## Physics 23 Practice Problems Chapters 8, 9, and 10

## Chapter 8 Problems

1. Convert 90 radians to rotations.
2. A wheel completes 10 rotations in 23 seconds. What was its average angular velocity?
3. The angular velocity of a rotating wheel changes from $10 \mathrm{rad} / \mathrm{s}$ to $50 \mathrm{rad} / \mathrm{s}$ in three seconds. What was its angular displacement during this time?
4. In four seconds, a wheel rotates through 40 rad ; at the end of this time period, its angular velocity is $14 \mathrm{rad} / \mathrm{s}$. What was its initial angular velocity?
5. A vinyl record is spinning at a constant rate of 78 RPM (rotations per minute). How many rotations are completed in 50 seconds?
6. A rotating wheel's angular velocity changes from $20 \mathrm{rad} / \mathrm{s}$ to $60 \mathrm{rad} / \mathrm{s}$ in eight seconds. What was its angular acceleration?
7. The angular velocity of a rotating object is initially $12 \mathrm{rad} / \mathrm{s}$. Five seconds later its angular velocity is $32 \mathrm{rad} / \mathrm{s}$. After ten more seconds, what will be its angular velocity?
8. A grindstone, initially at rest, is given a constant angular acceleration so that it makes 20.0 rotations in the first 8.00 s . What is its angular acceleration?
9. The angular velocity of a rotating sphere is $4 \mathrm{rad} / \mathrm{s}$. It is angularly accelerating at the rate of $2 \mathrm{rad} / \mathrm{s}^{2}$. What will be its angular displacement over the next 10 seconds?
10. A wheel is rotating at $44 \mathrm{rad} / \mathrm{s}$ and decelerating at the rate of $-3 \mathrm{rad} / \mathrm{s}^{2}$. How many seconds will it take for the wheel to rotate through 200 more radians?
11. While accelerating from $12 \mathrm{rad} / \mathrm{s}$ to $46 \mathrm{rad} / \mathrm{s}$, a wheel rotates through 580 radians. What must have been the wheel's acceleration (in $\mathrm{rad} / \mathrm{s}^{2}$ )?
12. A fan rotating with an initial angular velocity of 1000 RPM is switched off. In 2.0 seconds, the angular velocity decreases to 200 RPM. Through how many rotations does the blade undergo during this time?
13. At a certain instant, a disk whose radius is 1.6 m is rotating at $5.0 \mathrm{rad} / \mathrm{s}$, and accelerating at $2.0 \mathrm{rad} / \mathrm{s}^{2}$. (a) What is the tangential velocity of a point on the edge of the disk? (b) What is the tangential acceleration?
14. The $200-\mathrm{N}$ beam in the figure is hinged to a wall; the other end is attached to a wire connected to the ceiling. What is the tension (in N ) in the wire?

15. 6000 N force is required to lift the front end of an automobile. A light, six-meter long pole is used as a lever, and a sturdy boulder is available as a fulcrum. If the greatest force a person can exert downward at one end of the lever is 800 N , how far from the front end of the automobile must the boulder be placed to lift the front end?
16. The weight of the pole in Problem 1 was declared to be "light," i.e., ignorably small. Assume now that the weight of the pole is 200 N. How far from the car could the fulcrum be placed to lift the car, assuming the person's maximum force of 800 N is applied?
17. As shown in the figure below, a 2.4-meter beam at rest is attached to a hinge at the side of a building. The beam is supported by a wire that makes an angle of 40 degrees with respect to the beam. The tension T in the wire is 900 N . What is the weight of the beam?


## Chapter 8 Problem Solutions

| 1. $90 / 2 \pi=14.32 \mathrm{rev}$ | 2. $\begin{aligned} \bar{\omega} & =\theta / \mathrm{t} \\ & =10(2 \pi) / 23 \\ & =2.73 \mathrm{rad} / \mathrm{s} \end{aligned}$ | $\text { 3. } \begin{aligned} \quad \theta=\bar{\omega} t \\ =1 / 2\left(\omega_{\mathrm{o}}+\omega\right) \mathrm{t} \\ =1 / 2(10+50) 3 \\ =90 \mathrm{rad} \end{aligned}$ |
| :---: | :---: | :---: |
| 4. $\begin{aligned} \bar{\omega} & =\theta / \mathrm{t} \\ & =40 / 4 \\ & =10 \mathrm{rad} / \mathrm{s} \\ \bar{\omega} & =1 / 2\left(\omega_{\mathrm{o}}+\omega\right) \\ 10 & =1 / 2\left(\omega_{\mathrm{o}}+14\right) \\ \omega_{\mathrm{o}} & =6 \mathrm{rad} / \mathrm{s} \end{aligned}$ | 5. Quicker: $78(50 / 60)=65$ Longer: $\begin{aligned} \bar{\omega}= & \theta / \mathrm{t} \\ = & 78 \mathrm{rot} / 60 \mathrm{~s} \\ & =1.3 \mathrm{rot} / \mathrm{s} \end{aligned}$ <br> The angular velocity is constant so the average angular velocity equals the initial angular velocity: $\begin{aligned} \omega_{\mathrm{o}} & =1.3 \mathrm{rot} / \mathrm{s} \\ \theta & =\omega_{\mathrm{o}} \mathrm{t}+1 / 2 \alpha \mathrm{t}^{2} \\ & =(1.3 \mathrm{rot} / \mathrm{s})(50 \mathrm{~s})+0 \\ & =65 \mathrm{rot} \end{aligned}$ <br> Note: $\alpha=0$ because angular velocity is constant. <br> 6. $\begin{aligned} \omega & =\omega_{o}+\alpha \mathrm{t} \\ 60 & =20+\alpha(8) \\ \alpha & =5 \mathrm{rad} / \mathrm{s}^{2} \end{aligned}$ | 7. $\begin{aligned} 32 & =12+\alpha(5) \\ \alpha & =4 \mathrm{rad} / \mathrm{s}^{2} \end{aligned}$ <br> Re-start clock and set the initial velocity to $32 \mathrm{rad} / \mathrm{s}$ : $\begin{aligned} \omega & =\omega_{\mathrm{o}}+\alpha \mathrm{t} \\ \omega & =32+4(10) \\ & =72 \mathrm{rad} / \mathrm{s} \end{aligned}$ |
| $\begin{aligned} 8 . \quad \theta & =\omega_{\mathrm{o}} \mathrm{t}+1 / 2 \alpha \mathrm{t}^{2} \\ 20(2 \pi) & =0+1 / 2 \alpha(8)^{2} \\ \alpha & =3.93 \mathrm{rad} / \mathrm{s}^{2} \end{aligned}$ | $\text { 9. } \begin{aligned} \quad & \theta=\omega_{\mathrm{o}} \mathrm{t}+1 / 2 \alpha \mathrm{t}^{2} \\ = & 40+1 / 2(2) 10^{2} \\ = & 140 \mathrm{rad} \end{aligned}$ | $\begin{aligned} 10 . & \theta=\omega_{0} t+1 / 2 \alpha t^{2} \\ 200 & =44 t+1 / 2(-3) t^{2} \\ t & =5.62 \mathrm{~s} \end{aligned}$ |
| $\text { 11. } \begin{aligned} \omega^{2} & =\omega_{0}^{2}+2 \alpha \theta \\ 46^{2} & =12^{2}+2 \alpha(580) \\ \alpha & =1.7 \mathrm{rad} / \mathrm{s}^{2} \end{aligned}$ | 12. $\begin{aligned} \bar{\omega} & =1 / 2\left(\omega_{0}+\omega\right) \\ & =1 / 2(1000+200) \\ & =600 \mathrm{rot} / \text { minute } \\ & =10 \mathrm{rot} / \mathrm{second} \\ \theta & =\bar{\omega} \mathrm{t} \\ & =(10 \mathrm{rot} / \mathrm{s})(2 \mathrm{~s}) \\ & =20 \text { rotations } \end{aligned}$ | 13. <br> (a) $\begin{aligned} \mathrm{v} & =\omega \mathrm{r} \\ & =5.0(1.6) \\ & =8.0 \mathrm{~m} / \mathrm{s} \end{aligned}$ <br> (b) $\begin{aligned} \mathrm{a} & =\alpha \mathrm{r} \\ & =2.0(1.6) \\ & =3.2 \mathrm{~m} / \mathrm{s}^{2} \end{aligned}$ |



The angular acceleration of the beam is zero, so the sum of the torques is zero
$(\mathrm{L} / 2)(200) \cos 60-\mathrm{LT} \cos 10=0$

$$
\mathrm{T}=49.24 \mathrm{~N}
$$

15. The lever will exert a $6000-\mathrm{N}$ force upward (not shown) on the automobile, so by Newton's Third Law, the car exerts a 6000 N downward force (shown in the figure at the right) on the lever.



| 17. |
| :--- | :--- |
| The beam is in equilibrium, so the sum of |
| the torques is zero: |
| $(1.2) \mathrm{w}-(2.4) 900 \sin 40=0$ <br> $\mathrm{w}=1157 \mathrm{~N}$ |

## Chapter 9 Problems

1. The total torque acting on an object whose rotational inertia is $20 \mathrm{~kg}-\mathrm{m}^{2}$ is $100 \mathrm{~m}-\mathrm{N}$. What is the object's angular acceleration?
2. A rope is around a pulley whose radius is 0.20 m and whose moment of inertia is $0.40 \mathrm{~kg}-\mathrm{m}^{2}$. The rope is pulled with a force of 28 N . What is the resulting angular acceleration of the pulley?
3. A $28 \mathrm{~m}-\mathrm{N}$ torque is acting on an object initially at rest and having a rotational inertia of $1.4 \mathrm{~kg}-\mathrm{m}^{2}$. After how many seconds will the object have rotated through 2560 radians?
4. A net torque of $30 \mathrm{~m}-\mathrm{N}$ acts on an object whose rotational inertia is $12 \mathrm{~kg}-\mathrm{m}^{2}$, initially rotating at $3.0 \mathrm{rad} / \mathrm{s}$. What will be its angular velocity after the object has experienced an angular displacement of 30 radians?
5. A bicycle wheel of radius 0.70 m is rotating at an angular speed of $6.3 \mathrm{rad} / \mathrm{s}$ as the bicycle rolls on a horizontal surface without slipping. What is the speed of the bicycle?

## Chapter 9 Problem Solutions

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1.
\alpha=\tau/I
    = 100/20
    = 5 rad}/\mp@subsup{\textrm{s}}{}{2
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| 3. | 4. |
| :---: | :---: |
| $\omega_{\mathrm{o}}=0$ | $\omega_{\mathrm{o}}=3.0 \mathrm{rad} / \mathrm{s}$ |
| $\tau=28 \mathrm{~m}-\mathrm{N}$ |  |
| $\mathrm{I}=1.4 \mathrm{~kg}-\mathrm{m}^{2}$ | $\begin{aligned} \alpha & =30 / 12 \\ & =2.5 \mathrm{rad} / \mathrm{s}^{2} \end{aligned}$ |
| $\alpha=28 / 1.4$ |  |
| $=20 \mathrm{rad} / \mathrm{s}^{2}$ | $\begin{aligned} & \omega^{2}=3.0^{2}+2(2.5)(30) \\ & \omega=12.61 \mathrm{rad} / \mathrm{s} \end{aligned}$ |
| $\begin{aligned} \theta & =\omega_{\mathrm{o}} \mathrm{t}+1 / 2 \alpha \mathrm{t}^{2} \\ 2560 & =0+1 / 2(20) \mathrm{t}^{2} \\ \mathrm{t} & =16 \mathrm{~s} \end{aligned}$ |  |

$$
\begin{aligned}
5 . \mathrm{v} & =\omega \mathrm{r} \\
& =(6.3)(0.70) \\
& =4.41 \mathrm{~m} / \mathrm{s}
\end{aligned}
$$

## Chapter 10 Problems

1. The frequency of oscillation of a spring-mass system is 20 Hz . What is the period of oscillation?
2. A spring is resting horizontally on a tabletop, with one end attached to a wall. A force is then applied to the other end, and when the spring has been stretched by 0.50 m the force acting on the spring is 200 N . What is the spring constant of the spring?
3. The spring constant of a spring lying on a table top is $100 \mathrm{~N} / \mathrm{m}$. The left end is attached to the wall, and a $5-\mathrm{kg}$ object is attached to the right end. The object is pulled to right by 10 cm and released at time $\mathrm{t}=0$.
(a) What is the amplitude of the resulting oscillatory motion, in centimeters?
(b) What is the angular frequency?
(c) What is the period?
(d) What is the frequency?
(e) What is this object's equation of motion?
(f) What will be the object's location at time $\mathrm{t}=0.25 \mathrm{~s}$ ?
(g) When will the object's location be when $\mathrm{x}=-4.0 \mathrm{~cm}$ for the first time?
4. The spring constant of a spring is $800 \mathrm{~N} / \mathrm{m}$, and the object attached to it has a mass of 2.0 kg . The amplitude of the object's motion is 0.80 m . What is the first time (in milli-seconds) at which the object's kinetic energy is one-third of the spring's potential energy?

## Chapter 10 Problem Solutions

MODE: Radian

| 1. $\begin{aligned} \mathrm{T} & =1 / \mathrm{f} \\ & =1 / 20 \\ & =0.05 \mathrm{~s} \end{aligned}$ |
| :---: |
| $\text { 2. } \begin{aligned} \mathrm{k} & =\mathrm{F} / \mathrm{x} \\ & =200 \mathrm{~N} / 0.5 \mathrm{~m} \\ & =400 \mathrm{~N} / \mathrm{m} \end{aligned}$ |
| 3. <br> (a) $\mathrm{A}=10 \mathrm{~cm}$ <br> (b) $\omega=(\mathrm{k} / \mathrm{m})^{1 / 2}$ $\begin{aligned} & =(100 / 5)^{1 / 2} \\ & =4.47 \mathrm{rad} / \mathrm{s} \end{aligned}$ |
| $\text { (c) } \begin{aligned} \omega & =2 \pi \mathrm{f} \\ 4.47 & =2 \pi / \mathrm{T} \\ \mathrm{~T} & =1.40 \mathrm{~s} \end{aligned}$ |
| $\text { (d) } \begin{aligned} \mathrm{f}= & 1 / \mathrm{T} \\ & =1 / 1.40 \\ & =0.71 \mathrm{~Hz} \end{aligned}$ |
| (e) $\mathrm{x}=10 \cos (4.47 \mathrm{t})$ <br> (f) $10 \cos [(4.47)(0.25)]=4.38 \mathrm{~cm}$ |
| $\begin{aligned} (\mathrm{g})-4.0 & =10 \cos (4.47 \mathrm{t}) \\ 4.47 \mathrm{t} & =\cos ^{-1}(-0.40) \\ \mathrm{t} & =0.44 \mathrm{~s} \end{aligned}$ |



