Concluding Lecture (L24): Choosing a Model

Warm-Up Activity

What was the topic you found most interesting in PH 211?

(A) Kinematics

(B) Forces

(C) Energy

(D) Momentum

A Model for Motion

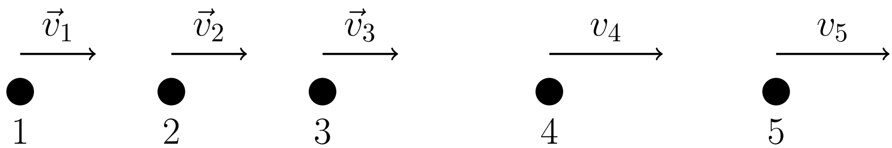
Quantities

- Position: $\vec{r}$
- Velocity: $\vec{v} = \frac{d\vec{r}}{dt}$
- Acceleration: $\vec{a} = \frac{d\vec{v}}{dt}$

Assumptions

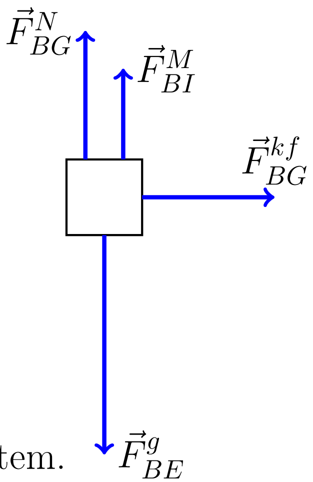
- Use the Particle Model

Motion Diagram



A Model for Interactions

- Quantities
  - Mass m
  - Force $\vec{F}$
- Laws
  - Net force is proportional to acceleration: $\vec{F}^{net} = m\vec{a}$
  - Forces come in pairs: $\vec{F}_{AB} = -\vec{F}_{BA}$
- Asssumptions
  - We can treat multiple objects as a system.
  - All forces act as if on the center of the system.
- Diagram



Types of Forces

- Gravity $\vec{F}^g_{AB} = m_A \vec{g}_B$
  - Newtonian $\vec{g}_B = G\frac{M_B}{r^2}(-\hat{r})$, $G = 6.67408 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$
  - Near-Earth $\vec{g}_E = g(-\hat{y}),\ g = 9.81\frac{\mathrm{m}}{\mathrm{s}^2} \approx 10\frac{\mathrm{m}}{\mathrm{s}^2}$
- Normal $\vec{F}^N$ always $\perp$; varies in magnitude
- Tension $\vec{F}^T$ uniform (massless, inextensible rope)
- Spring $\vec{F}^S = -k(\vec{x} - \vec{x}_{eq})$
- Friction
  - Static Friction $F^{sf} \leq \mu_s |\vec{F}^N|$
  - Kinetic Friction $F^{kf} = \mu_k |\vec{F}^N|$

Not Forces

- Momentum
- Inertia
- Velocity
- Acceleration

A Deeper Model for Interactions

- Quantities
  - Energy E
  - Work $W = \int_{r_i}^{r_f} \vec{F} \cdot d\vec{r}$
  - Kinetic Energy $K = \frac{1}{2}mv^2$
  - Potential Energy $U =$ depends on interaction
    You have to tell everyone where zero PE is!
    - Gravity $U_g = mgy$
    - Spring $U_{sp} = \frac{1}{2}kx^2$
  - Momentum $\vec{p} = m\vec{v}$
  - Impulse $\vec{J}_{net} = \int_{t_i}^{t_f} \vec{F}^{net} dt$
- Laws
  - Work-energy theorem $W_{\text{net,ext}} = \Delta E_{\text{total}}$
  - Impulse-momentum theorem $\vec{J}_{net} = \Delta\vec{p}$

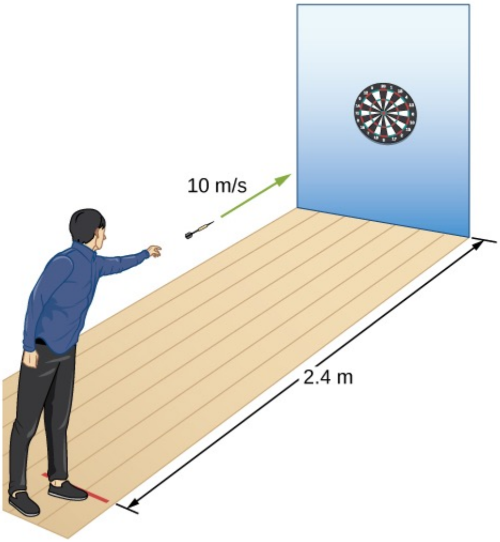
Putting the Pieces Together

- How do we use problems we've already solved to help us solve new ones?
- For each scenario, which model(s) would you use, and why?
  - Kinematics (motion, projectiles)
  - Forces (friction, springs, multiple objects)
  - Energy (work, power, potential energy, systems)
  - Momentum (impulse, systems)

L24-1: Choosing a Model – Dart

A dart is thrown horizontally at a speed of 10 m/s directly at the bullseye of a dartboard 2.4 meters away from the thrower.

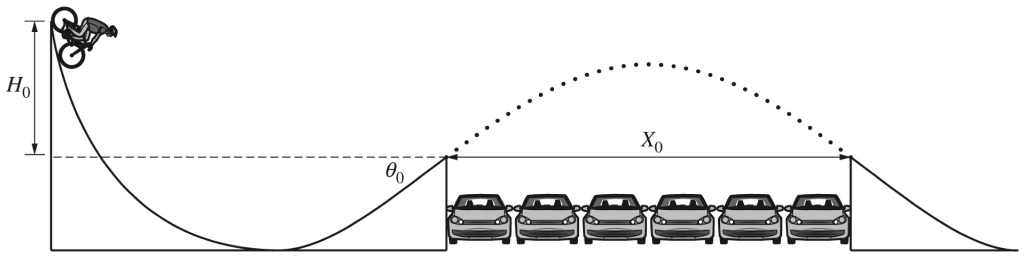
Where does the dart strike the board?



L24-2: Choosing a Model – The Ramp

A stunt cyclist builds a ramp that will allow the cyclist to coast down the ramp and jump over several parked cars, as shown below. To test the ramp, the cyclist starts from rest at the top of the ramp, coasts down to the bottom, jumps over six cars, and lands on a second ramp.

Goal: Derive an expression for X_0.



Note: Figure not drawn to scale.

Problem Credit: College Board ©2021

L24-3: Choosing a Model – Arrow

You fire a 0.05 kg arrow at an unknown speed. It embeds in a 0.35 kg block that slides on a frictionless surface until it compresses a spring of spring constant $k = 4000$ N/m a distance of 0.10 m.

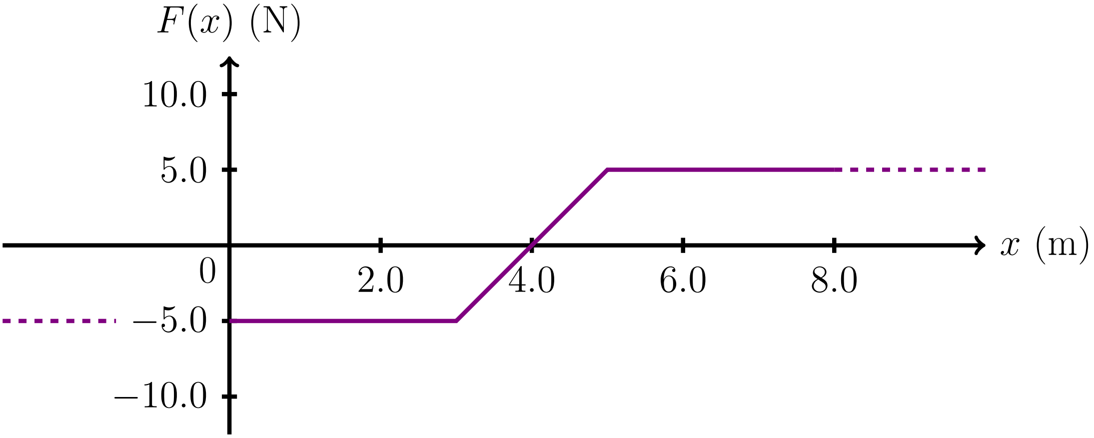
What was the speed at which the arrow was fired?

Problem Credit: Etkina College Physics

L24-4: Choosing a Model – Force

The plot below shows the net force applied in the x-direction to a 2 kg particle moving parallel to the x-axis. The velocity of the particle at $x = 0$ is +6 m/s in the x-direction.

Find the particle's speed at $x = 4$ m.



Problem Credit: OpenStax University Physics

Main Ideas

- This concludes the course.
- We've tried to introduce you to how a physicist looks at the universe.
- I hope you feel more capable than at the beginning of the term.
- Congratulate yourself for working so hard!