PHYS12 CH123:

Test Prep

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2. Chapter 1: Measurement and Problem Solving
3. Chapter 2 and 3: Motion in One and Two Dimensions
4. Conclusion
5. Problem 37: Tennis Serve
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Overview

- Review of key concepts from Chapters 1-3
- Practice problems with step-by-step solutions
- Focus on:
    - Significant figures and uncertainties
    - Unit conversions
    - Velocity and displacement calculations
    - Vector addition

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Problem 1: Significant Figures and Uncertainties

Question

(a) How many significant figures are in the numbers 99 and 100?
(b) If the uncertainty in each number is 1, what is the percent uncertainty in each?
(c) Which is a more meaningful way to express the accuracy of these two numbers, significant figures or percent uncertainties?

Problem 1: Solution (Part a)

Question

(a) How many significant figures are in the numbers 99 and 100?

Solution

(a) 99 has <u>2</u> sig. figs.; 100 has <u>3</u> sig. figs. at most

Explanation

- For 99: Both digits are non-zero, so both are significant.
- For 100: The 1 is non-zero, so it's significant. The zeros to the right of a non-zero digit are potentially significant. If this is an exact number, it has 1 sig. fig. If it's a measurement, it could have up to 3 sig. figs.
- Always clarify with the context whether trailing zeros are significant.

Significant Figures in 100

3 Significant Figures

Example: Digital scale reads 100 g

- All digits significant
- Precise to nearest gram
- Written as 1.00×10^2 g

1 Significant Figure

Example: About 100 people

- Only 1 is significant
- Estimate or rounding
- Written as 1×10^2 people

Infinite Significant Figures

Example: Exact numbers

- 100 cents in a dollar
- 100 years in a century
- Defined, not measured

Problem 1: Solution (Part b)

Question

(b) If the uncertainty in each number is 1, what is the percent uncertainty in each?

Solution

(b) For 99: $\frac{1}{99} \times 100 = 1.01\% = \underline{1.0\%}$
For 100: $\frac{1}{100} \times 100 = \underline{1.00\%}$ (if all zeros are significant)

Explanation

- Percent uncertainty $= \frac{\text{absolute uncertainty}}{\text{measured value}} \times 100\%$
- For 99: $\frac{1}{99} \times 100 = 1.01\%$, rounded to 1.0% (2 sig. figs.)
- For 100: $\frac{1}{100} \times 100 = 1.00\%$ (3 sig. figs. if all zeros are significant)
- Note: The uncertainty in the result should not be more precise than the given uncertainty (1).

Problem 1: Solution (Part c)

Question

(c) Which is a more meaningful way to express the accuracy of these two numbers, significant figures or percent uncertainties?

Solution

(c) Percent uncertainties are a more meaningful way to express the accuracy of these two numbers.

Explanation

- Significant figures give a rough idea of precision, but can be ambiguous (e.g., for 100).
- Percent uncertainty provides a clear, quantitative measure of relative accuracy.
- In this case, percent uncertainty shows that both numbers have similar accuracy (about 1%), which isn't clear from sig. figs. alone.
- Percent uncertainty is particularly useful for comparing measurements

Problem 1: Solution (Part c)

Solution

(c) Percent uncertainties are a more meaningful way to express the accuracy of these two numbers.

Explanation

- Significant figures give a rough idea of precision, but can be ambiguous (e.g., for 100).
- Percent uncertainty provides a clear, quantitative measure of relative accuracy.
- In this case, percent uncertainty shows that both numbers have similar accuracy (about 1%), which isn't clear from sig. figs. alone.
- Percent uncertainty is particularly useful for comparing measurements with different magnitudes.

Problem 2: Percent Uncertainty

Question

(a) A person's blood pressure is measured to be 120 ± 2 mm Hg. What is its percent uncertainty?
(b) Assuming the same percent uncertainty, what is the uncertainty in a blood pressure measurement of 80 mm Hg?

Problem 2: Solution (Part a)

Solution

(a) $\%unc = \frac{2 \text{ mm Hg}}{120 \text{ mm Hg}} \times 100\% = 1.7\% = \underline{2\%}$
(1 sig. fig because of 2 mm Hg)

Problem 2: Solution (Part b)

Solution

(b) $\delta bp = \frac{1.7\%}{100\%} \times 80 \text{ mm Hg} = 1.3 \text{ mm Hg} = \underline{1 \text{ mm Hg}}$
(1 sig. fig because of 2 mm Hg)

Problem 3: Uncertainty and Unit Conversion

Question

(a) A car speedometer has a 5.0% uncertainty. What is the range of possible speeds when it reads 90 km/h?
(b) Convert this range to miles per hour. (1 km = 0.6214 mi)

Problem 3: Solution (Part a)

Solution

(a) $\delta v = \frac{5.0\%}{100\%} \times 90.0 \text{ km/h} = 4.5 \text{ km/h}$

Thus, the range $= 90.0 \pm 5 \text{ km/h} = 85$ to 95 km/h.

Problem 3: Solution (Part b)

Solution

(b) Converting to miles per hour:

$$\frac{85.5 \text{ km}}{1 \text{ h}} \times \frac{0.6214 \text{ mi}}{1 \text{ km}} = 53.1 \text{ mi/h}$$
$$\frac{94.5 \text{ km}}{1 \text{ h}} \times \frac{0.6214 \text{ mi}}{1 \text{ km}} = 58.7 \text{ mi/h}$$

So the range is 53.1 to 58.7 mi/h

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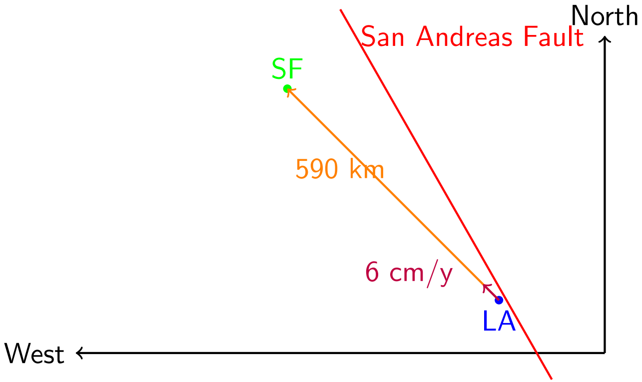
Problem 4: Displacement and Time

Question

Land west of the San Andreas fault in southern California is moving at an average velocity of about 6 cm/y northwest relative to land east of the fault. Los Angeles is west of the fault and may thus someday be at the same latitude as San Francisco, which is east of the fault. How far in the future will this occur if the displacement to be made is 590 km northwest, assuming the motion remains constant?

Problem 4: Visualization



Problem 4: Solution

Equations

Velocity equation: $v = \frac{\Delta x}{\Delta t}$ Rearranged for time: $\Delta t = \frac{\Delta x}{v}$

Solution

$$\begin{aligned}
\Delta t = \frac{\Delta x}{v} &= \frac{590 \text{ km}}{6 \text{ cm/year}} \times \frac{100000 \text{ cm}}{1 \text{ km}} \\
&= \frac{5.90 \times 10^5 \text{ m}}{6 \text{ cm/year}} \times \frac{100 \text{ cm}}{1 \text{ m}} \\
&= 9.83 \times 10^6 \text{ years} = 1 \times 10^7 \text{ years} \\
&= \underline{10 \text{ million years}}
\end{aligned}$$

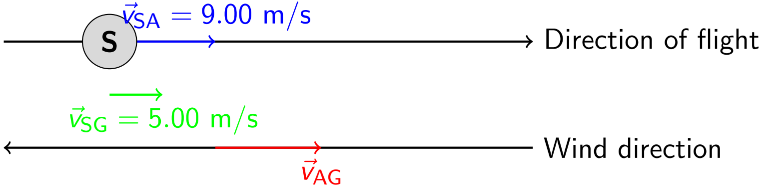
Problem 5: Relative Motion (Part 1)

Question

A seagull flies at a velocity of 9.00 m/s straight into the wind. (a) If it takes the bird 20.0 min to travel 6.00 km relative to the Earth, what is the velocity of the wind?
(b) If the bird turns around and flies with the wind, how long will he take to return 6.00 km?
(c) Discuss how the wind affects the total round-trip time compared to what it would be with no wind.

Problem 5: Visualization

S: Seagull, A: Air, G: Ground



Problem 5: Solution (Part a)

Equations

Relative velocity: $\mathbf{v_{SG}} = \mathbf{v_{SA}} + \mathbf{v_{AG}}$ Rearranged for wind velocity: $\mathbf{v_{AG}} = \mathbf{v_{SG}} - \mathbf{v_{SA}}$ Velocity from displacement and time: $v = \frac{x}{t}$

Solution

(a) Let A = air, S = seagull, G = ground

$$v_{\mathrm{SG}} = \frac{x_{\mathrm{SG}}}{t} = \frac{6.00 \times 10^3 \text{ m}}{(20 \text{ min})(60 \text{ s}/1 \text{ min})} = 5.00 \text{ m/s}$$

$$v_{AG} = v_{\mathrm{SG}} - v_{\mathrm{SA}} = 5.00 \text{ m/s} - 9.00 \text{ m/s} = -4.00 \text{ m/s}$$

Problem 5: Solution (Part b)

Equations

Relative velocity (with wind): $v_{SG} = v_{SA} - v_{AG}$ Time from displacement and velocity: $t = \frac{x}{v}$

Solution

(b) Flying with the wind:

$$v_{SG} = v_{SA} - v_{AG} = 9.00 \text{ m/s} - (-4.00 \text{ m/s}) = 13.00 \text{ m/s}$$

$$t = \frac{x_{SG}}{v_{SG}} = \frac{6.00 \times 10^3 \text{ m}}{13.00 \text{ m/s}} = 462 \text{ s} = \underline{7 \text{ min } 42 \text{ s}}$$

Problem 5: Solution (Part c)

Solution

(c) The wind will always slow down the round trip time, relative to having no wind present.

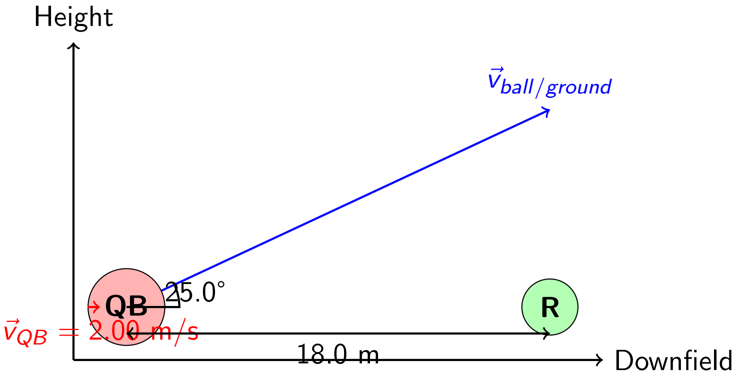
Problem 6: Vector Addition (Part 1)

Question

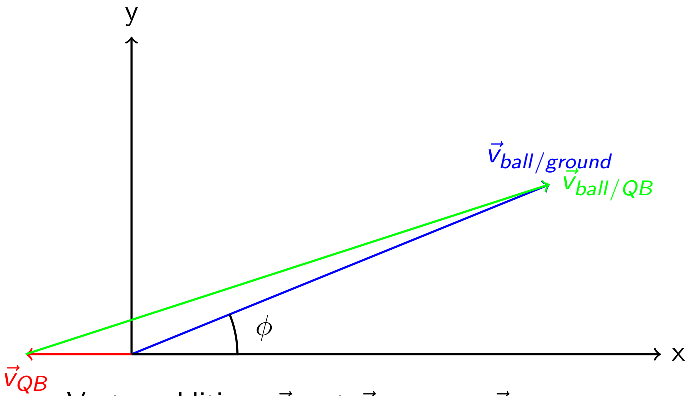
A football quarterback is moving straight backward at a speed of 2.00 m/s when he throws a pass to a player 18.0 m straight downfield. The ball is thrown at an angle of 25.0° relative to the ground and is caught at the same height as it is released.

What is the initial velocity of the ball relative to the quarterback?

Problem 6: Visualization



Problem 6: Vector Addition Visualization



Vector addition: $\vec{v}_{QB} + \vec{v}_{ball/QB} = \vec{v}_{ball/ground}$

Problem 6: Solution (Part 1)

Equations

Vector addition: $\vec{v}_{QB} + \vec{v}_{ball/QB} = \vec{v}_{ball/ground}$

Component equations:

$v_{QB_x} + v_{ball/QB_x} = v_{ball/ground_x} = v_{ball/ground} \cos\phi$

$v_{QB_y} + v_{ball/QB_y} = v_{ball/ground_y} = v_{ball/ground} \sin\phi$

Solution

(relative to ground)

$$
\begin{aligned}
v_{QB_x} + v_{ball/QB_x} &= v_{ball/ground} \cos\phi \\
-2\ \text{m/s} + v_{ball/QB_x} &= (15.2\ \text{m/s}) \cos 25.0^\circ \Rightarrow v_{ball/QB_x} = 15.8\ \text{m/s} \\
v_{QB_y} + v_{ball/QB_y} &= v_{ball/ground} \sin\phi \\
0 + v_{ball/QB_y} &= (15.2\ \text{m/s}) \sin 25.0^\circ \Rightarrow v_{ball/QB_y} = 6.42\ \text{m/s}
\end{aligned}
$$

Quarterback Velocity Problem

Problem Context

- Quarterback moving backward at 2.00 m/s
- Ball thrown at 25.0° angle relative to ground
- Ball travels 18.0 m downfield

Calculation Steps

1. Use projectile motion equation: $R = \frac{v^2 \sin(2\theta)}{g}$
2. Rearrange to solve for v: $v = \sqrt{\frac{Rg}{\sin(2\theta)}}$
3. Given: $R = 18.0$ m, $\theta = 25.0°$, $g = 9.8$ m/s^2
4. Calculate: $v \approx 15.2$ m/s

Key Point

The calculated velocity (15.2 m/s) is relative to the ground, not the quarterback.

Problem 6: Solution (Part 2)

Equations

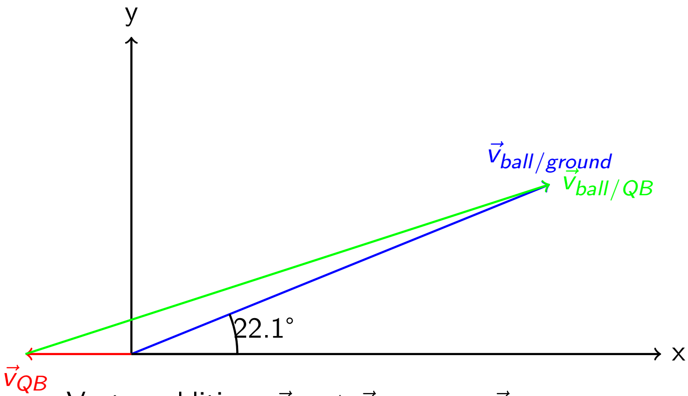
Magnitude of velocity vector: $v = \sqrt{v_x^2 + v_y^2}$ Angle of velocity vector: $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

Solution

$$v_{ball/QB} = \sqrt{v_{ball/QB_x}^2 + v_{ball/QB_y}^2} = \sqrt{(15.8\text{ m/s})^2 + (6.42\text{ m/s})^2} = \underline{17.0\text{ m/s}}$$

$$\theta = \tan^{-1}\left(\frac{v_{ball/QB_y}}{v_{ball/QB_x}}\right) = \tan^{-1}\left(\frac{6.42}{15.8}\right) = \underline{22.1^\circ}$$

Problem 6: Vector Addition Visualization



Vector addition: $\vec{v}_{QB} + \vec{v}_{ball/QB} = \vec{v}_{ball/ground}$

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Key Takeaways

- Importance of significant figures and uncertainties in measurements
- Proper use of unit conversions
- Understanding relative motion and vector addition
- Practice solving multi-step problems
- Always check units and reasonableness of answers

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Problem 37: Tennis Serve

Question

A tennis player serves at a speed of 170 $\mathrm{km/h}$ from a height of 2.5 m and an angle $\boldsymbol{\theta}$ below the horizontal. The baseline is 11.9 m from the net, which is 0.91 m high.
What is the angle θ such that the ball just crosses the net?
Will the ball land in the service box, which has an outermost service line 6.40 m from the net?

Problem 37: Solution (Part 1)

- Convert initial velocity:

$$v_0 = 170 \text{ km/h} = 47.2 \text{ m/s}$$

- Calculate vertical distance to net:

$$y = 2.50 \text{ m} - 0.91 \text{ m} = 1.59 \text{ m}$$

- Use kinematic equation:

$$y = v_{0y}t + \frac{1}{2}at^2$$

Problem 37: Solution (Part 2)

- In x-direction:

$$x = 11.9\mathrm{m} = (47.2\ \mathrm{m/s})(\cos\theta)t$$

$$t = \frac{0.252}{\cos\theta}$$

- Substitute into kinematic equation:

$$1.59\ \mathrm{m} = (11.9\ \mathrm{m})\tan\theta + (0.311\ \mathrm{m})(1 + \tan^2\theta)$$

- Solve for θ:

$$\tan\theta = 0.107 \text{ or } \underline{\theta} = 6.1^\circ$$

Problem 37: Solution (Part 3)

- Calculate time for ball to fall 2.5 m:

$$t = 0.366 \text{ s}$$

- Calculate range:

$$R = v_x t = 17.2 \text{ m}$$

- Answer: Yes, the ball lands 5.3 m from the net, within the service box.

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Problem 39: Gun Sights

Question

(a) A gun is sighted to hit targets at the same height, 100.0 m away. How low will the bullet hit if aimed at a target 150.0 m away? The muzzle velocity is 275 $\mathrm{m/s}$.
(b) Discuss qualitatively how a larger muzzle velocity would affect this problem and what would be the effect of air resistance.

Problem 39: Gun Sights

Question

(a) A gun is sighted to hit targets at the same height, 100.0 m away. How low will the bullet hit if aimed at a target 150.0 m away? The muzzle velocity is 275 $\mathrm{m/s}$.
(b) Discuss qualitatively how a larger muzzle velocity would affect this problem and what would be the effect of air resistance.

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Problem 39: Solution (Part 1)

- Use range equation to find initial angle:

$$R = \frac{v_0^2 \sin 2\theta_0}{g}$$

$$\theta_0 = \frac{1}{2} \sin^{-1} \left(\frac{gR}{v_0^2} \right)$$

$$\theta_0 = \frac{1}{2} \sin^{-1} \left[\frac{\left(9.80 \mathrm{~m/s^2}\right)\left(100\mathrm{m}\right)}{\left(275 \mathrm{~m/s}\right)^2} \right] = 0.3712^\circ$$

Problem 39: Solution (Part 2)

- Calculate time to travel 150 m:

$$x - x_0 = 150 \text{ m} = v_0 \cos\theta_0 t$$

$$t = \frac{x - x_0}{v_0 \cos\theta_0} = \frac{150\text{m}}{(275 \text{ m/s}) \cos 0.3712^\circ} = 0.5455 \text{ s}$$

Problem 39: Solution (Part 3)

- Calculate vertical displacement:

$$y - y_0 = v_{0y} t - \frac{1}{2} g t^2$$

$$= (275 \text{ m/s}) \sin 0.3712^\circ (0.5455 \text{ s}) - \frac{1}{2}(9.80 \text{m/s}^2)(0.5455 \text{ s})^2$$

$$= -0.730 \text{ m}$$

- The bullet hits 0.730 m below the target.

Problem 39: Qualitative Discussion

(b) Effects of larger muzzle velocity and air resistance

- Larger muzzle velocity:
  - Flatter trajectory
  - Less vertical drop
  - Bullet would hit closer to the target
- Air resistance:
  - Reduces horizontal velocity
  - Increases vertical drop
  - Bullet would hit lower than calculated