General Physics I
Homework Chapter 7

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03/30/2016

Homework: Chapter 7

Problem (1)

Use the definition of scalar product, $\vec{a} \bullet \vec{b} = ab\cos\theta$, and the fact that $\vec{a} \bullet \vec{b} = a_x b_x + a_y b_y + a_z b_z$ to calculate the angle between the two vectors given by $\vec{a} = 4.0\hat{i} + 5.0\hat{j} + 6.0\hat{k}$ and $\vec{b} = 1.0\hat{i} - 3.0\hat{j} + 4.0\hat{k}$.

R:

$$\begin{aligned}
a = & \ |\vec{a}| = \sqrt{4.0^2 + 5.0^2 + 6.0^2} \\
= & \ \sqrt{77} = 8.775 \\
b = & \ \left|\vec{b}\right| = \sqrt{1.0^2 + (-3.0)^2 + 4.0^2} \\
= & \ \sqrt{26} = 5.099 \\
\vec{a} \bullet \vec{b} = & \ (4.0)(1.0) + (5.0)(-3.0) + (6.0)(4.0) \\
= & \ 4 - 15 + 24 = 13 \\
\vec{a} \bullet \vec{b} = & \ ab\cos\theta \\
13 = & \ (8.775)(5.099)\cos\theta \\
\theta = & \ \cos^{-1}\left(\frac{13}{44.744}\right) \\
= & \ 73.109^o
\end{aligned} \tag{1}$$

Problem (2)

If a Saturn V rocket with an Apollo spacecraft attached had a combined mass of $2.78 \times 10^5\ kg$ and reached a speed of $11.7\ km/s$, how much kinetic energy would it then have?

R:

$$\begin{aligned}
K &= \frac{1}{2}mv^2 \\
&= \frac{1}{2}\left(2.78 \times 10^5\ kg\right)(11.7\ km/s)^2 \\
&= \left(1.39 \times 10^5\ kg\right)\left(1.17 \times 10^4\ m/s\right)^2 \\
&= \left(1.39 \times 10^5\ kg\right)\left(1.3689 \times 10^8\ m^2/s^2\right) \\
&= 1.9028 \times 10^{13}\ kg \times m^2/s^2 \\
&= 1.9028 \times 10^{13}\ J
\end{aligned} \tag{2}$$

Problem (3)

The only force acting on a 2.8 sl canister that is moving in a xy plane has a magnitude of 4.7 lb. The canister initially has a velocity of 3.9 ft/s in the positive x direction, and some time later has a velocity of 5.6 ft/s in the positive y direction. How much work is done on the canister by the 4.7 lb force during this time?

R:

$$\begin{aligned}
|\vec{v_i}| &= 3.9\ ft/s \\
K_i &= \frac{1}{2}(2.8\ sl)(3.9\ ft/s)^2 \\
&= 21.294\ ft \times lb \\
|\vec{v_f}| &= 5.6\ ft/s \\
K_f &= \frac{1}{2}(2.8\ sl)(5.7\ ft/s)^2 \\
&= 45.486\ ft \times lb \\
W_{net} &= K_f - K_i \\
&= (45.486\ ft \times lb) - (21.294\ ft \times lb) \\
&= 24.192\ ft \times lb
\end{aligned} \tag{3}$$

Problem (4)

A floating ice block moves through a displacement $\vec{d} = (15\ ft)\hat{i} - (24\ ft)\hat{j}$, pushed by a force $\vec{F} = (14\ lb)\hat{i} - (11\ lb)\hat{j}$ on the block. How much work does the force do on the block during the displacement? Note that the displacement is **not** parallel to the force.

R:

$$\begin{aligned} W &= \vec{F} \bullet \Delta\vec{r} \\ &= F_x r_x + F_y r_y \\ &= [(15\ ft)(14\ lb)] + [(-24\ ft)(-11\ lb)] \\ &= (210\ ft \times lb) + (264\ ft \times lb) \\ &= 474\ ft \times lb \end{aligned} \tag{4}$$

Problem (5)

The figure shows three forces applied to a trunk that moves leftward by 2.3 m over a frictionless floor. The force magnitudes are $F_1 = 5.3\ N$, $F_2 = 6.7\ N$, and $F_3 = 4.1\ N$ and the indicated angle is $\theta = 69^o$. During the displacement, what is the net work done on the trunk by the three forces?

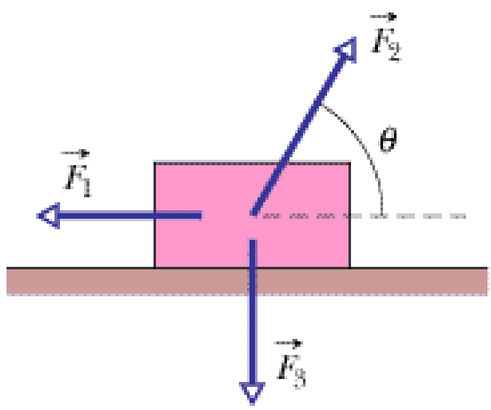

Figure 1: Illustration of Problem 5

R:

$$\begin{aligned}
W_1 &= F_1 r\cos\theta_1 \\
&= (5.3\ N)(2.3\ m)\cos 0^o \\
&= 12.19\ N\times m = 12.19 J \\
W_2 &= F_2 r\cos\theta_2 \\
&= (6.7\ N)(2.3\ m)\cos 111^o \\
&= -5.52\ N\times m = -5.52\ J \\
W_3 &= F_3 r\cos\theta_3 \\
&= (4.1\ N)(2.3\ m)\cos 90^o \\
&= 0 \\
W_{net} &= W_1 + W_2 + W_3 \\
&= (12.19\ J) + (-5.52\ J) + (0) \\
&= 6.67\ J
\end{aligned} \tag{5}$$

Problem (6)

During spring semester at MIT, residents of the parallel buildings of the East Campus dorms battle one another with large catapults that are made with surgical hose mounted on a window frame. A balloon filled with dyed water is placed in a pouch attached to the hose, which is then stretched through the width of the room. Assume that the stretching of the hose obeys Hooke's Law with a spring constant of 38 lb/ft. If the hose is stretched by 6.1 ft and then released, how much work does the force from the hose do on the balloon in the pouch by the time reaches its relaxed length?

R:

$$\begin{aligned}
W_s &= \frac{1}{2}kx^2 \\
&= \frac{1}{2}(38\ lb/ft)(6.1\ ft)^2 \\
&= (19\ lb/ft)\left(37.21\ ft^2\right) \\
&= 669.78\ ft\times lb
\end{aligned} \tag{6}$$

Problem (7)

A 2.5 kg block moves in a straight line on a horizontal frictionless surface under the influence of a force that varies with position as shown the figure. How much work is done by the force as the block moves from the origin to $x = 8.0\ m$?

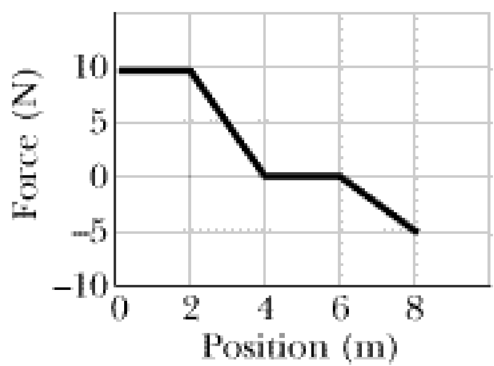

Figure 2: Illustration of Problem 7

R:

$$
\begin{aligned}
W_{(0\ m\ \rightarrow\ 2\ m)} &= (10\ N)(2\ m) = 20\ J \\
W_{(2\ m\ \rightarrow\ 4\ m)} &= \frac{1}{2}(10\ N)(2\ m) = 10\ J \\
W_{(4\ m\ \rightarrow\ 6\ m)} &= 0 \\
W_{(6\ m\ \rightarrow\ 8\ m)} &= \frac{1}{2}(-5\ N)(2\ m) = -5\ J \\
W_{net} &= \sum W = 20\ J + 10\ J - 5\ J \\
&= 25\ J
\end{aligned} \tag{7}
$$

Problem (8)

The force on a particle is directed along an x axis and given by $F = 4.2x - 3.1$ where x is in meters and F is in Newtons. Find the work done by the force in moving the particle from $x = 0$ and $x = 2.9\ m$.

R:

$$
\begin{aligned}
W &= \int_{x_i}^{x_f} F(x)\ dx \\
&= \int_0^{2.9\ m} (4.2\ N/m)x - (3.1\ N)\ dx \\
&= \left[(2.1\ N/m)x^2 - (3.1\ N)x\right]_0^{2.9\ m} \\
&= (2.1\ N/m)\,(2.9\ m)^2 - (3.1\ N)(2.9\ m) \\
&= (17.661\ J) - (8.99\ J) \\
&= 8.671\ J
\end{aligned} \tag{8}
$$

Problem (9)

A 6.5 lb block is pulled at a constant speed of 2.4 ft/s across a horizontal floor by an applied force of 19 lb directed 14^o above the horizontal. What is the **rate** at which the force does work on the block?

R:

$$
\begin{aligned}
P &= \vec{F} \bullet \vec{v} = Fv\cos\theta \\
&= (19\ lb)(2.4\ ft/s)\cos 14^o \\
&= 44.245\ ft \times lb/s
\end{aligned} \tag{9}
$$

Problem (10)

The loaded cab of an elevator has a mass of 2300 kg and moves 130 m up the shaft in 22 s at constant speed. At what average **rate** does the force from the cable do work on the cab?

R:

$$\begin{aligned}
F_c = F_g &= (2300\ kg)\left(9.8\ m/s^2\right) = 22\ 540\ N \\
W &= (22\ 540\ N)(130\ m) = 2\ 930\ 200\ J \\
\bar{P} &= \frac{\Delta W}{\Delta t} \\
\bar{P} &= \frac{2\ 930\ 200\ J}{22\ s} = 133\ 190.\bar{9}\bar{0}\ W
\end{aligned} \tag{10}$$

Problem (11)

A horse pulls a cart with a force of 98 lb at an angle of 19^o above the horizontal and moves along at a speed of 3.7 mi/h.

Question (a)

How much work (in $ft \times lb$) does the force do in 25 min?
R:

$$\begin{aligned}
3.7\ mi/h &= 3.7\ mi/h \times \left(\frac{5280\ ft}{1\ mi}\right) \times \left(\frac{1\ h}{3600\ s}\right) \\
&= 5.42\bar{6}\ ft/s \\
25\ min &= 25\ min \times \left(\frac{60\ s}{1\ min}\right) \\
&= 1500\ s \\
W &= (98\ lb)(5.42\bar{6}\ ft/s)(1500\ s)\cos 19^o \\
&= 754\ 259.078\ ft \times lb
\end{aligned} \tag{11}$$

Question (b)

What is the average power (in horsepower, hp) of the force?
R:

$$\begin{aligned}\bar{P} &= \frac{\Delta W}{\Delta t} \\ &= 497.708 ft \times lb/s \times \left(\frac{1\ hp}{550\ ft \times lb/s}\right) \\ &= 0.905\ hp = \cos 19^o\ hp \end{aligned} \tag{12}$$