Warm Up Exercises: Drag, Circular Motion

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1 Memory Bank

- Force of drag, in air or other gas: $F_D = \frac{1}{2}C\rho A v^2$.
- In the above formula, C is an empirical constant, ρ is the density of the air or gas, A is the area of the object, and v is the object's velocity.
- Let $\Delta\theta$ be the *angular displacement*, $\Delta\theta = \theta_f - \theta_i$. Let the time duration be $\Delta t = t_f - t_i$. Let the angular velocity be $\omega = \Delta\theta/\Delta t$. If $t_i = 0$ seconds and $\theta_i = 0$ degrees, then we can use *omega* to write $\theta = \omega t$ (just like $x = vt$. If an object is rotating with angular velocity ω on a circle of radius r, then the position versus time is:

$$\vec{r}(t) = r\cos(\omega t)\hat{i} + r\sin(\omega t)\hat{j} \tag{1}$$

- $a_{\mathrm{C}} = r\omega^2$ ... Centripetal force.
- $v = r\omega$ ... Radial velocity.

2 Drag Forces, Circular Motion

1. Suppose a cyclist with $A = 0.5$ m^2, $C = 1.0$, and total mass $m = 70$ kg is pedalling at 20 m/s. Assume the density of air is $\rho = 1.2$ kg m^{-3}. (a) What is the drag force on the system? (b) What is the drag force if the speed drops to 10 m/s? (c) Suppose the speed is now 20 m/s again, but the cyclist ducks down to lower the area to $A = 0.25$ m^2. What is the new drag force?

2. Prove Eq. 1 using trigonometry. *It is helpful to draw a graph and recall that $\theta = \omega t$.*

3. Suppose a system is rotating about the origin with a radius $r = 1.0$ m, and angular speed $\omega = 2\pi/10$ radians per second. (a) Where is the system at $t = 0$ seconds? (b) Where is the system at $t = 5$ seconds? (c) What are the radial velocity and centripetal acceleration?

4. Find the time t that makes the position $\vec{r} = -1.0\hat{j}$ m.