Calculations

- RPM
- exit speed
- generate energy
- wheel size
- energy lost when in contact with wheel

Tennis Ball (US Open Wilson)

$m = 58g = 0.058kg$

Exit Speed

$$R = \frac{V^2 \sin(2\theta)}{g}$$

$$Rg = V^2 \sin(2\theta)$$

$$\frac{Rg}{\sin(2\theta)} = V^2$$

$$V = \sqrt{\frac{Rg}{\sin(2\theta)}}$$

$$V = \sqrt{\frac{6.096 \cdot 9.8}{\sin(90)}}$$

$\theta = 45°$

$g = 9.8 m/s^2$

$R = 20ft = 6.096m$

$V = 7.73 m/s$

RPM

wheel diameter: 4 in

exit speed: 7.73 m/s

$D = 4in = 0.1016m$

$$RPM = \frac{Revs}{min}$$

$$\text{wheel circumference} = \pi D = \pi(0.1016) = 0.3192\,m \uparrow 1\,rev$$

$$\frac{\text{speed (m/s)}}{\text{rev (m)}} = \frac{V}{\pi D} = \frac{7.73\,m/s}{1\,rev} = \frac{7.73\,m/s}{0.3192\,m} = 24.2168\ revs/s$$

$$RPM = \frac{24.2168\,revs}{1\,s} \times \frac{60s}{1min} = 1453.01\ RPM \text{ for each wheel}$$

Energy

$$E = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.058 \times 7.73^2 = 1.733J$$ at minimum ball exit energy

Torque

$$E = F \cdot d$$

d: distance which wheels contact/accelerate the tennis ball

$d \approx 2\,in = 0.0508\,m$

$1.733J = F \cdot 0.0508$

$F_{total} \approx 34.11N$

2 wheels so F equally divided among both wheels

$$F_{wheel} = \frac{F_{total}}{2} = \frac{34.11}{2} = 17.055N$$

r: radius of wheel

$$r = \frac{4in}{2} = 2in = 0.0508m$$

$\tau = F \cdot r$

$\tau = 17.055 \cdot 0.0508$

$\tau = 0.8664\ Nm$ for each wheel

Power

$P = \tau \cdot w$ (τ: torque, w: angular speed)

$\tau = 0.8664\ Nm$ for each wheel

$$w = \frac{RPM \cdot 2\pi}{60s} = \frac{1453.01 \cdot 2\pi}{60} = 152.16\ rad/s$$

$P = 0.8664 \cdot 152.16 = 131.83\,W$