Name: ---------- **Quiz 13** **Time: 20 minutes**

ME:5160 **Fall 2023**

The exam is closed book and closed notes.

Two baseballs of diameter 7.35 cm are connected to a rod 56 cm long, as shown in the Figure below. The system is in sea-level standard air (ρ=1.225 kg/m^3, μ=1.78E-5 kg/m-s) and is spinning at 400 r/min. (a) What is the Reynolds number for flow around the baseballs, and is the flow laminar or turbulent? (b) What power, in Watts, is required to keep the system spinning, if the drag of the rod is negligible? (Hint: Velocity V=rΩ; Power P=FV)

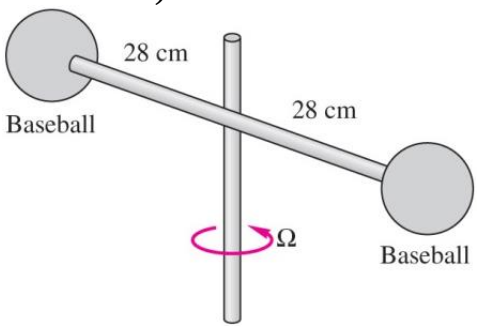
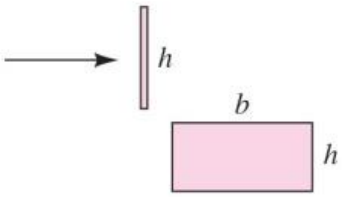
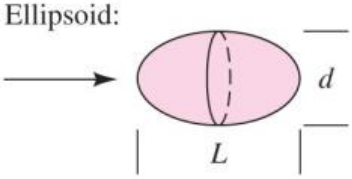


Table: Drag of three-dimensional bodies: $F_D = C_D\left(\frac{1}{2}\rho V^2 A\right)$

Body	Ratio	C_D based on frontal area	
Rectangular plate: 	*b/h* 1	1.18	
	5	1.2	
	10	1.3	
	20	1.5	
	∞	2.0	
		Laminar	**Turbulent**
Ellipsoid: 	*L/d* 0.75	0.5	0.2
	1	0.47	0.2
	2	0.27	0.13
	4	0.25	0.1
	8	0.2	0.08

Solution:

(a)

$$\Omega = 400\ (rpm) = 400 \times \frac{2\pi}{60}\left(\frac{rad}{s}\right) = 41.9\ (\frac{rad}{s})$$

$$V_b = \Omega r_b$$

$$r_b = 0.28 + \frac{0.0735}{2} = 0.31675 \quad \text{(+1)}$$

$$V_b = (41.9)(0.31675) \approx 13.3\ m/s \quad \text{(+2)}$$

$$Re = \frac{\rho V D}{\mu} = \frac{(1.225)(13.3)(0.0735)}{(1.78E{-}5)} \approx \mathbf{67,275} \quad \boldsymbol{Laminar} \quad \text{(+2)}$$

(b)

From the Table (L/d=1 and laminar): $C_D \approx 0.47$ (+1)

Then the drag force on each baseball is approximately:

$$F_b = C_D \frac{\rho}{2} V_b^2 \left(\frac{\pi}{4} D^2\right) = (0.47)\left(\frac{1.225}{2}\right)(13.3)^2 \frac{\pi}{4}(0.0735)^2 \approx 0.215\ N \quad \text{(+2)}$$

$$P_b = F_b V_b \times 2 = (0.215)(13.3) \times 2 = \mathbf{5.72\ W} \quad \text{(+2)}$$