Assignment 8, PHYS 2302

assigned Thursday, December 1; due Thursday, December 8*

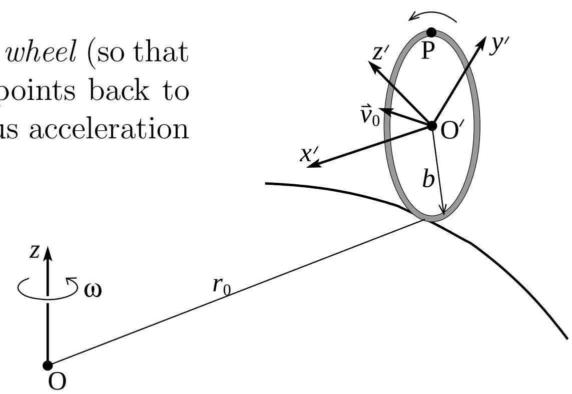
*accepted without late penalty until day of final examination.

Problem 1 (FC 5.3) A plumb bob hangs from the ceiling of a boxcar in a train accelerating at $g/10$. If the plumb line is held steady (not allowed to oscillate like a pendulum), find the tension in the cord.

Problem 2 (FC 5.22) As in Example 4.3 from class (Example 5.2.2 in the text), a bicycle wheel of radius b travels with constant speed, v_0, around a track of radius r_0.

Using the coordinate system (x', y', z') *fixed to the wheel* (so that $\hat{j}'$ and $\hat{k}'$ rotate with the wheel while $\hat{\imath}'$ always points back to $\hat{k}$ fixed to inertial frame O), find the instantaneous acceleration at point P, as shown in the figure.

This is different from what we did in class where $\hat{k}'$ remained vertical. If nothing else, this problem should convince you of the value in choosing a "sensible" coordinate system!



Hints:

1. As defined, all points along the rim are *at rest* relative to O′ $\Rightarrow$ $\vec{v}' = 0$ and $\vec{a}' = 0$.

2. If $\hat{j}' \propto -\vec{v}_0$ and $\hat{k}'$ points vertically at $t = 0$, then at time t, $\hat{k}$ (unit vector in vertical direction) is given by:
$$\hat{k} = \sin\Omega t\,\hat{j}' + \cos\Omega t\,\hat{k}',$$
where $\vec{\Omega} = (v_0/b)\,\hat{\imath}'$ is the angular velocity of the wheel about its own axis. Thus, when P reaches the highest point, its position vector relative to O′ is given by:
$$\vec{r}' = b\hat{k} = b\left(\sin\frac{v_0 t}{b}\,\hat{j}' + \cos\frac{v_0 t}{b}\,\hat{k}'\right).$$

3. The only other thing to watch for is $\vec{\omega}$. Here, the angular velocity of O′ relative to O actually has *two* terms: one an "orbital" term as O′ goes around the track "orbiting" O, the other a "spin" term as O′ spins with the wheel about the $\hat{\imath}'$ axis.

Problem 3 (FC 5.8) A bug with mass m crawls with constant speed in a circular path of radius b about the centre of a turntable rotating with constant angular speed ω. If the coefficient of static friction between the bug and turntable surface is μ_s, how fast (relative to the turntable) can the bug crawl without slipping if the bug moves:

a) in the direction of rotation; and

b) opposite to the direction of rotation?

Hint: Start with equation 5.3.2 (eds. 6 and 7) and, in the "hunting and gathering" step, be sure to include all *three* real forces.

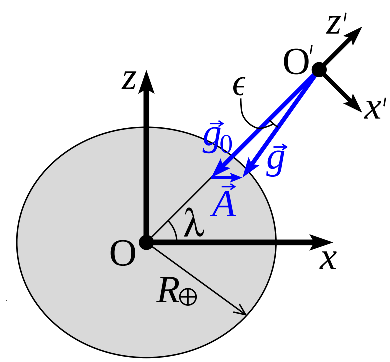
Problem 4 (FC 5.13) A pebble drops from the observation deck of the CN Tower ($h = 433$ m) at latitude $\lambda = 43.6°$ N. Ignoring air resistance, find the deflection caused by the Coriolis force by the time the pebble reaches the ground.

Problem 5 In class, we showed that the effective acceleration of gravity, $\vec{g}$, experienced on earth doesn't actually point to the earth's centre because it is the vector sum of the "true" acceleration of gravity, $\vec{g}_0$, that *does* point to the earth's centre and the inertial acceleration $\vec{A} = (R_\oplus \omega^2 \cos\lambda)\hat{\imath}$, as shown in the figure. Here, $R_\oplus$ is the radius of the earth, ω is the angular speed of the earth about its axis, and λ is the latitude. Thus, a plumb bob hanging "vertically" deviates from "true vertical" by a small deflection angle, ϵ.

a) Show that the deflection angle is given by,

$$\tan\epsilon = \frac{\frac{1}{2}R_\oplus\omega^2\sin 2\lambda}{g_0 - R_\oplus\omega^2\cos^2\lambda},$$

where $g_0 \sim 9.823\,\mathrm{m\,s^{-2}}$ is the magnitude of the "true" acceleration of gravity.



b) Show that ϵ is a maximum for $\lambda \approx 45°$, and find that maximum value. What is the approximation you had to make to arrive at this value for λ?