Periodic and Rotational Motion Problems

1. Lance pushes on his bike pedal at a constant velocity and with a force of 160 lbs. The pedal has a radius of 12 inches, the front sprocket has a radius of 6 inches, the back sprocket has a radius of 3 inches, and the rear wheel has a radius of 24 inches. The wheel exerts ____ lbs of force against the road in order to propel the bike forward.

2. Lance spins the pedal at with an angular velocity of 90 revolutions per minute. How fast should the bike go in miles per hour?

3. Assume that the Earth is perfectly round and has a radius of $6.375 \times 10^6$ m. Find the linear velocity (in mi/hr) of a tree that grows at the equator.

4. A geosynchronous satellite flies 300 km above the tree from question 2. How fast is its orbital speed (linear velocity) in miles per hour? (Hint: You must add the Earth’s radius to find the radius of the orbit)

5. A centrifuge with a radius of 0.15 m is capable of exerting 300 000 g’s ($300 \ 000 \times \ 9.8 \ m/s^2$) on the contents of the test tube. How fast is it spinning in revolutions per minute (RPMs).

6. If a test tube containing .5 grams of red blood cells was spun in this centrifuge, the tube would push against the cells with a force of _______ lbs.

7. On July 19, 1969, Apollo 11’s orbit around the moon was 111 km above the surface. The radius of the moon is 1785 km and the mass of the moon is $7.3 \times 10^{22}$ kg. What was the velocity of Apollo 11 in miles per hour?

8. How many hours did Apollo 11 take to orbit the moon once? (use info from #7)

9. If the gravity of the Moon causes objects near its surface to accelerate at 1/6 the rate that they would fall near Earth, how many times would we expect a 2 m long pendulum to oscillate (vibrate to and fro) during a 1 minute time frame?

10. Emadi curls 50 lbs with his left arm. His bicep inserts into the radius 2 inches from the elbow and 16 inches from the dumbbell (the weight, not Emadi). How many pounds of force must his bicep exert?

11. The 16 inch diameter wheels on Chris’s POS turn at a rate of 1000 RPMs. Go Chris Go! How fast is his car going in miles per hour?

12. A 200 lb window washer stands on a weightless scaffold. He stands 10 feet from rope A and 4 feet from rope B. What is the tension on rope A?

13. A 200 lb man walks from the Equator ($0^\circ$) to $45^\circ$ North Latitude. His Eastward linear velocity will increase, decrease, or stay the same? (Note that his mass and movement has no appreciable effect on the spin rate of Earth because the Earth is so massive.)

14. His apparent weight will increase, decrease, or stay the same? (use info from #13)
1. \( F_A = 160 \text{ lb}, \quad r_A = 12 \text{ in}, \quad r_B = 6 \text{ in} \)

\[
F_A \cdot r_A = F_B \cdot r_B
\]

160 \cdot 12 = F_B \cdot 6

F_B = 320 \text{ lb}

Along chain:
\[
F_B = F_c
\]

320 \text{ lb} = 320 \text{ lb}

\[
F_c \cdot r_c = F_D \cdot r_D
\]

320 \cdot 3 = F_D \cdot 24

F_D = 40 \text{ lb}

\[
M_A = \frac{F_{out}}{F_m} = \frac{40}{160} = 0.25
\]

2. \( \omega_A = 90 \text{ RPM}, \quad \frac{5.655}{\text{rad/min}} \)

\[
\omega_A = \omega_B \quad \frac{5.655}{\text{rad/min}} = \frac{V_B}{r_B}
\]

1 \text{ rev} = 3393 \text{ in/min}

90 \text{ rev/min} / 1 \text{ rev} = 5.655 \text{ rad/min}

\[
V_B = 3393 \text{ in/min} \quad V_c = V_D
\]

\[
\frac{3393 \text{ in/min}}{3 \text{ in}} = \frac{V_D}{24 \text{ in}}
\]

V_D = 27144 \text{ in/min}

\[
\frac{27144 \text{ in/min}}{12 \text{ in}} / \frac{5280 \text{ ft}}{1 \text{ in}} = 25.7 \text{ m/min}
\]
3

\[ T = 24\ h \]

\[ r = 6.375 \times 10^6\ m = 3.984\ mi \]

\[ V = \frac{2\pi\ r}{T} \]

\[ V = \frac{2\pi\cdot 3.984\ mi}{24\ h} = 1043\ mi/h \]

4

\[ T = 24\ h \]

\[ R_{\text{Total}} = R_{\text{Earth}} + h_{\text{sat}} \]

\[ = 6.375 \times 10^6\ m + 300\ km \]

\[ = 4171.5\ mi + 187.5\ mi \]

\[ \frac{300\ km}{1\ mi} = 187.5\ mi \]

\[ V = \frac{2\pi\ r}{T} \]

\[ V = \frac{2\pi\cdot 4171.5\ mi}{24\ h} = 1092\ mi/h \]
5) \[ V = \omega r \]

\[ W = ? \text{ RPM} \]

\[ a_c = \frac{V^2}{r} \rightarrow V = \sqrt{a_c r} \]

\[ V = \frac{2940000 \text{ m/s}^2 \cdot 0.15 \text{ m}}{2} = 664 \text{ m/s} \]

\[ W = \frac{664 \text{ m/s}}{0.15 \text{ m}} = 4426 \text{ rad/s} \]

\[ = \frac{4426 \text{ rad/rev}}{60 \text{ s}} = \frac{417 \text{ rad/rev}}{1 \text{ min}} \]

\[ F_c = m a_c \]

\[ F_c = \left( 6000 \text{ kg} \right) \left( 2940000 \text{ m/s}^2 \right) \]

\[ F_c = 1470 \text{ N} \]

\[ = 330 \text{ lb} \]

6) \[ F_c = m a_c \]

\[ F_c = \left( 6000 \text{ kg} \right) \left( 2940000 \text{ m/s}^2 \right) \]

\[ F_c = 1470 \text{ N} \]

\[ = 330 \text{ lb} \]
\[ V = \frac{2 \pi r}{T} \Rightarrow T = \frac{2 \pi r}{V} \]

\[
T = \frac{2 \pi \cdot 1,896,000 \text{ m}}{1,602 \text{ m/s}}
T = 7,434 \text{ s}
\]

\[
\frac{7,434 \text{ s}}{1 \text{ h}} \times \frac{1 \text{ h}}{3,600 \text{ s}} = 2.06 \text{ h}
\]
\[ \Sigma F = F_A + F_B \]
\[ F_A = -50 \text{ Lb} \]
\[ F_B = \text{?} \]
\[ r_A = 16 \text{ in} \]
\[ r_B = 2 \text{ in} \]

\[ \theta = \frac{r_A}{r_B} = \frac{16}{2} = 8 \text{ in} \]

\[ W = 1000 \text{ RPM} \rightarrow \frac{\text{rev}}{\text{h}} \]

\[ V = \omega r = \frac{\pi}{60} \text{ m/s} \]

\[ V = \omega \cdot r = \frac{\pi}{60} \cdot 3015.928 \text{ in} = 376.991 \text{ rad/h} \]

\[ \frac{1000 \text{ rev}}{60 \text{ min}} = \frac{\pi \text{ rad}}{1 \text{ rev}} = \frac{376.991}{\text{h}} \]

\[ \frac{3.015928 \text{ in}}{1 \text{ hr}} = \frac{1 \text{ mi}}{12 \text{ in}} = \frac{47.6}{\text{mi/h}} \]
\[ \Sigma \Gamma = \Gamma_A + \Gamma_B \]
\[ \theta = (F_A \cdot r_A) + (F_B \cdot r_B) \]
\[ \theta = (F_A \cdot 14) + (200 \cdot 4) \]
\[ F_A = 57.1 \text{ lb} \]