\cos 180° = -6.0W$

This negative result tells us that force $\vec{F}_1$ is transferring energy from the box at the rate of 6.0 J/s.

For force $\vec{F}_2$, at angle $\theta_2 = 60°$ to velocity $\vec{v}$, we have:

$P_2 = F_2 v \cos\theta_2 = (4.0N)(3.0m/s)\cos 60° = 6.0W$

This positive result tells us that force $\vec{F}_2$ is transferring energy to the box at the rate of 6.0 J/s.

The net power is the sum of the individual powers:

$P_{net} = P_1 + P_2 = -6.0W + 6.0W = 0$

This tells us that the net rate of transfer of energy to or from the box is zero. Thus, the kinetic energy $(K = \frac{1}{2}mv^2)$ of the box is not changing, and so the speed of the box will remain at 3.0 m/s.

Instantaneous power - unit vectors

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At a certain instant, a particle-like object is acted on by a force $\vec{F} = \left(4\hat{\imath} - 2\hat{\jmath} + 9\hat{k}\right) N$ while the object's velocity is $\vec{v} = \left(-2\hat{\imath} + 4\hat{k}\right)\ m/s$. What is the instantaneous rate at which the force does work on the object?

$$P = \vec{F} \cdot \vec{v} = \left(4\hat{\imath} - 2\hat{\jmath} + 9\hat{k}\right) \cdot \left(-2\hat{\imath} + 4\hat{k}\right)$$

$$P = (4 \times -2) + (-2 \times 0) + (9 \times 4) = 28\ w$$