General Physics I
Homework Chapter 10

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Homework: Chapter 10

Problem (1)

A good baseball pitcher can throw a baseball toward home plate at 95 mi/h with a spin of 1300 rev/min. How many revolutions does the baseball make on its way to home plate? For simplicity, assume that the 60 ft path is a straight line.

R:

$$\begin{aligned} v &= 95\ mi/h \times \left(\frac{5280\ ft}{1\ mi}\right) \times \left(\frac{1\ h}{3600\ s}\right) \\ &= 139.\overline{3}\ ft/s \\ \omega &= 1300\ rev/min \times \left(\frac{1\ min}{60\ s}\right) \\ &= 21.\overline{6}\ rev/s \\ t &= \frac{x}{v} = \frac{60\ ft}{139.\overline{3}\ ft/s} \\ &= 0.431\ s \\ n_{rev} &= (21.\overline{6}\ rev/s)(0.431\ s) = 9.33\ rev \end{aligned} \tag{1}$$

Problem (2)

A disk, initially rotating at 145 rad/s, is slowed down with a constant angular acceleration of magnitude 3.40 rad/s^2.

Question (a)

How much time does the disk take to stop?

R:

$$\begin{aligned}\omega &= \omega_0 + \alpha t \\ t &= \frac{\omega - \omega_0}{\alpha} \\ &= \frac{0 - 145\ rad/s}{-3.40\ rad/s^2} \\ &= 42.647\ s \end{aligned} \tag{2}$$

Question (b)

Through what angle (rad) does the disk rotate during that time?

R:

$$\begin{aligned}\theta &= \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \\ \theta &= 0 + (145\ rad/s)(42.647\ s) + \frac{1}{2}\left(-3.4\ rad/s^2\right)(42.647\ s)^2 \\ \theta &= (6183.815\ rad) - (3091.903\ rad) \\ \theta &= 3091.912\ rad \end{aligned} \tag{3}$$

Problem (3)

An astronaut is being tested in a centrifuge. The centrifuge has a radius of 25 ft and, in starting, rotates according to $\theta = 0.22t^2$, where t is in seconds and θ is in radians. When $t = 3.6\ s$,

Question (a)

What is the magnitude of the astronaut's angular velocity?

R:

$$\begin{aligned} \omega &= \frac{d\theta}{dt} = \left(0.44\ rad/s^2\right) t \\ &= \left(0.44\ rad/s^2\right)(3.6\ s) \\ &= 1.584\ rad/s \end{aligned} \tag{4}$$

Question (b)

What is the magnitude of the astronaut's linear velocity?
R:

$$\begin{aligned} v &= r\omega \\ &= (25\ ft)(1.584\ rad/s) \\ &= 39.6\ ft/s \end{aligned} \tag{5}$$

Question (c)

What is the magnitude of the astronaut's tangential acceleration?
R:

$$\begin{aligned} \alpha &= \frac{d\omega}{dt} = 0.44\ rad/s^2 \\ a_t &= r\alpha \\ &= (25\ ft)\left(0.44\ rad/s^2\right) \\ &= 11\ ft/s^2 \end{aligned} \tag{6}$$

Question (d)

What is the magnitude of the astronaut's centripetal acceleration?
R:

$$\begin{aligned} a_c &= r\omega^2 \\ &= (25\ ft)(1.584\ rad/s)^2 \\ &= (25\ ft)\left(2.509\ rad^2/s^2\right) \\ &= 62.725\ ft/s^2 \end{aligned} \tag{7}$$

Problem (4)

Calculate the rotational inertia of a wheel that has a kinetic energy of 21 kJ when rotating at 590 rev/min.

R:

$$
\begin{aligned}
\omega &= 590\ rev/min \times \left(\frac{2\pi\ rad}{1\ rev}\right) \times \left(\frac{1\ min}{60\ s}\right) \\
&= 61.785\ rad/s \\
K_{rot} &= \frac{1}{2} I \omega^2 \\
I &= \frac{2K_{rot}}{\omega^2} \\
&= \frac{2(21000\ J)}{(61.785\ rad/s)^2} \\
&= \frac{42000\ J}{3817.344\ s^{-2}} \\
&= 11\ kg \times m \qquad (8)
\end{aligned}
$$

Problem (5)

The body in fig. 1 is pivoted at O. Three forces act on it in the directions shown: $F_A =$ 9.3 N at point A, 7.5 m from O; $F_B =$ 11.0 N at point B, 5.4 m from O; and $F_C =$ 8.8 N at point C, 4.4 m from O. Taking the clockwise direction to be negative, what is the net torque about O?

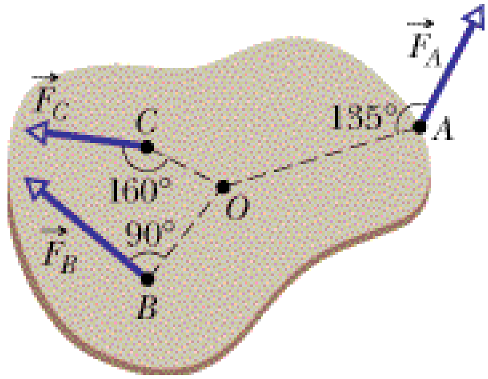

Figure 1: Illustration of Problem 5

R:

$$
\begin{aligned}
\tau_A &= r_{A\perp} F_A \\
&= (7.5\ m)(9.3\ N)\sin 45^o \\
&= 49.321\ N \times m \\
\tau_B &= r_{B\perp} F_B \\
&= -(4.4\ m)(8.8\ N)\sin 90^o \\
&= -38.720\ N \times m \\
\tau_C &= r_{C\perp} F_C \\
&= (5.4\ m)(11.0\ N)\sin 30^o \\
&= 29.700\ N \times m \\
\tau_{net} &= \tau_A + \tau_B + \tau_C \\
&= (49.321\ N \times m) + (-38.720\ N \times m) + (29.700\ N \times m) \\
&= (49.321\ N \times m) + (-38.720\ N \times m) + (29.700\ N \times m) \\
&= 40.301\ N \times m
\end{aligned} \tag{9}
$$

Problem (6)

During the launch from a board, a diver's angular speed about her center of mass changes from zero to 4.9 rad/s in 220 ms. Her rotational inertia about her center of mass is 9.2 $sl \times ft^2$. During the launch,

Question (a)

What is the magnitude of her average angular acceleration?

R:

$$\begin{aligned}\overline{\alpha} &= \frac{\Delta\omega}{\Delta t} \\ &= \frac{4.9\ rad/s}{0.22\ s} \\ &= 22.\overline{27}\ rad/s^2\end{aligned} \tag{10}$$

Question (b)

What is the magnitude of the average external torque on her from the board?

R:

$$\begin{aligned}\tau &= I\alpha \\ &= \left(9.2\ sl \times ft^2\right)\left(22.\overline{27}\ s^{-2}\right) \\ &= 204.\overline{90}\ lb \times ft\end{aligned} \tag{11}$$

Problem (7)

A 1.5 *sl* wheel, essentially a thin hoop with radius 2.4 ft, is rotating at 420 rev/min. It must be brought to a stop in 12 s.

Question (a)

How much work must be done to stop it?

R:

$$\begin{aligned}
I &= mr^2 \\
&= (1.5\ sl)(2.4\ ft)^2 \\
&= 8.64\ sl \times ft^2 \\
\omega &= 420\ rev/min \times \left(\frac{2\pi\ rad}{1\ rev}\right) \times \left(\frac{1\ min}{60\ s}\right) \\
&= 43.982\ rad/s \\
W &= K_f - K_i \\
&= (0) - \frac{1}{2} I\omega^2 \\
&= -\frac{1}{2}\left(8.64\ sl \times ft^2\right)\left(43.982\ rad/s\right)^2 \\
&= -\left(8.64\ sl \times ft^2\right)\left(1934.4425\ s^{-2}\right) \\
&= -16\ 713.5829\ lb \times ft \\
|W| &= 16\ 713.5829\ lb \times ft
\end{aligned} \tag{12}$$

Question (b)

What is the required average power?

R:

$$\begin{aligned}
|P| &= \frac{\Delta |W|}{\Delta t} \\
&= \frac{16\ 713.5829\ lb \times ft}{12\ s} \\
&= 1392.7986\ lb \times ft/s \\
&= 2.5324\ hp
\end{aligned} \tag{13}$$

Problem (8)

An automobile crankshaft transfers energy from the engine to the axle at the rate of 48 kW when rotating at a speed of 2700 rev/min. What torque does the crankshaft deliver?

R:

$$\begin{aligned}
\omega &= 2700\ rev/min \times \left(\frac{2\pi\ rad}{1\ rev}\right) \times \left(\frac{1\ min}{60\ s}\right) \\
&= 282.743\ rad/s \\
P &= \tau\omega \\
\tau &= \frac{P}{\omega} \\
\tau &= \frac{48000\ W}{282.743\ s^{-1}} \\
\tau &= 169.765\ N \times m
\end{aligned} \tag{14}$$