Key Concepts

Chapter 2

Newton's laws

Free-body diagram

Drag force

Power

Work-kinetic energy theorem

$F = ma$ (N: kg · m/s²)

$P = \frac{\Delta E}{t}$ (W: J/s)

$W = \Delta E$ (J)

Takeaways

This question is solved like all other force/acceleration problems: (1) draw a free-body diagram, (2) add the forces in each direction, and (3) solve. The tricky part of this question is in the units because the power of the motor is given. Use dimensional analysis to guide you.

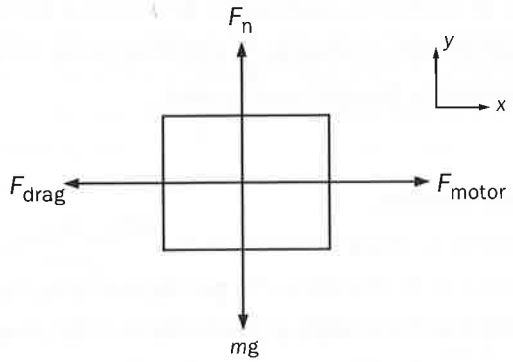
Things to Watch Out For

Terminal velocity problems will always involve a drag force that depends on velocity.

Terminal Velocity

A 5,000 N golf cart experiences a drag force equal to $65v$ kg/s, where v is the speed of the golf cart. If the golf cart has an electric motor that has a maximum power output of 76 kW, what is the golf cart's maximum speed on a level fairway?

1) Draw a free-body diagram.



There are two horizontal forces forces acting on the golf cart: the force of the motor (labeled F_{motor}) and the drag force (labeled F_{drag}).

2) Add the forces in the *x* direction.

$\Sigma F_x = ma_x = F_{motor} - F_{drag}$

Add the forces in the x direction. Because there is no friction, it will not be necessary to solve for the normal force, so we can disregard the y direction. Set the sum of the forces equal to ma. This is Newton's second law.

3) Set the acceleration equal to zero.

$a_x = 0 \rightarrow F_{motor} - F_{drag} = 0$

$F_{motor} = F_{drag}$

The maximum velocity of the cart will occur when the acceleration of the cart is zero—that is, when the cart motor can no longer exert enough force to accelerate the cart. This means that the force of the motor equals the drag force.

4) Find the force of the motor from the power.

Power is change in energy per time. Work is equal to the change in energy. Work is also equal to the force times distance. Use these relations and solve for the force of the motor.

$$P = \frac{\Delta E}{t}$$

$$P_{motor} = \frac{\Delta E}{t}$$

$$W = \Delta E \rightarrow P = \frac{w}{t} = \frac{F_{motor} d}{t}$$

$$F_{motor} = \frac{P_{motor} t}{d}$$

Distance divided by time is velocity. Use this to get the force in terms of the power and velocity.

$$\frac{d}{t} = v \rightarrow F_{motor} = \frac{P_{motor}}{v}$$

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5) Set the forces equal and solve.

Set the forces equal, as in step 3, and plug in the force expressions from the question and from step 4. Solve for the velocity.

$$F_{motor} = F_{drag}$$

$$\frac{P_{motor}}{v} = 65\, v$$

$$v^2 = \frac{P_{motor}}{65} = 1{,}169.2$$

$$v = 34.2 \text{ m/s}$$

Similar Questions

1) If $F_{drag} = bv^2$ for a ball of mass 3 kg, and the terminal velocity of the ball is 30 m/s, what is b?
2) If a block with a mass of 2 kg slides down a frictionless inclined plane at 30° to the horizontal, what is the terminal velocity of the block if the force of air resistance is given by $F_{drag} = 12v$?
3) In general, $F_{drag} = bv^2$. For ball 1, $b = 1.26$. For ball 2, $b = 2.1$. The balls both have a mass of 2 kg. What is the ratio of the terminal velocities for ball 1 and ball 2?