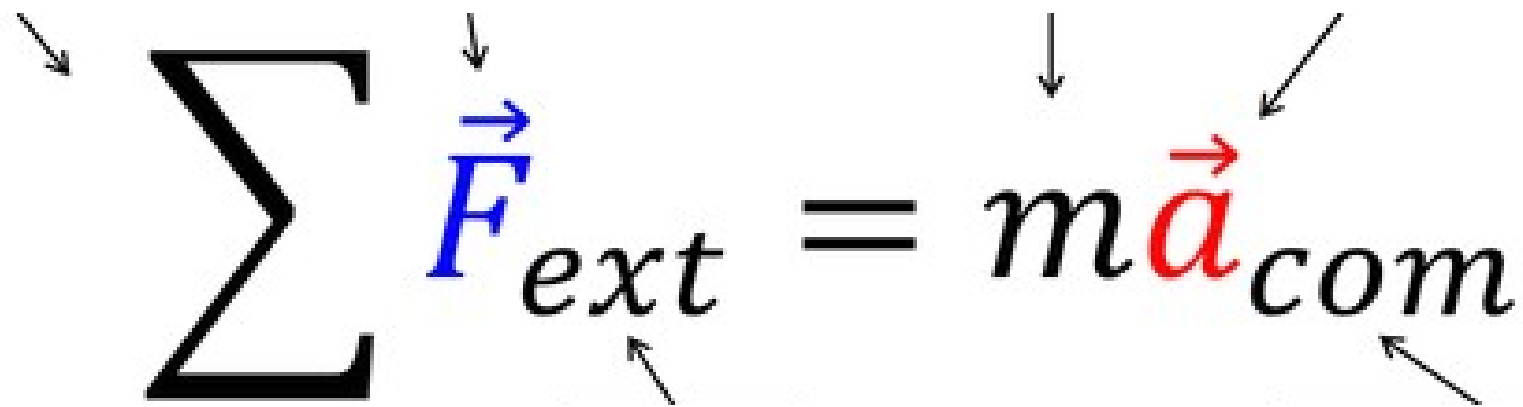


PH201 Recitation 5

Forces Part 1: 2nd Law Application

Warm-Up 1: 1 minute

- Label each of the following quantities
- Say the equation in words



The image shows the equation $\sum \vec{F}_{ext} = m \vec{a}_{com}$. The Greek letter sigma (Σ) is black. The vector \vec{F} is blue with a right-pointing arrow above it, and the word "ext" is black. The equals sign is black. The mass m is black. The vector \vec{a} is red with a right-pointing arrow above it, and the word "com" is black. There are five small black arrows pointing to the sigma, the blue \vec{F} , the m , the red \vec{a} , and the "com" term.

$$\Sigma \vec{F}_{ext} = m \vec{a}_{com}$$

To find the infographics on BoxSand go to Tips & Tricks => Mathematical Representation

Warm-Up 1: Solution

Newton's Second Law (N2L)

The diagram shows the equation $\sum \vec{F}_{ext} = m \vec{a}_{com}$ with several labels and arrows pointing to specific parts of the equation:

- A box labeled "Summation or addition" has an arrow pointing to the summation symbol Σ .
- A box labeled "Force" has an arrow pointing to the vector \vec{F} .
- A box labeled "external" has an arrow pointing to the subscript "ext".
- A box labeled "Mass" has an arrow pointing to the scalar m .
- A box labeled "Acceleration" has an arrow pointing to the vector \vec{a} .
- A box labeled "center of mass" has an arrow pointing to the subscript "com".

In words: The **sum** of all the **forces external** to the system, acting on the system, is equal to the **mass** of the system multiplied by the **acceleration of the center of mass** of the system

Discussion Question 1: 3 minutes

- A constant force is applied to object A and causes it to accelerate at 5 m/s^2 . The same force is applied to object B and causes it to accelerate at 3 m/s^2 . Applied to object C it accelerates at 8 m/s^2 .
- Rank the objects from least mass to greatest mass.

Discussion Question 2: 3 minutes

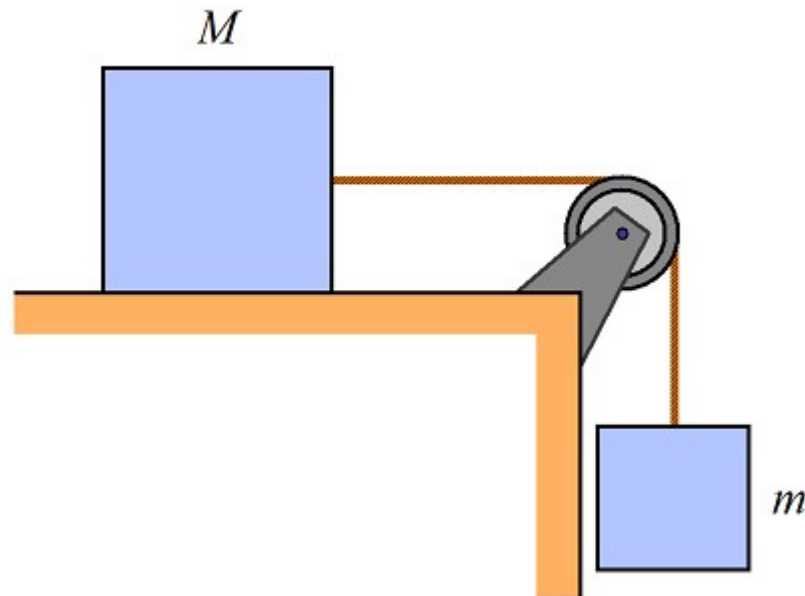
- An object experiencing a constant force accelerates at 10 m/s^2 . What will the acceleration of this object be if
 - A. The force is doubled? Explain
 - B. The mass is doubled?
 - C. The force and mass is doubled?
- If an object is at rest, are there any forces acting on it?

Discussion Question 3: 3 minutes

- A semi is going with velocity 10m/s hits a car (going with velocity 30m/s) head on. How does the force the car applies to the semi relate to the force the semi applies to the car?
 - A. Bigger than
 - B. Less than
 - C. Same
 - D. Not enough info

Discussion Question 4: 3 minutes

- In the figure, block m is falling and dragging block M across a frictionless table. Draw a free body diagram for both m and M .



Problem of the Day

- You go to the wormhole one day to work on some challenge homework when you notice the sign above the door is a bit off. The sign is hanging just fine, you just notice that the 2 ropes holding the sign are no longer centered. Instead, you notice that the sign is still its normal 0.5m below the ceiling, but the ropes are no longer centered on the ceiling. There are 2 ropes that connect to the either end of the sign. The left rope connects to the ceiling 2m to the left of the left end of the sign, and the right rope connects to the ceiling 3m to the right of the right end of the sign. If the sign has a mass of 8kg, what is the tension in each rope? Use relative quantities to check your answer.

Problem Orientation: 8 min

1. Read and Visualize: 2 min
2. Discuss with your group: 1 min
3. Individually draw your FBD: 2 min
4. Compare with your group and come to consensus: 1 min
5. List knowns and unknowns: 1 min
6. What's being asked and what physics is needed to solve the problem: 1 min

Problem of the Day

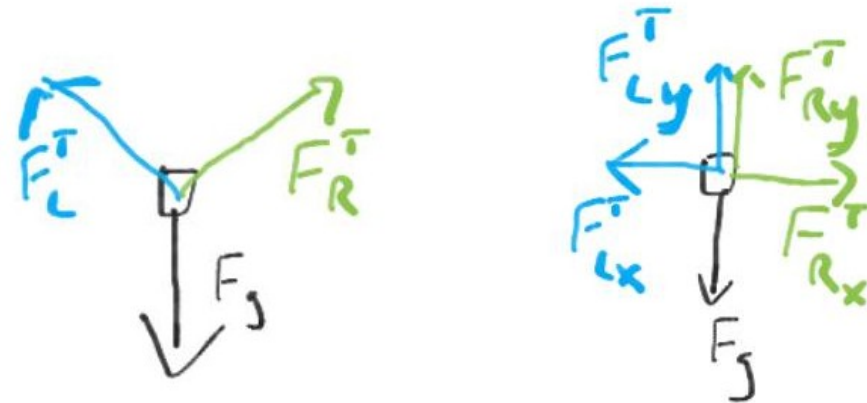
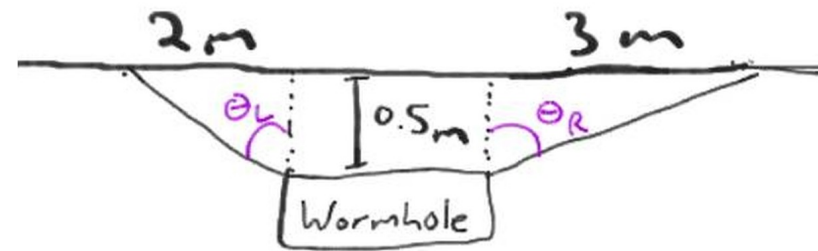
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Problem Orientation: 8 min

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Problem Orientation: 8 min



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K

Problem Orientation: 8 min

$$F_g = mg$$

$$m = 8 \text{ kg}$$

$$g = 9.8 \text{ m/s}^2$$

$$\Delta x_R = 3 \text{ m}$$

$$\Delta x_L = 2 \text{ m}$$

$$\Delta y_R = \Delta y_L = 0.5 \text{ m}$$

$$\tan \theta_L = \frac{2 \text{ m}}{0.5 \text{ m}}$$

$$\theta_L = \tan^{-1}(4) = 76.0^\circ$$

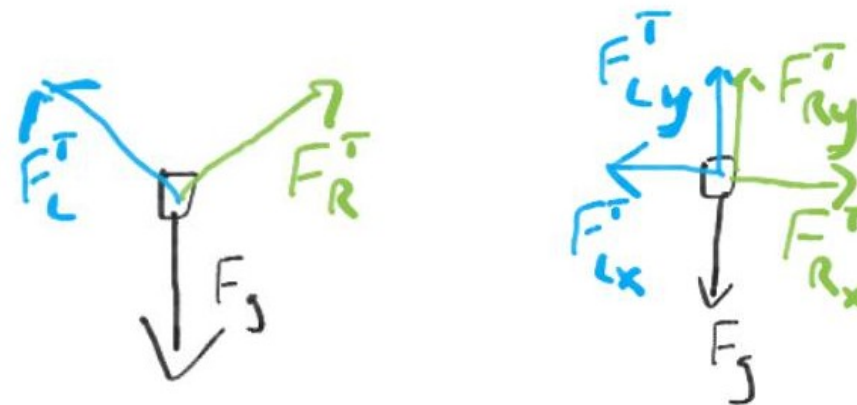
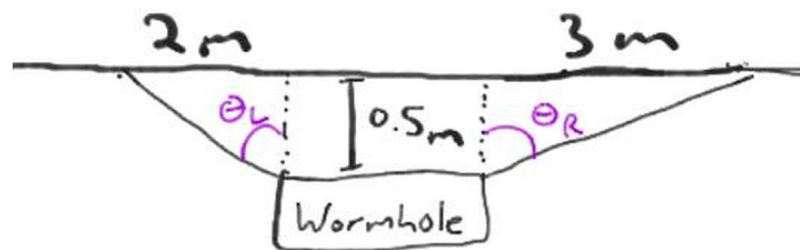
$$\tan \theta_R = \frac{3 \text{ m}}{0.5 \text{ m}}$$

$$\theta_R = \tan^{-1}(6) = 80.5^\circ$$

UK

$$F_R^T ?$$

$$F_L^T ?$$



Problem of the Day

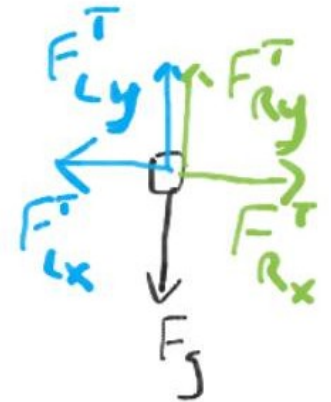
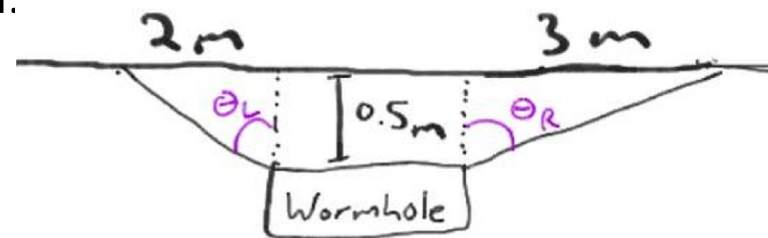
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Solve the problem: 8 min

Problem of the Day

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Solve the problem: 8 min



K

$$\begin{aligned}
 F_g &= mg & \Delta x_R &= 3\text{ m} \\
 m &= 8\text{ kg} & \Delta x_L &= 2\text{ m} \\
 g &= 9.8\text{ m/s}^2 & \Delta y_R &= \Delta y_L = 0.5\text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \tan \theta_L &= \frac{2\text{ m}}{0.5\text{ m}} & \tan \theta_R &= \frac{3\text{ m}}{0.5\text{ m}} \\
 \theta_L &= \tan^{-1}(4) & \theta_R &= \tan^{-1}(6) \\
 &= 76.0^\circ & &= 80.5^\circ
 \end{aligned}$$

UK

$$F_R^T ?$$

$$F_L^T ?$$

Problem of the Day

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Solve the problem: 8 min

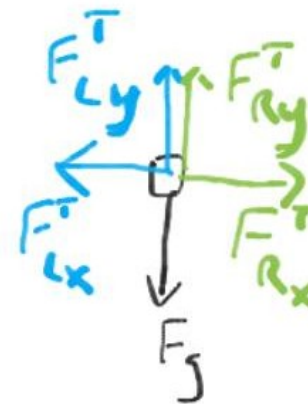
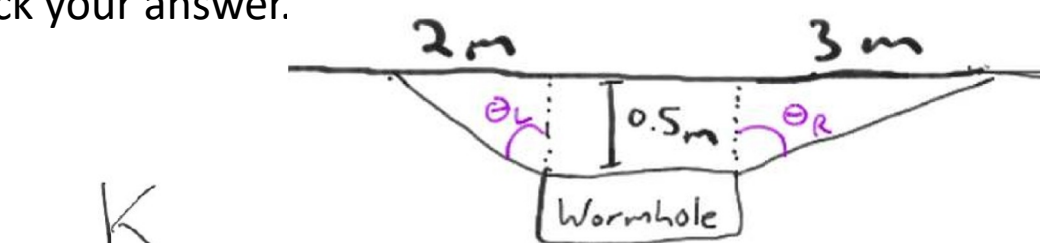
$$\Sigma F_x = m a_x$$

$$F_{Lx}^T + F_{Rx}^T = 0$$

$$F_{Lx}^T = -F_{Rx}^T$$

$$\Sigma F_y = m a_y$$

$$F_{Ly}^T + F_{Ry}^T + F_g = 0$$



K

$$F_g = mg \quad \Delta x_R = 3m$$

$$m = 8 \text{ kg} \quad \Delta x_L = 2m$$

$$g = 9.8 \text{ m/s}^2 \quad \Delta y_R = \Delta y_L = 0.5m$$

UK

$$\tan \theta_L = \frac{2m}{0.5m} \quad \tan \theta_R = \frac{3m}{0.5m}$$

$$\theta_L = \tan^{-1}(4) \quad \theta_R = \tan^{-1}(6)$$

$$= 76.0^\circ \quad = 80.5^\circ$$

F_R^T ?
 F_L^T ?

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Solve the problem: 8 min

$$\Sigma F_x = 0$$

$$F_{Lx}^T + F_{Rx}^T = 0$$

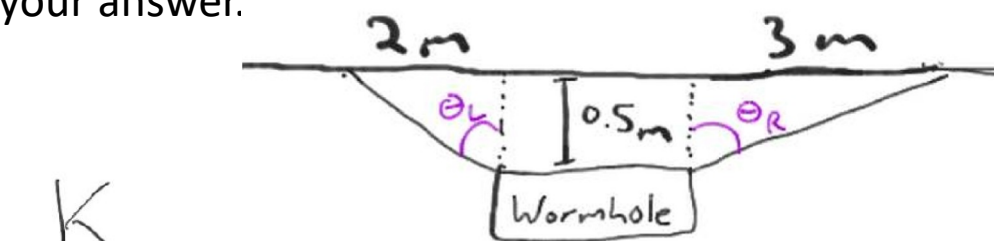
$$F_{Lx}^T = -F_{Rx}^T$$

$$|F_L^T| \sin \theta_L = |F_R^T| \sin \theta_R$$

$$|F_L^T| = |F_R^T| \frac{\sin \theta_R}{\sin \theta_L}$$

$$\Sigma F_y = 0$$

$$F_{Ly}^T + F_{Ry}^T + F_g = 0$$



K

$$F_g = mg$$

$$\Delta x_R = 3m$$

$$m = 8kg$$

$$\Delta x_L = 2m$$

$$g = 9.8 m/s^2$$

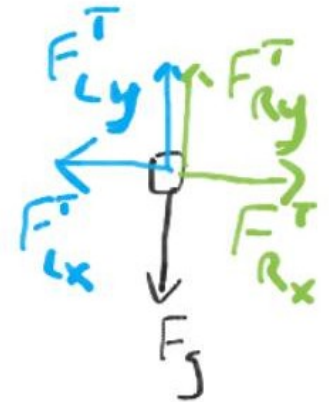
$$\Delta y_R = \Delta y_L = 0.5m$$

$$\tan \theta_L = \frac{2m}{0.5m}$$

$$\tan \theta_R = \frac{3m}{0.5m}$$

$$\theta_L = \tan^{-1}(4) = 76.0^\circ$$

$$\theta_R = \tan^{-1}(6) = 80.5^\circ$$



UK

$$F_R^T ?$$

$$F_L^T ?$$

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Solve the problem: 8 min

$$\Sigma F_x = \max_x$$

$$F_{Lx}^T + F_{Rx}^T = 0$$

$$F_{Lx}^T = -F_{Rx}^T$$

$$|F_L^T| \sin \theta_L = |F_R^T| \sin \theta_R$$

$$|F_L^T| = |F_R^T| \frac{\sin \theta_R}{\sin \theta_L}$$

$$\Sigma F_y = \max_y$$

$$F_{Ly}^T + F_{Ry}^T + F_g = 0$$

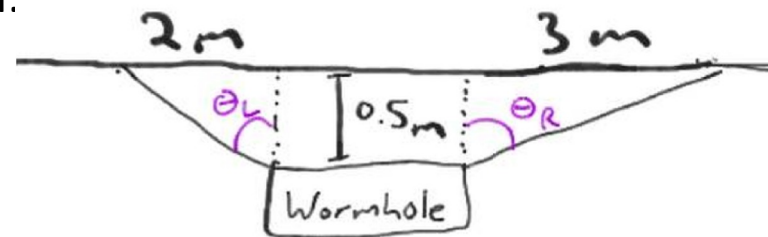
$$F_L^T \cos \theta_L + F_R^T \cos \theta_R = F_g$$

$$F_R^T \frac{\cos \theta_L}{\sin \theta_L} \cdot \sin \theta_R + F_L^T \cos \theta_R = mg$$

$$F_R^T \left[\frac{\sin \theta_R}{\tan \theta_L} + \cos \theta_R \right] = mg$$

$$F_R^T = \frac{mg}{\left[\frac{\sin \theta_R}{\tan \theta_L} + \cos \theta_R \right]}$$

$$F_R^T = 190.8 \text{ N}$$



K

$$F_g = mg \quad \Delta x_R = 3 \text{ m}$$

$$m = 8 \text{ kg} \quad \Delta x_L = 2 \text{ m}$$

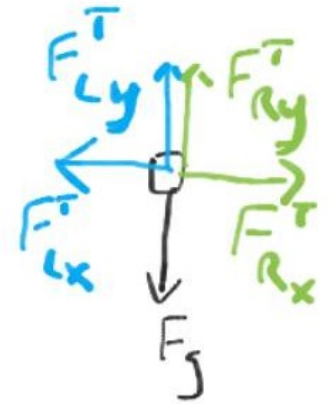
$$g = 9.8 \text{ m/s}^2 \quad \Delta y_R = \Delta y_L = 0.5 \text{ m}$$

$$\tan \theta_L = \frac{2 \text{ m}}{0.5 \text{ m}}$$

$$\theta_L = \tan^{-1}(4) = 76.0^\circ$$

$$\tan \theta_R = \frac{3 \text{ m}}{0.5 \text{ m}}$$

$$\theta_R = \tan^{-1}(6) = 80.5^\circ$$



UK

$$F_R^T ?$$

$$F_L^T ?$$

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Solve the problem: 8 min

$$\Sigma F_x = m a_x$$

$$F_{Lx}^T + F_{Rx}^T = 0$$

$$F_{Lx}^T = -F_{Rx}^T$$

$$|F_L^T| \sin \theta_L = |F_R^T| \sin \theta_R$$

$$|F_L^T| = |F_R^T| \frac{\sin \theta_R}{\sin \theta_L}$$

$$|F_L^T| = 190.8 \text{ N} \frac{\sin \theta_R}{\sin \theta_L}$$

$$|F_L^T| = 194.0 \text{ N}$$

$$\Sigma F_y = m a_y$$

$$F_{Ly}^T + F_{Ry}^T + F_g = 0$$

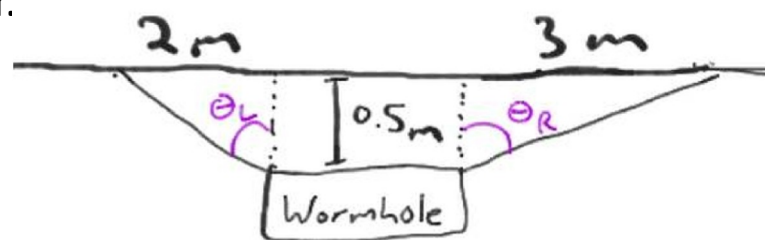
$$F_L^T \cos \theta_L + F_R^T \cos \theta_R = F_g$$

$$F_R^T \frac{\cos \theta_L}{\sin \theta_L} \sin \theta_R + F_L^T \cos \theta_R = mg$$

$$F_R^T \left[\frac{\sin \theta_R}{\tan \theta_L} + \cos \theta_R \right] = mg$$

$$F_R^T = \frac{mg}{\left[\frac{\sin \theta_R}{\tan \theta_L} + \cos \theta_R \right]}$$

$$F_R^T = 190.8 \text{ N}$$



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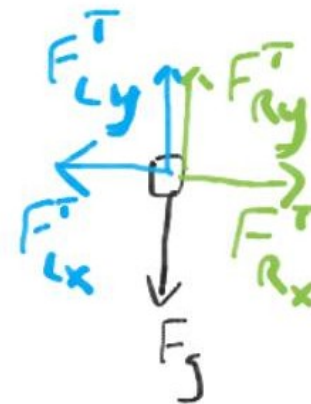
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$$\tan \theta_R = \frac{3 \text{ m}}{0.5 \text{ m}}$$

$$\theta_R = \tan^{-1}(6) = 80.5^\circ$$



UK

$$F_R^T ?$$

$$F_L^T ?$$

Problem Orientation

You're flying your 10,000-kg Scooty Puff Pro spaceship at a constant speed of 20 km/s in the positive x-direction. All of the sudden it malfunctions and many of the thrusters are stuck on. The main thruster is stuck on producing a 800 kN force in the positive x-direction. Two of the small maneuvering thrusters are also stuck on, one producing a 100 kN force in a direction 30° from the positive y-direction towards the negative x-direction, and the other is producing a 150 kN force in a direction 10° from the negative y-direction towards the negative x-direction. After 2 minutes of this the two maneuvering thrusters shut off and the main thruster decreases in magnitude to 200 kN, while still applying the force in the positive x-direction. It takes an additional 6 minutes to fix the problem and turn all of them off. How far and in what direction would you have to travel to get to where you would have been if the malfunction had not occurred.

Wrap-Up

- What did we learn?

