INNOPOLIS UNIVERSITY

Physics Homework 1

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1 Problem

In some movie cars were dropped from the sky. What would be the terminal velocities of each car, if they are performing a free-fall headfirst without tumbling in the air?

Given:

- $\rho = 1.007 \frac{\text{kg}}{\text{m}^3}$
- $g = 9.81 \frac{\text{m}}{\text{s}^2}$

Find:

- $v_{\text{terminal of each car}}$

Solution

Formula Deriving

$$\Sigma F = m \cdot a \tag{1.1}$$

The cars are going to reach their terminal velocity after the acceleration become 0, meaning that gravitational force and drag force are balancing each other. Thus:

$$F_g = F_d$$

Formula for drag force:

$$F_d = 0.5 \cdot C_d \cdot \rho \cdot v^2 \cdot A \tag{1.2}$$

Connecting 1.1 and 1.2:

$$m \cdot g = 0.5 \cdot C_d \cdot \rho \cdot v^2 \cdot A$$

Solving for v:

$$v = \sqrt{\frac{2 \cdot m \cdot g}{C_d \cdot \rho \cdot A}} \tag{1.3}$$

Substitute

$$v_{\text{terminal of Jeep}} = \sqrt{\frac{2 \cdot 2000\,kg \cdot 9.8\,\frac{\text{kg}}{s^2}}{0.5 \cdot 1.007 \frac{kg}{m^3} \cdot 2.58\,m^2}} \approx \boxed{173.3 \frac{m}{s}}$$

$$v_{\text{terminal of Dodge}} = \sqrt{\frac{2 \cdot 2450\,kg \cdot 9.8\,\frac{\text{kg}}{s^2}}{0.38 \cdot 1.007 \frac{kg}{m^3} \cdot 2.41\,m^2}} \approx \boxed{228.2 \frac{m}{s}}$$

$$v_{\text{terminal of Subaru}} = \sqrt{\frac{2 \cdot 1550\, kg \cdot 9.8\, \frac{\text{kg}}{s^2}}{0.33 \cdot 1.007 \frac{kg}{m^3} \cdot 2.225\, m^2}} \approx \boxed{202.7 \frac{m}{s}}$$

ANSWER

- $173.3 \frac{m}{s}$
- $228.2 \frac{m}{s}$
- $202.7 \frac{m}{s}$

2 Problem

Object is rotating. Subjects to gravitational force.

Given:

- $m = 0.25kg$
- $R = 0.7m$
- $T_{max} = 30N$
- $g = 9.8m/s^2$

Questions:

- Find the position of the mass on the circular trajectory (exactly) where the string has maximum tension at a given constant speed of the mass
- What is the maximum speed (m/s, round to 1 decimal place), when the string does not break for any position of the object on the whole circle trajectory

Solution

Maximum tension

Tension in the string appears because of the 2 forces: F_{gravit} and F_{centr}
The forces are constant. The maximum tension is going to appear at the **lowest point** of the circle. *Because the forces will point at the same direction.*

Maximum speed

$$T = T_{gravit} + T_{centr}$$

$$T = \frac{mv^2}{R} + mg$$

Now set the tension to the maximum allowed value. Solve for v:

$$v_{max} = \sqrt{\frac{R(T_{max} - mg)}{m}}$$

$$v_{max} = \sqrt{\frac{0.7m(30N - 0.25kg * 9.8m/s^2)}{0.25kg}}$$

$$v_{max} = \sqrt{\frac{0.7m(30N - 0.25kg * 9.8m/s^2)}{0.25kg}}$$

$$v_{max} \approx \boxed{8.78m/s}$$

ANSWER:

- Lowest point
- $8.78 m/s$

3 Problem

4 Problem