# First Person Physics Answer Guide

## Chapter 1

### Lesson 1: Position, Distance and Speed

**Question 1:** Solve the equation 5x = 3x − 2

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**Answer:** -1

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**Question 2:** A toddler has become lost in the forest and her father is trying to retrieve her. He is currently located due north of a large tree and he hears her shouts coming from due south of his position. Do we know from this information whether the toddler is north or south of the tree?

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**Answer:** No

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**Question 3:** Anita and Nick are playing tug-of-war near a mud puddle. They are each holding on to an end of a taut rope that has a knot exactly in the middle. Anita's position is 5.2 meters east of the center of the puddle and Nick's position is 3.0 meters west of the center of the puddle. What is the location of the knot relative to the center of the puddle? Treat east as positive and west as negative.

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**Answer:** 1.1 meters

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**Question 4:** A jogger is moving at a constant velocity of +3.0 m/s directly towards a traffic light that is 100 meters away. If the traffic light is at the origin, x = 0 m, what is her position after running 20 seconds?

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**Answer:** -40 m

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### Lesson 2: Displacement and Velocity

**Question 1:** A spatially challenged goldfish swims along the x-axis only. Its initial position is 7.5 m. After swimming back and forth a while, it finds itself at the position 3.7 m. Calculate the fish's displacement (including its sign).

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**Answer:** -3.8 m

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**Question 2:** A runner starts at position −41 m and moves 87 m forward. What is the runner's final position? Assume forward is positive.

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**Answer:** 46 m

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**Question 3:** A ball drops to the ground from a height of 41 cm. Up is positive and the ground is at 0 cm. What is the ball's displacement?

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**Answer:** -41 cm

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**Question 4:** A caterpillar is 11.0 cm up a flower stem and moves down to a height of 6.20 cm. The caterpillar believes up is positive and down is negative. What is its displacement?

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**Answer:** -4.8 cm

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**Question 5:** An airplane flies 43 kilometers west. East is positive displacement. What is the airplane's displacement?

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**Answer:** -43 km

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**Question 6:** A rocket moves from the position −210 km to −20.0 km. What is its displacement?

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**Answer:** 190 km

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**Question 7:** A particle moves along the x-axis from the origin to the position −15 mm. What is its displacement?

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**Answer:** -15 mm

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**Question 8:** A motorcycle moves along a straight track. It starts at the position 30 meters, goes backwards 20 meters, forward 30 meters, back 5.0 meters, back 12 more meters, and finally ends up at the position 23 meters. What is its displacement?

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**Answer:** -7 m

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## Lesson 3: Average and Instantaneous Velocity

**Question 1:** Elaine wants to return a movie she rented at the store, which is 5.0 kilometers away in the positive direction. It takes her 10 minutes to drive to the store, 1.0 minute to deposit the movie, and 9.0 more minutes to drive home. What is her average velocity for the entire trip?

**Answer:** 0.0 m/s

**Question 2:** A slug has just started to move straight across a busy street in Littletown that is 8.000 meters wide, at a constant speed of 5.265 millimeters per second. The concerned drivers on the street halt until the slug has reached the opposite side. How many seconds elapse until the traffic can start moving again?

**Answer:** 1519 s

**Question 3:** A car moves from position 74.0 km to 140 km in 2.40 hours. What is its average velocity?

**Answer:** 27.5 km/h

**Question 4:** A rocket is propelled horizontally from position 62 m to position −24 m in 1.7s. Find its average velocity.

**Answer:** 51 m/s

**Question 5:** With an average velocity of 8.10 m/s, what is the displacement (including its sign) of a sled during a straight run of 12.0s?

**Answer:** 97.2 m

## Lesson 4: Acceleration

**Question 1:** David is driving a minivan to work, and he is stopped at a red light. The light turns green and David drives to the next red light, where he stops again. Is David’s average acceleration from light to light positive, negative, or zero?

**Answer:** Zero

**Question 2:** A spaceship moving straight up accelerates from a velocity of 130 m/s to a velocity of 220 m/s with an average acceleration of 14.0 m/s$^2$ . How much time is required for this maneuver?

**Answer:** 6.43 s

**Question 3:** A rock's velocity changes from 36.1 m/s to 21.6 m/s in 4.20 seconds. At what constant rate is it accelerating?

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**Answer:** 3.45 m/s$^2$

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**Question 4:** A runner's velocity is 3.0 m/s at time 6.0 s and 2.5 m/s at time 13 s. Find the runner's average acceleration.

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**Answer:** -0.07 m/s$^2$

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## Lesson 5: Advanced Motion Equations

**Question 1:** Starting at 1.3 m/s, a runner accelerates at a constant 0.21 m/s$^2$ for 6.8 s. What is the runner's displacement during this time interval?

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**Answer**: 13.7 m

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**Question 2:** A car accelerates from rest at 1.50 m/s$^2$ along a 210 m stretch of straight road. Find the car's instantaneous velocity at the end of the stretch.

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**Answer:** 25.1 m/s

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**Question 3:** A high-speed test vehicle is brought to rest by throwing out a drag chute behind it, causing a constant acceleration of −11.0 m/s$^2$. The vehicle has a velocity of 51.0 m/s when the chute ejects. What is the shortest distance needed for the test vehicle to stop after the chute is ejected?

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**Answer:** 118.23 m

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# Chapter 2

## Lesson 2: Position-Time Graphs

**Question 1:** The graph shows the mouse's velocity versus time. Describe the instantaneous acceleration at point B as positive, negative or zero.

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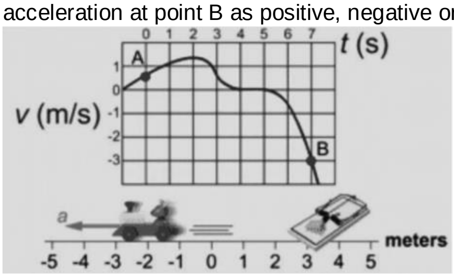


**Answer:** Negative

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**Question 2:** What is the average velocity between points **A** and **B**?

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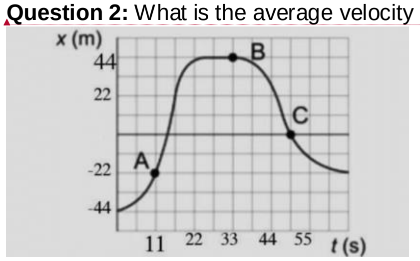


**Answer:** $\bar{v} = 3$ m/s

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**Question 3:** The graph shows the mouse's velocity versus time. Describe the instantaneous acceleration at point A as positive, negative or zero.

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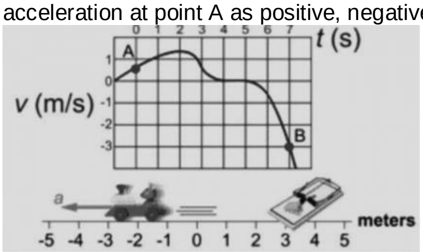


**Answer:** Positive

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**Question 4: :** A graph of the velocity versus time of a hockey puck is shown. Calculate the puck's displacement from t = 1.0 s to t = 4.0 s.

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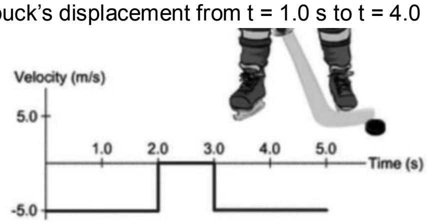


**Answer:** -10 m

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**Question 5:** The graph shows position as a function of time for a particle moving along the x-axis. Which one of the statements, referring to the labeled points, is correct?

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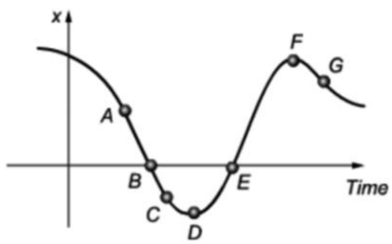


**Answer:** The acceleration is most negative at F.

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## Lesson 4: Freefall Acceleration

**Question 1:** What is the egg's **velocity** after falling from rest for 0.11 seconds? Assume the upward direction is positive and the downward direction is negative?

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**Answer:** $v_f$ = -1.078 m/s

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**Question 2:** What is the egg's **acceleration** after falling from rest for 0.18 seconds? Assume up is the positive direction.

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**Answer:** $a = -9.8 \text{ m/s}^2$

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## Lesson 5: Reference Frame

**Question 1:** A daring villain leaps forward on a train at 3.30 m/s, but a person standing on the ground sees the villain moving forward at 11.9 m/s. How fast is the train moving relative to the ground?

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**Answer:** 8.6 m/s

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**Question 2:** Agent Bond is in the middle of one of his trademark, nearly impossible getaways. He is in a convertible driving west at a speed of 23.0 m/s (this is the reading on his speedometer) on top of a train, heading toward the back end. The train is moving horizontally, due east at 15.0 m/s. As the convertible goes over the edge of the last train car, Bond jumps off. With what horizontal velocity relative to the convertible should he jump to hit the ground with a horizontal velocity of 0 m/s, so that he merely shakes, but does not spill (nor stir) his drink? Consider east to be the positive direction.

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**Answer:** 8 m/s

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**Question 3:** Sarah's friends have decided that it is inconsiderate to make Sarah walk down the riverbank to meet them, so they decide to come straight across the river to meet her. The motor propels the boat at a speed of 5.0 m/s relative to the water and the current flows at 3.2 m/s with respect to the ground. If they want to move directly across the river without being deflected downstream or moving upstream, find the angle between the direction in which they need to point the boat and their path across the river. State the angle as positive.

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**Answer:** 40 °

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**Question 4:** Two students, Jim and Sarah, are walking to different classrooms from the same cafeteria. How does Jim's velocity in Sarah's reference frame relate to Sarah's velocity in Jim's reference frame?

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**Answer:** They are equal but opposite

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**Question 5:** Sam is heading north on a highway while Lexine heads south on the same highway. Fred is pulled over due to a flat tire. Identify and describe the motion relative to Lexine's reference frame. Please submit your answer on paper.

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**Answer:** Answers may vary. Initially Sam's velocity from Lexine's reference frame is approaching her at the observed speed of his car plus the observed speed of Lexine. After he

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stops, his velocity in Lexine's reference frame is approaching her at just the observed speed of Lexine.
Also: Initially Lexine sees Sam moving toward her at the sum of her speed and Sam's. After Sam stops, Lexine will see him moving toward her at her speed.

# Chapter 3

## Lesson 1: Metric System and Conversions

**Question 1:** Express 3.0 meters in feet.

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**Answer:** 9.8 ft

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**Question 2:** Convert 15.0 miles per hour to kilometers per hour

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**Answer:** 24.1 km/h

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**Question 3:** Convert 36 kilograms to grams.

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**Answer:** $3.6 \times 10^4$ g

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**Question 4:** Convert 510 centimeters to inches.

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**Answer:** 201 in

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**Question 5:** Convert $4.4 \times 10^{-4}$ kiloliter (kL) to centiliters (cL).

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**Answer:** 44 cL

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**Question 6:** Convert 15 millimeters to meters.

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**Answer:** .015 m

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**Question 7:** In ancient times, the length of 8.0 wombats was equal to 5.0 nerfs. How long are 21 nerfs in wombats?

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**Answer:** 33.6 wombats

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**Question 8:** Convert 10.0 m/s to miles per hour.

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**Answer:** 22.4 mi/h

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## Lesson 2: Scientific Notation

**Question 1:** Express $14.0 \times 10^{-4}$ millimeters as a decimal number, keeping the unit as millimeters.

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**Answer:** 0.0014 mm

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**Question 2:** An electron can tunnel through an energy barrier with probability 0.0000000000375. (This is a concept used in quantum mechanics.) Express this probability in scientific notation.

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**Answer:** $3.75 \times 10^{-11}$

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**Question 3:** A $3.70 \times 10^{6}$ kg piece splits off an iceberg of mass of $5.96 \times 10^{7}$ kg. Calculate the mass of the remaining iceberg and express the answer in scientific notation.

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**Answer:** $5.59 \times 10^{7}$

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**Question 4:** Express $2.80 \times 10^{5}$ millimeters in meters, using a decimal number.

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**Answer:** 280 m

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**Question 5:** Evaluate $(5.7 \times 10^{6}$ kg$) \times (6.3 \times 10^{-2}$ m/s$^{2}$ ) and express the answer in scientific notation.

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**Answer:** $3.6 \times 10^{5}$ kg * m/s$^{2}$

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**Question 6:** Multiply $3.65 \times 10^{23}$ by $4.12 \times 10^{154}$ by $1.11 \times 10^{-11}$ and express the answer in scientific notation.

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**Answer:** $1.67 \times 10^{167}$

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## Lesson 4: Nature of Science

**Question 1:** One story says that Sir Isaac Newton “discovered” gravity when an apple hit him on the head, and he realized that masses attract one another. Let’s say he wrote a letter the next day to a friend explaining his discovery. Did his letter contain a hypothesis or a theory? Please submit your answer on paper.

**Answer:** Answers may vary.
Potential Answer: A hypothesis. It had not been tested by independent scientists across the world and it was not widely accepted. It was a hypothesis that was true, but it was not yet a theory.

**Question 2:** “87% of the time your explanation correctly predicts the results of the experiment.” Is this a hypothesis or a theory? Please submit your answer on paper.

**Answer:** Answers may vary. Potential answer: Since the explanation is not confirmed 100% by the experiments, it is a hypothesis, not a theory.

**Question 3:** What are the key elements of the National Academy’s definition of science? Please submit your answer on paper.

**Answer:** Answers may vary.
Potential Answer: It uses experiments to test hypotheses and explanations. Science generates knowledge through this process. Science must make predictions that are experimentally testable and falsifiable. Scientific theories can never be proven true (as they always remain open to test), but they can be proven false. After a theory has been subjected to many tests, we say that it is true because the weight of evidence supports it.

**Question 4:** Explain how “science” was conducted, using Einstein’s general theory of relativity as a case study. Use the National Academy’s definition of science in your answer. Please submit your answer on paper.

**Answer:** Answers may vary.
Potential Answer: Einstein created a hypothesis about the relationship of light and gravity. It would explain the behavior of light near bodies with great mass, such as the Sun. Scientists tested his explanation and found it true. General relativity is now an accepted part of science theory, and the knowledge generated has been applied in many other situations.

## Lesson 5: Science Experiments

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**Question 1:** Explain how you demonstrated safe practices during a lab as part of your lab write up. Please submit your answer on paper.

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**Answer:** Answers may vary.

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**Question 2:** In your next lab, explain how you will demonstrate an understanding of the use of resources. Please submit your answer on paper.

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**Answer:** Answers may vary.
Potential Answer: Response depends on lab; lab should include consumable materials.

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**Question 3:** In your next lab, explain how you will demonstrate an understanding of the proper disposal or recycling of materials. Please submit your answer on paper.

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**Answer:** Answers may vary.
Potential Answer: Response depends on lab; lab should include materials that require disposal (e.g. some forms of batteries) and other materials (e.g. paper, rechargeable batteries).

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**Question 4:** Choosing a piece of equipment in your lab, explain how you can increase its precision and its accuracy. Please submit your answer on paper

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**Answer:** Answers may vary.
Potential Answer: Answers will vary. Remember that precision means more information while accuracy means closer to the accepted value. Higher precision means that repeated experimental measurements are more closely grouped together.

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## Lesson 6: Science, News and Marketing

**Question 1:** Compare and contrast the scientific evidence offered by the rival golf manufacturers for their scientific explanations about their golf balls' behavior. Please submit your answer on paper.

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**Answer:** Answers may vary.
Potential Answer: One vendor offered an explanation based on modeling golf ball behavior. The other used experimental data.

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**Question 2:** What are some of the ways in which the scientific explanations of helmet safety can be analyzed using logical reasoning? Please submit your answer on paper.

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**Answer:** Answers may vary.
Potential Answer: One way is to compare the tests performed on the helmets in laboratories to the actual experiences of football players on the field.

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**Question 3:** Apply scientific information from various sources such as scientific journals and newspapers to present your view on a topic of scientific debate. Use the format suggested in the book for organizing your presentation. Please submit your answer on paper.

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**Answer:** Answers may vary. Answers can be graded using the format suggested in the textbooks.

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## Lesson 7: Math Fundamentals Review

**Question 1:** Evaluate (a ·6)/(a −11) when a = 5.

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**Answer:** -5

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**Question 2:** Evaluate $-4x^3 - 3x$ when $x = -9$.

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**Answer:** 2943

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# Chapter 4

## Lesson 1: Two-Dimensional Motion

**Question 1:** It is half as far from Baker to Chester as from Acme to Dunsville. Describe the displacement vector from Baker to Chester.

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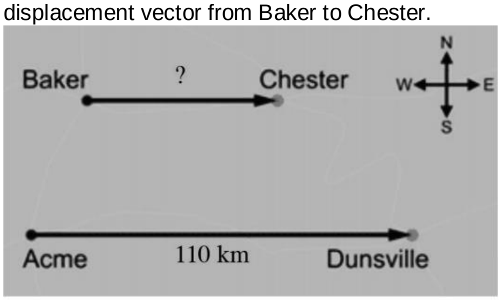


**Answer:** $\Delta x_{BC}$ = 55 km east

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**Question 2:** A car starts a trip at (2.0, 8.0) km and ends at (–28, 2.0) km. What are the components of the car's displacement vector?

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**Answer:** Δ x = -30 km Δ y = -6 km

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**Question 3:** An ice skater glides with constant velocity (8.9, –3.8) m/s. What are the components of the skater's displacement after 9.2 s?

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**Answer:** Δ x = 81.9 m Δ y = -35.0 m

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**Question 4:** During 9.0 s, a canary moves (–55, –62) m. Find the components of the canary's average velocity.

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**Answer:** $\bar{v}_x$ = -6.1 m/s $\bar{v}_y$ = -6.9 m/s

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## Lesson 2: Projectile Motion

**Question 1:** A piece of climbing gear is thrown straight down from a 200 m cliff at a speed of 16.0 m/s. What will its velocity be when it lands? Assume up is positive and down is negative while ignoring air resistance

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**Answer:** -64.6 m/s

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**Question 2:** A stone is thrown horizontally from the edge of a cliff above a level plain and takes 7.70 s to reach the ground. Find the vertical displacement of the stone. Assume up is positive and down is negative.

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**Answer:** 291 m

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**Question 3:** A cannon shell strikes a target 560 m away. The horizontal component of the shell's initial velocity is 89.0 m/s. Find the vertical component of the initial velocity. The shell is launched and strikes at the same height.

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**Answer:** 30.8 m/s

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**Question 4:** You fire a squirt gun horizontally from an open window in a multistory building and make note of where the spray hits the ground. Then you walk up to a window 5.0 m higher and fire the squirt gun again, discovering that the water goes 1.5 times as far. Ignore air resistance. How long does the second shot take to hit the ground?

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**Answer:** 1.7 s

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# Lesson 3: Combining Vectors Graphically

**Question 1:** A plane is coming in for a landing at the speed 230 m/s with the x-component of 200 m/s. What is its vertical component? Assume up is positive, down is negative.



**Answer:** $v_y = -113$ m/s



**Question 2:** Suzy is holding her kite on a string 25.0 m long when the kite hits the top of a flagpole, which is 14.7 m higher than her hands. Assuming that the string is taut and forms a straight line, what is the horizontal distance from her hands to the flagpole?

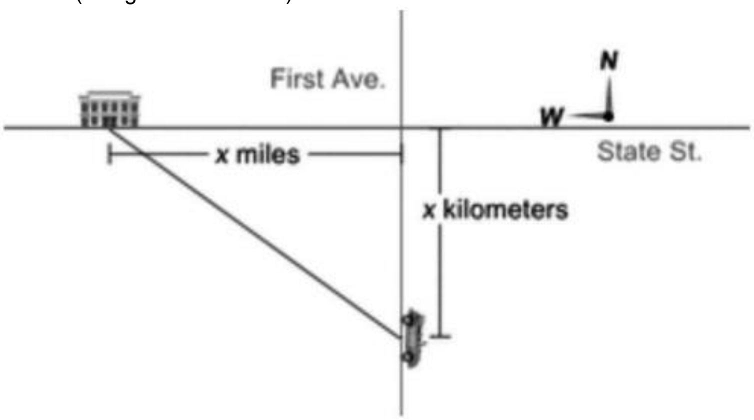


**Answer:** 20.2 m



**Question 3:** A hapless motorist is trying to find his friend’s house, which is located 5.00 miles west of the intersection of State Street and First Avenue. Instead of driving west, the confused motorist sets out due south from the intersection and drives that number of kilometers (not miles) instead. He then stops when he does not arrive at his friend’s house. When he stops, how far (straight line distance) is he from his friend’s house in kilometers?






**Answer:** 9.47 km



**Question 4:** A Pythagorean triple is a set of three integers (a, b, c) that could form three sides of a right triangle. (3, 4, 5) and (5, 12, 13) are two examples. There exists a Pythagorean triple of the form (7, n, n + 1). Find n.



**Answer:** 24

## Lesson 5: Vectors and Trigonometry

**Question 1:** Your projectile launching system is partially jammed. It can only launch objects with an initial vertical velocity of 42.0 m/s, though the horizontal component of the velocity can vary. You need your projectile to land 209 m from its launch point. What horizontal velocity do you need to program into the system?

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**Answer:** 24.4 m/s

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**Question 2:** A cannon is used to eliminate an enemy machine gun position 330 m away over level ground. The shell is in the air for 3.10 s. At what angle above the horizontal is the cannon aimed?

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**Answer: 8.12**°

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**Question 3:** A shell is fired from a mortar over level terrain. The firing speed is 57.0 m/s and the mortar is aimed 61.0° above the horizontal. Find the range of the shell.

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**Answer:** 281 m

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**Question 4:** If there were no air resistance, how fast would you have to throw a football at an initial 45° angle in order to complete an 80 meter pass?

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**Answer:** 28 m/s

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**Question 5:** What is the angle of elevation needed for a cannon with a firing speed of 170 m/s to strike a target 1.2 km away and at the same height as the cannon?

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**Answer:** 12 °

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## Lesson 6: Rectangular Vector Multiplied by Scalar

**Question 1:** What is the car’s displacement vector z if it travels 19 times as far as vector u?

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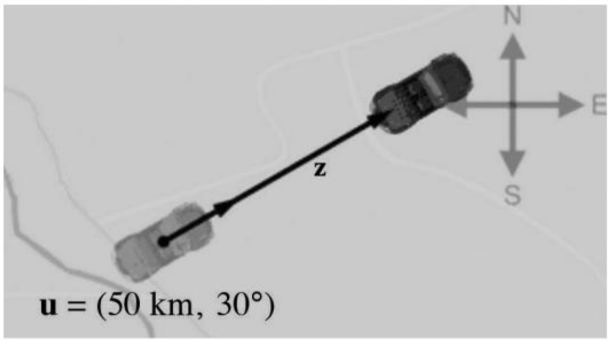


**Answer:** 950 km

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**Question 2:** Find the x- and y-components of the displacement vector (20.0 m, 110°).

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**Answer:** x = -6.8 m y = -18.8 m

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**Question 3:** Write the velocity vector with magnitude and angle.

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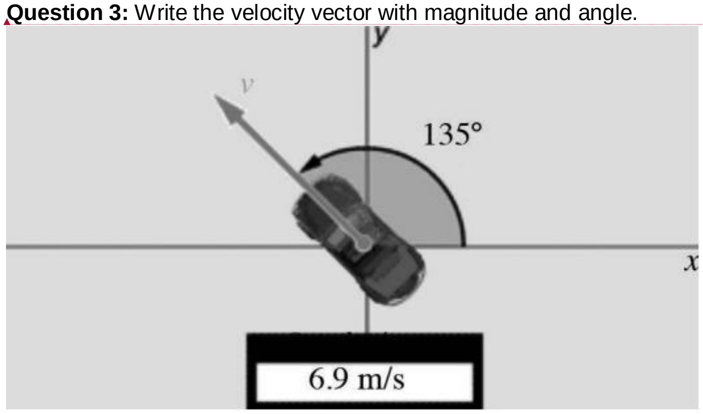


**Answer:** (v, θ) = ( 6.9 m/s, 135 °)

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## Lesson 7: Converting Between Vector Forms

**Question 1:** A plane is coming in for a landing at the speed 230 m/s at the angle 12.0 degrees with the horizontal. What is the magnitude of how quickly it is descending vertically?

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**Answer:** $v_y$ = -47.8 m/s

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**Question 2:** What are the magnitude and angle of the acceleration vector (–1.70, –2.80) m/s$^2$ ?

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**Answer:** a = 3.28 m/s$^2$ θ = 238.7°

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**Question 3:** What are the x- and y-components of the velocity vector (99 m/s, 98°)?

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**Answer:** $v_x$ = -14 m/s $v_y$ = 98 m/s

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**Question 4:** The x-component of a cannon's acceleration is 20.0 m/s$^2$ and it is aimed at 30.0 degrees north of west. What is the y-component of its acceleration?

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**Answer:** 11.5 m/s$^2$

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**Question 5:** Fred's friends are in a boat. If they could travel perpendicularly to the shore, they could land at his position. However, a strong current $v_c$ is greater than the maximum $v_m$ of the motor. Find the magnitude of the angle, measured relative to the straight-across direction, at which his friends should point the boat to minimize the distance Fred has to walk.

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**Answer:** arcsin ($v_c$/$v_m$)

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# Chapter 5

## Lesson 1: Force and Newton's First Law

**Question 1:** A force of 55 N pushes a cart to the right and a force of magnitude 63 N pushes the same cart to the left. What net force acts on the cart? Assume to the right is positive and to the left is negative.

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**Answer:** -8 N

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**Question 2:** A rocket in deep space is moving at 234.6 m/s. No net force acts on it. Can you tell what its velocity will be 32 seconds later? Explain your reasoning. Please submit your answer on paper.

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**Answer:** 234.6 m/s; no forces of friction or other act on a rocket in space.

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## Lesson 2: Newton's Second Law

**Question 1:** An asteroid of mass $4.9\times10^{18}$ kg is on a collision course with Earth. Our planet will be saved if the asteroid is given an acceleration of merely $1.4 \times 10^{-5}$ m/s$^2$ . Find the required force.

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**Answer:** $6.9 \times 10^{13}$ N

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**Question 2:** A student applies an upward force of 57 N to a 5.5-kg physics textbook. Find the book's acceleration (positive for up, negative for down).

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**Answer:** 10.4 m/s$^2$

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**Question 3:** An airplane of mass 2867 kg flies at a constant horizontal velocity. The force of air resistance on it is 2225 N. What is the net force on the plane (magnitude and direction)?

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**Answer:** 0 N (direction does not matter)

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**Question 4:** A 2.4 kg block moves at a constant velocity of 11 m/s. What net force is acting on it?

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**Answer:** 0

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**Question 5:** What is the suitcase's acceleration? Assume up is positive and down is negative.

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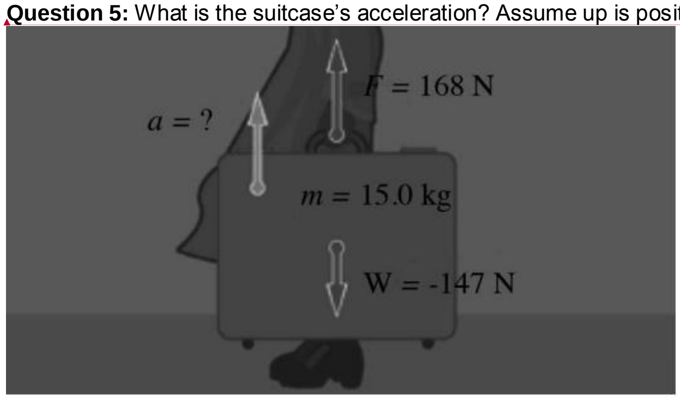


**Answer:** 1.4 m/s$^2$

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## Lesson 3: Newton's Third Law and Types of Forces

**Question 1:** A young elephant weighs 4170 N. What is its mass?

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**Answer:** 426 kg

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**Question 2:** A planet and an asteroid, with mass considerably smaller than that of the planet, collide head on. Which statement is correct?

**Answer:** The force of the planet on the asteroid is equal in magnitude to the force of the asteroid on the planet.

**Question 3:** A dog on Earth weighs 136 N. The same dog weighs 154 N on Neptune. What is the acceleration due to gravity on Neptune?

**Answer:** 11.1 m/s$^2$

**Question 4:** A 46.0-kg penguin stands on ice. A helium balloon is attached to the penguin by means of a harness and pulls upward with a force of 80.0 N. What is the normal force of the ice on the penguin?

**Answer:** 371 N

**Question 5:** Anna pushes horizontally on a 57 kg penguin with force of 19 N, but the penguin does not budge. Find the force of static friction between the penguin's feet and the ground.

**Answer:** 19 N

**Question 6:** A large crate has a mass of 214 kg. A horizontal force of positive 214 N is applied to it, causing it to accelerate at 0.130 m/s$^2$ horizontally. What is the force of friction opposing the motion of the crate? Use the correct sign to indicate the direction of the force of friction. It is the sole force opposing the crate's motion in this direction. Assume the applied force is to the right and right is defined as the positive direction.

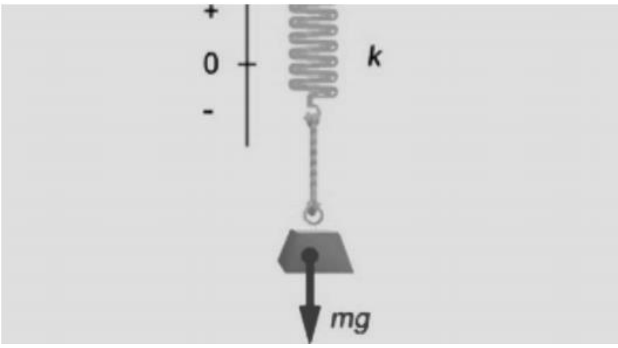
**Answer:** 186 N

**Question 7:** On a faraway moon, a space explorer ties a rope to a mass of 63.0 kg. An upward tension of 200 N causes the mass to accelerate up at 2.00 m/s$^2$ . What is the freefall acceleration on this moon? State the magnitude (positive) value of this acceleration.

**Answer:** 5.17 m/s$^2$

## Lesson 4: Forces that Change

**Question 1:** An object of mass 39.0 kg is suspended by a rope from a vertical spring, as in the figure. The spring constant is 650 N/m. Find the displacement of the end of the spring from its rest position (with its sign).




**Answer:** -0.59 m

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**Question 2:** An object moves through air and undergoes a drag force of 80.0 N. Its cross-sectional area is 0.110 m$^2$ , its drag coefficient is 0.810, and the density of air is 1.10 kg/m$^3$ . Find the object's speed.

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**Answer:** 40.4 m/s

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**Question 3:** A spring with spring constant 20 N/m is stretched 0.33 m in the positive x direction, referring to the figure. What is the spring's restoring force (with its sign)?

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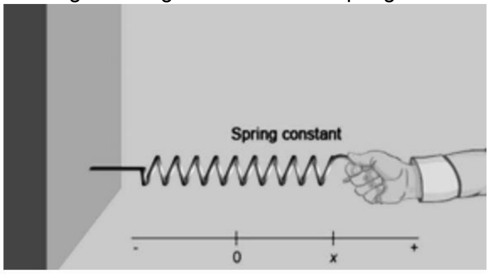


**Answer:** -6.6 N

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**Question 4:** A box of supplies is parachuted to the crew of a capsized fishing boat, stranded on a desolate island. On its way down, the falling box reaches a terminal velocity of 15.0 m/s. The parachute presents a cross-sectional area of 27.0 m$^2$ , its drag coefficient is 1.40, and the density of the air is 1.1 kg/m$^3$ . What is the combined mass of the box and parachute?

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**Answer:** 477 kg

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## Lesson 5: Free-body Diagrams

**Question 1:** The blocks in the diagram are connected by a massless cord and are being pulled to the right by an external force F. They are accelerating at 1 $m/s^2$ . The coefficient of kinetic friction between the blocks and the surface is 0.2. If needed, use g = 9.8 $m/s^2$ . The tension in the cord between the blocks is most nearly

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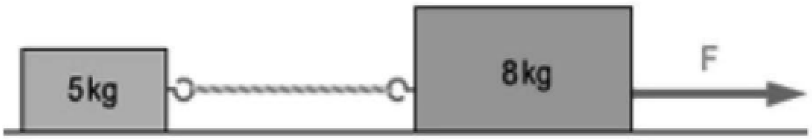


**Answer:** 15 N

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**Question 2:** In the illustrated setup the table is frictionless. The blocks' masses are mA = 4.0 kg and mB = 5.4 kg. What is the tension in the rope?

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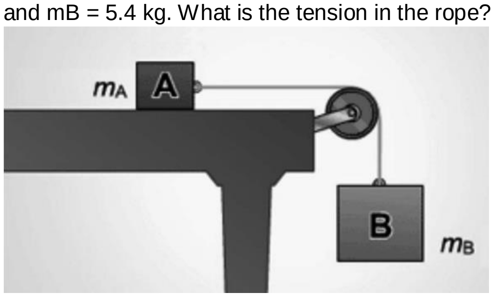


**Answer:** 53.0 N

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**Question 3:** A person with mass 80.0 kg stands on a scale in an elevator that is accelerating downward at 1.70 $m/s^2$ . Find the person's weight as shown by the scale.

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**Answer:** 648 N

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**Question 4:** The blocks in the diagram are connected by a massless cord and are being pulled to the right by an external force F. They are accelerating at 2 $m/s^2$ . If needed, use g = 9.81 $m/s^2$. With a coefficient of kinetic friction of 0.3, the external force acting on the 8 kg block is most nearly

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**Answer:** 64 N

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**Question 5:** Penguin Penelope, with a mass of 49 kg, stands on practically frictionless ice. She is pushed to the right with a force of 38 N by Penguin Peter, while Penguin Patty pushes her to

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the left with a 23-N force. To make matters worse, a wind simultaneously blows her to the left with a force of 8.0 N. What is Penelope's acceleration (positive to the right and negative to the left)?

**Answer:** 0.14 m/s$^2$

## Lesson 6: Force Problems Using Trigonometry

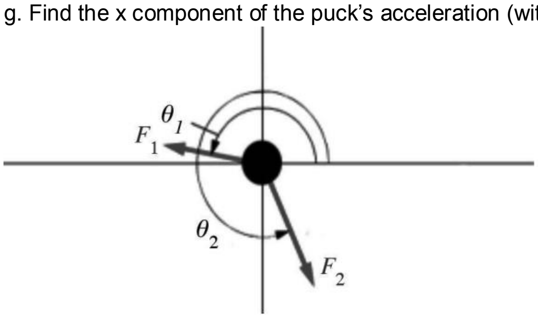
**Question 1:** A 46.0-kg penguin slides on its chest down a frictionless icy hill inclined at 29.0° from the horizontal. Find the normal force of the hill on the penguin.

**Answer:** 394 N

**Question 2:** A 7.8 kg chair is pushed across a frictionless floor with a force of 42 N that is applied at an angle of 22° downward from the horizontal. What is the magnitude of the acceleration of the chair?

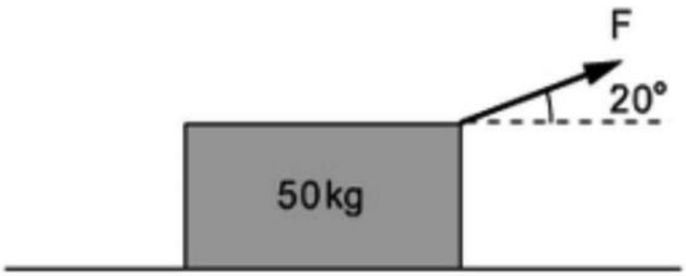
**Answer:** 5.0 m/s$^2$

**Question 3:** Two hockey players simultaneously strike the puck horizontally with forces $F_1$ = 330 N, $\theta_1$ = 170° and $F_2$ = 300 N, $\theta_2$ = 350°, as shown in the figure. The mass of the puck is 167 g. Find the x component of the puck's acceleration (with its sign).




**Answer:** -177 m/s$^2$

**Question 4:** A block of mass 3 kg slides along a horizontal surface while a 20-N force is applied to it at an angle of 25°, as shown. If needed, use g = 9.81 m/s$^2$ . For a coefficient of kinetic friction of 0.3 between the block and the surface, the frictional force acting on the block is most nearly




**Answer:** 11 N

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**Question 5:** A climber of mass 64.8 kg is rappelling down a cliff, but has momentarily paused. She stands with her feet pressed against the icy, frictionless rock face and her body horizontal. A rope of negligible mass is attached to her near her waist, 1.04 m horizontally from the rock face. There is 5.25 m of rope between her waist and where the rope is attached to a chock in the face of the vertical wall she is descending. Calculate the tension in the rope.

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**Answer:** 649 N

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# Chapter 6

## Lesson 1: Work

**Question 1:** An engine accelerates a go-kart at the rate of 1.20 m/s$^2$ for 2.40 meters. If the go-kart's mass is 155 kg, how much work does the engine do?

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**Answer:** 446.4 J

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**Question 2:** A locomotive has 2.000 × 10$^5$ J of kinetic energy and is stopped in 130.0 meters by a constant force directly opposing the motion. What is the force?

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**Answer:** -1538 J

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**Question 3:** A cart in a supermarket is pushed horizontally by a 200 N force for 3.00 meters. How much work is done?

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**Answer:** 600 J

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**Question 4:** Calculate how much work a 0.560 kg squirrel needs to perform in order to climb from the ground to the top of a 20.0 m high building.

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**Answer:** 110 J

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**Question 5:** Calculate how much work a 0.570 kg squirrel needs to perform in order to climb from the ground to the top of a 16.0 m high building.

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**Answer:** 89.4 J

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**Question 6:** A force applied to a tennis ball is described by the function F(x) = 2.00x + 5.00, with the force *F* in newtons and the position *x* in meters. How much work does it do on a tennis ball that moves from −2.00 m to a new position at 3.00 m?

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**Answer:** 30 J

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## Lesson 2: Work: Force at an Angle

**Question 1:** In the diagram, the displacement Δx is 3.00 m, the angle is θ = 40°, and the force F = 140 N. Find the work the woman performs.

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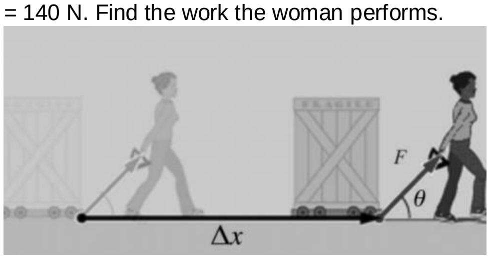


**Answer:** W= 322 J

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**Question 2:** A parent pushes a baby stroller from home to daycare along a level road with a force of 48 N directed at an angle of 30° below the horizontal. If daycare is 0.83 km from home, how much work is done by the parent?

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**Answer:** 34502 J

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**Question 3:** An airline pilot pulls her 12.0 kg rollaboard suitcase along the ground with a force of 25.0 N for 10.0 meters. The handle she pulls on makes an angle of 47.0 degrees with the horizontal. How much work does she do over the ten-meter distance?

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**Answer:** 171 J

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**Question 4:** When playing shuffleboard, a player exerts a constant force of 3.3 N on an initially stationary puck, at an angle 55° below the horizontal. If the player pushes the puck for 1.5 m, how fast is the puck moving when it is released? The mass of a puck is 0.49 kg. Ignore the force of friction.

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**Answer:** 3.41 m/s

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## Lesson 3: Kinetic Energy

**Question 1:** How much mass, moving at 5.6 m/s, has a kinetic energy of 33 J?

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**Answer:** 2.1 kg

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**Question 2:** What constant horizontal force, acting over 29 m of level trail, gives a friction-free 57 kg skier, starting from rest, a speed of 6.8 m/s?

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**Answer:** 45 N

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**Question 3:** A 0.50 kg cream pie strikes a circus clown in the face at a speed of 5.00 m/s and stops. What is the change in kinetic energy of the pie?

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**Answer:** -6.3J

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**Question 4:** A person pushes a penguin, doing 320 J of work on the 54 kg penguin sliding over frictionless ice at an initial speed of 2.9 m/s. Find the penguin's final speed.

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**Answer:** 4.5 m/s

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## Lesson 4: Potential Energy

**Question 1:** Two boxes of the same mass are lifted to the same height. Does it necessarily take the same amount of power to lift each box?

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**Answer:** No

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**Question 2:** Right before it is dropped from rest, a rock has 2900 J of total energy. If a few moments later it has 1200 J of potential energy, how much kinetic energy does it now have?

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**Answer:** $KE_f$ = 1700 J

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**Question 3:** A child on a swing pumps hard and achieves a speed of 6.6 m/s at the swing's lowest point. She then stops pumping. How high above the lowest point does the swing reach after that?



**Answer:** 2.2 m



**Question 4:** A spring with spring constant 300 N/m is compressed by 0.060 m and then used to propel a 0.0080 kg ball from the ground at an angle of 35° above horizontal. If needed, use g = 10 $m/s^2$. Assuming level ground and no air resistance, the speed of the ball immediately before striking the ground is most nearly



**Answer:** 12 m/s



**Question 5:** A 4.0-kilogram rocket is launched from the ground with an initial velocity of 25 m/s. It accelerates at −1.5 $m/s^2$. Graph its potential energy for the first 4 seconds of its motion. Please submit your answer on paper.

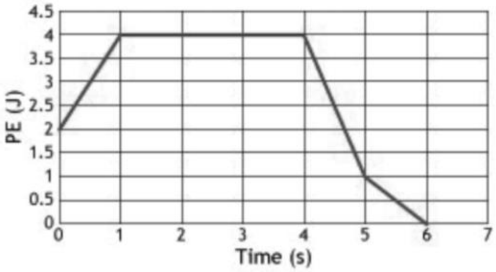


**Answer:** Potential energy increases depending on height of rocket at each second.



**Question 6:** Describe how the potential energy of the system increases, decreases, or stays the same, using the graph that you see.






**Answer:** Potential energy increases, stays the same, then decreases to 0.



## Lesson 5: Energy Conservation and Energy Transfer

**Question 1:** A child on a swing pumps hard and achieves a speed of 7.1 m/s at the swing's lowest point. She then stops pumping. How high above the lowest point does the swing reach after that?



**Answer:** 2.6 m

**Question 2:** A bungee jumper jumps from a high bridge with one end of the bungee cord attached to him and other end to the bridge. He does not hit the water. Ignoring air resistance and nonmechanical forms of energy, choose the correct statement. At the lowest point in the jumper's motion, the gravitational potential energy he loses in the process has converted to

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**Answer:** Elastic Potential Energy

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**Question 3:** Mechanical energy is conserved in the system whose energy is shown in the graph. All energy in the system is either kinetic energy, or potential energy. Graph, on a separate piece of paper, the potential energy of the system for the first 6 seconds.Please submit your answer on paper.

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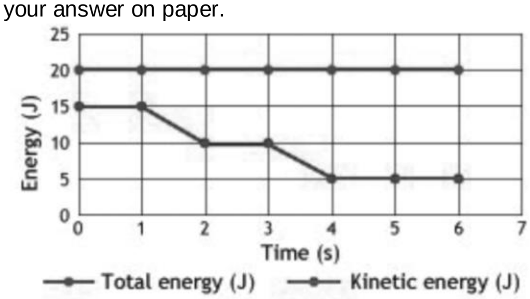


**Answer:** Potential energy + Kinetic energy should always equal total energy.

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**Question 4:** During 18 s an engine increases the speed of a 1800 kg vehicle from 15 m/s to 28 m/s. Assuming no losses, what average power is the engine producing?

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**Answer:** 27950 W

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**Question 5:** A rock starts at ground level with 649 joules of kinetic energy and rises until it ceases moving. What is its gravitational potential energy at this point?

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**Answer:** 649 J

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**Question 6:** An engine does 290 J of work per minute. What is its power in watts?

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**Answer:** 4.83 W

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**Question 7:** Lamborghini states that its 2004 Murciélago® has a mass of 1650 kg. On a particular test run, its 580 hp (433 kW) engine accelerates the car from 0 to 100 km/h (62 mph) in 3.60 seconds. Assume the engine is working at its maximum power. How much energy is consumed by dissipative forces like air resistance and friction as the car accelerates from 0 to 100 km/h?

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**Answer:** $9.23 \times 10^5$ J

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**Question 8:** Jin is sitting on top of a hemispherical, frictionless igloo of radius 2.40 meters. His friend pushes him, giving him an initial speed. Jin slides along the igloo and loses contact with it after he has traveled 1.60 meters along the surface. What was his initial speed?

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**Answer:** 2.9 m/s

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# Chapter 7

## Lesson 1: Momentum

**Question 1:** What is the velocity of a 11 kg puppy that has 1.8 kg • m/s of momentum?

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**Answer:** 0.2 m/s

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**Question 2:** A tennis ball bounces off a wall. Which is the correct statement?

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**Answer:** The impulse that the ball exerts on the wall is equal in magnitude to the impulse that the wall exerts on the ball.

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**Question 3:** Belle is playing tennis. The mass of the ball is 0.0567 kg and its speed after she hits it is 22.8 m/s. What is the magnitude of the momentum of the ball?

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**Answer:** 1.29 kg * m/s

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**Question 4:** A ball of mass 2.0 kg strikes the floor vertically at 5.0 m/s and rebounds with an initial speed of 3.0 m/s. The magnitude of the impulse that the floor exerts on the ball during this process is

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**Answer:** 16 kg • m/s

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**Question 5:** A golden retriever is sitting in a park when it sees a squirrel. The dog starts running, exerting a constant horizontal force of 89 N against the ground for 3.2 seconds. What is the magnitude of the dog's change in momentum?

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**Answer:** $2.8 \times 10^2$ kg • m/s

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**Question 6:** A rocket is moving through intergalactic space. It fires its side thrusters, ejecting spent fuel perpendicular to itself. The rocket has a constant velocity of 1504 m/s, but its momentum falls from $1.510 \times 10^5$ kg • m/s to $1.470 \times 10^5$ kg • m/s. What is its change in mass, with the correct sign?

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**Answer:** -2.7 kg

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## Lesson 2: Conservation of Momentum

**Question 1:** Two equal-mass balls with speeds 10 m/s and 8 m/s collide head-on, as shown, and bounce off each other along the original line of motion. The speeds of the balls after the collision could possibly be (not necessarily in the same order)

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**Answer:** 9 m/s and 7 m/s

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**Question 2:** An ice skater of mass M glides with speed v while carrying her favorite physics textbook, which has mass m. The skater then hurls the textbook in the forward direction, which causes her to come to a stop. What is the speed of the book relative to the ice immediately after it is thrown?

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**Answer:** (M + m)v/m

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**Question 3:** A stationary 3.50 kg rifle shoots a 0.0150 kg bullet with a velocity of positive 220 m/s. With what velocity does the rifle recoil? Recoil is a rifle’s movement after firing a bullet.

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**Answer:** 0.943 m/s

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**Question 4:** An astronaut holding a 0.390 kg box drifts to the left with an initial momentum (including that of the box) of 210 kg • m/s. He wants to throw the box to the left to stop his motion. With what velocity relative to the Earth should he toss the box? Assume right is in the positive direction and left is in the negative direction.

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**Answer:** -538 m/s

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**Question 5:** A 1.6 kg red ball moving at 3.5 m/s strikes a stationary blue 3.2 kg ball and bounces back at 0.15 m/s, causing the blue ball to start moving forward. What is the velocity of the blue ball immediately after the collision? Assume forward is positive.

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**Answer:** 1.68 m/s

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## Lesson 3: Collisions

**Question 1:** Object A is moving when it has a head-on collision with stationary object B. No external forces act on the objects. Which of the following situations are possible after the collision? Check all that are possible.

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**Answer:** A and B move in the same direction, A and B move in opposite directions, A is stationary and B moves.

**Question 2:** A boy leaps with 220 kg • m/s of momentum onto a sled moving with 40.0 kg • m/s of momentum. What is their combined momentum after the boy leaps on?

**Answer:** 260 kg • m/s

**Question 3:** A quarterback is standing stationary waiting to make a pass when he is tackled from behind by a linebacker moving at 4.75 m/s. The linebacker holds onto the quarterback and they move together in the same direction as the linebacker was moving, at 2.60 m/s. If the linebacker's mass is 143 kg, what is the quarterback's mass?

**Answer:** 118 kg

**Question 4:** A 1.30 kg book is resting on a horizontal surface. A large 0.120 kg spitball slides horizontally and sticks to the book. The book moves 0.320 m before coming to a rest. If the coefficient of kinetic friction between the book and the surface is 0.670, what was the speed of the spitball when it struck the book?

**Answer:** 24.3 m/s

## Lesson 4: Center of Mass

**Question 1:** Two small spheres are positioned along the x-axis with their centers at −0.72 m and 0.33 m. Their respective masses are 0.74 kg and 0.16 kg. Find the x-coordinate of the center of mass of the two spheres.

**Answer:** -0.53 m

**Question 2:** Two balls approach each other head-on, one with velocity +4.5 m/s, and the other with twice the mass of the first and velocity −3.2 m/s. What is the velocity of the center of mass of the system?

**Answer:** -0.63 m/s

**Question 3:** How far is the center of mass of the Earth-Moon system from the center of the Earth? The Earth's mass is $5.97 \times 10^{24}$ kg, the Moon's mass is $7.4 \times 10^{22}$ kg, and the distance between their centers is $3.8 \times 10^{8}$ m.

**Answer:** 4.65 x $10^6$ m

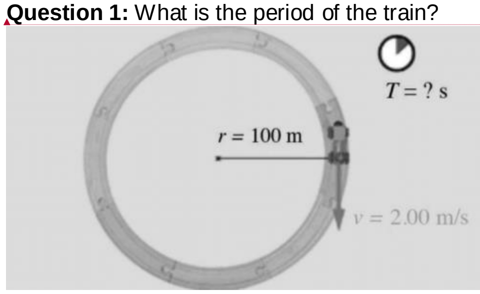
**Question 4:** A future space traveler is in an escape capsule, far from any significant sources of gravity. To fix his emergency beacon, he climbs the entire length of a ladder, in the positive direction, that runs from one end of the capsule to the other. As he climbs, the capsule undergoes a displacement of −14.5 m. If the capsule has a mass of 5.00 × $10^3$ kg and the space traveler has a mass of 95.0 kg, what is the length of the capsule? Assume that the capsule's center of mass is halfway between its ends. Note that the art is not to scale.

**Answer:** 763 meters

# Chapter 8

## Lesson 1: Circular Motion

**Question 1:** What is the period of the train?




**Answer:** T = 314 s

**Question 2:** A bicycle rider pedals around a circular track at 5.0 m/s. The track's radius is 61 m. What is the period of the bicyclist's motion?

**Answer:** 77 s

**Question 3:** In order to give the inhabitants near the rim of a cylindrical space station the feeling of Earth's gravity, the station rotates. The station has a radius of 560 m. At what linear speed must the rim rotate so its inhabitants experience the acceleration g?

**Answer:** 74 m/s

**Question 4:** A fighter pilot in training experiences “artificial gravity” in a device that swings her around in a horizontal circle of radius 9.7 m. Find her speed when her centripetal acceleration is 2.4 times the acceleration due to gravity.

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**Answer:** 15 m/s

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**Question 5:** A carousel’s outer edge moves at 4.8 m/s and the carousel completes a rotation every 10 seconds. Find the carousel’s radius.

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**Answer:** 7.6 m

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## Lesson 2: Centripetal Force

**Question 1:** A 46 kg girl slides around a circular segment of a water slide at a speed of 4.7 m/s. The radius of the circle segment is 13 m. What centripetal force acts on the girl?

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**Answer:** 78 N

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**Question 2:** A bee loaded with pollen flies in a circular path at a constant speed of 3.20 m/s. If the mass of the bee is 133 mg and the radius of its path is 11.0 m, what is the magnitude of the centripetal force?

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**Answer:** $1.2 \times 10^{-4}$ N

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**Question 3:** A level road has a section in the form of an unbanked circular arc with radius 150 m. A police car in a high-speed chase successfully negotiates this section at 55 m/s. The smallest possible value of the coefficient of static friction between the tires and the road is most nearly

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**Answer:** 2.1

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**Question 4:** Find the minimum speed of a roller coaster at the top of a vertical loop for a roller coaster with a mass of 2400 kg to complete the loop. The radius of the loop is 16 m.

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**Answer:** 13 m/s

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**Question 5:** You are playing tetherball with a friend and hit the ball so that it begins to travel in a circular horizontal path. If the ball is 1.2 meters from the pole, has a speed of 3.7 m/s, a mass of 0.42 kilograms, and its (weightless) rope makes a 49° angle with the pole, find the tension force that the rope exerts on the ball just after you hit it.

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**Answer:** 6.3 N

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## Lesson 3: Newton's Laws of Gravity

**Question 1:** If the gravitational force between a star and its planet of mass $5.0 \times 10^{30}$ kg is $1.1 \times 10^{21}$ N, and they are separated by distance $7.0 \times 10^{15}$ m, what must the mass of the star be?
**Answer:** $1.6 \times 10^{32}$ kg

**Question 2:** The top of Mt. Everest is 8850 m above sea level. Assume that sea level is at the average Earth radius of $6.38 \times 10^{6}$ m. What is the magnitude of the gravitational acceleration at the top of Mt. Everest? The mass of the Earth is $5.97 \times 10^{24}$ kg.

**Answer:** 9.76 $m/s^2$

**Question 3:** What is the magnitude of the difference in the acceleration of gravity between the surface of the water in a swimming pool at sea level and the surface of an Olympic diving platform, 10.0 meters above? Report the answer to three significant figures.

**Answer:** $3.07 \times 10^{-5}$ $m/s^2$

**Question 4:** Jupiter's mass is $1.90 \times 10^{27}$ kg. Find the acceleration due to gravity at the surface of Jupiter, a distance of $7.15 \times 10^{7}$ m from its center.

**Answer:** 24.8 $m/s^2$

**Question 5:** Puah, a member of the Planetary Penguin Platoon, has a mass of 92.0 kg, including her space suit and propulsion unit. With what gravitational force is Puah pulled toward Earth when she is hovering at an altitude of $3.70 \times 10^{6}$ m above Earth's surface? The mass of the Earth is $5.98 \times 10^{24}$kg and the radius of Earth is $6.38 \times 10^{6}$ m.

**Answer:** 361 N

**Question 6:** Imagine that the mass of the Sun doubled, and the distance between the Sun and Earth also doubled. What would be the effect on the gravitational force between them?

**Answer:** The force would be halved.

**Question 7:** Imagine the force of gravity ceased to function. How would the Moon's motion around the Earth change?

**Answer:** Like a rock from a sling, the moon would fly into space tangent to its rotation around Earth.

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## Lesson 4: Circular Orbits

**Question 1:** Calculate the escape speed from the surface of Venus, whose radius is $6.05 \times 10^6$ m and mass is $4.87 \times 10^{24}$ kg. Neglect the influence of the Sun's gravity.

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**Answer:** $1.0 \times 10^4$ m/s

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**Question 2:** Astronauts made an emergency landing on an asteroid of mass $9.00 \times 10^{20}$ kg and radius $2.30 \times 10^5$ m to replenish their spaceship's fuel supply. Their spaceship has a mass of $2.00 \times 10^4$ kg. They are ready to leave. Calculate their spaceship's minimum escape speed.

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**Answer:** 722 m/s

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**Question 3:** An asteroid orbits the Sun at a constant distance of $3.63 \times 10^{11}$ meters. The Sun's mass is $1.99 \times 10^{30}$ kg. What is the orbital speed of the asteroid?

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**Answer:** $1.91 \times 10^4$ m/s

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**Question 4:** The average density of Neptune is $1.67 \times 10^3$ kg/m$^3$. What is the escape speed at the surface? Neptune's radius is $2.43 \times 10^7$ m.

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**Answer:** $2.34 \times 10^4$ m/s

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**Question 5:** Jupiter's moon Callisto orbits the planet at a distance of $1.88 \times 10^9$ m from the center of the planet. Jupiter's mass is $1.90 \times 10^{27}$ kg. What is the period of Callisto's orbit, in hours?

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**Answer:** 400 hours

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**Question 6:** In a distant galaxy, a planet moves in a perfectly circular orbit around its sun. Does the planet's motion "obey" Kepler's first law concerning elliptical orbits?

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**Answer:** Yes. A circle is a special case of an ellipse where both focal points are located at the sun.

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**Question 7:** Johannes Kepler died before Sir Isaac Newton was born. Research and explain how Kepler was able to reach his conclusions without Newton's law of gravity.

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**Answer:** Answers may vary. One inspiration to scientists of Kepler's era was comets. These showy objects inspired scientists to understand their orbits, in part to predict when they would return. A crucial piece of the puzzle was what we now call Kepler's laws of orbits. Based on

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observations made by the Danish scientist Tycho Brahe, Johannes Kepler had concluded that planets move in elliptical orbits, and deduced other aspects of their motion. However, he could not explain why. Technology also played a crucial role. In the decades preceding Newton, optical telescopes were conceived of, built, and significantly improved. Previously, astronomy had been done without the benefit of lenses or mirrors. Scientists across the world could now make astronomical observations.

# Chapter 9

## Lesson 1: Rotational Motion

**Question 1:** You walk along the edge of a large circular lawn. You walk clockwise from your starting location until you have moved an angle of π radians. What geometric shape is defined by the following three points: your starting position, your final position, and the center point of the lawn?

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**Answer:** Straight Line

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**Question 2:** A right triangle has sides of length 1, 2 and the square root of 3. In radians, what is its smallest angle?

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**Answer:** ***π***/6 radians

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## Lesson 2: Fundamental Equations

**Question 1:** A central angle of 0.92π rad cuts an arc of length 7.5 m on a circle. Find the circle's radius.

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**Answer:** 8.2 m

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**Question 2:** The toy train starts from rest and reaches its final angular velocity in the time shown. What is its average angular acceleration?

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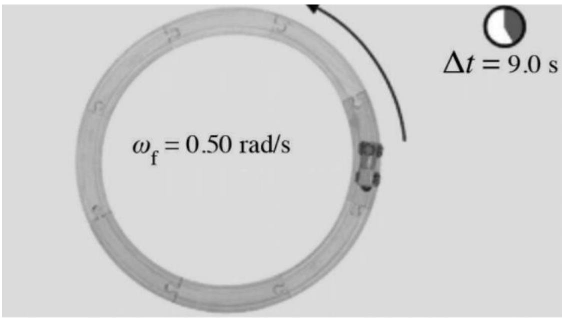


**Answer:** 0.056 rad/s$^2$

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**Question 3:** The toy train starts from rest and reaches its final angular velocity in the time shown. What is its average angular acceleration?

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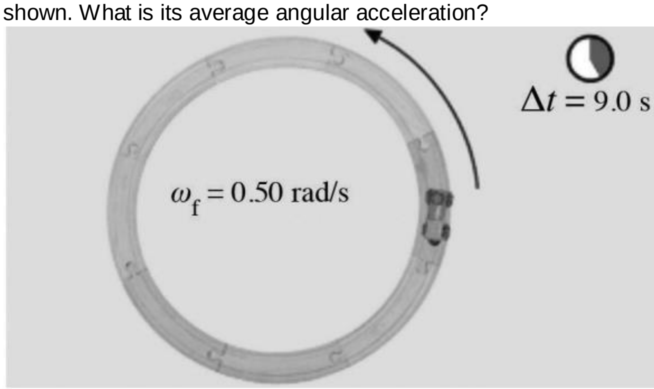


**Answer:** 1/18 rad/s$^2$

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**Question 3:** The blades of a fan rotate clockwise at −225 rad/s at medium speed, and −355 rad/s at high speed. If it takes 4.05 seconds to get from medium to high speed, what is the average angular acceleration of the fan blades during this time?

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**Answer:** -32.1 rad/s$^2$

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**Question 4:** An LP record rotates at 33 1/3 rpm (revolutions per minute) and is 12.0 inches in diameter. What is the angular velocity in rad/s for a fly sitting on the outer edge of an LP rotating in a clockwise direction?

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**Answer:** 3.49 rad/s

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## Lesson 3: Advanced Equations

**Question 1:** A potter's wheel rotates initially at the angular velocity of 13 rad/s. The motor is turned off, and has an angular acceleration of −2.6 rad/s$^2$ until it stops. What is the wheel's angular displacement as it stops?

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**Answer:** 32.5 rad

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**Question 2:** You accelerate your car from rest at a constant rate down a straight road, and reach 22.0 m/s in 115 s. The tires on your car have radius 0.320 m. Assuming the tires rotate in a counterclockwise direction, what is the angular acceleration of the tires?

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**Answer:** 0.095 rad/s$^2$

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**Question 3:** A cyclist starts from rest and rides in a straight line, increasing speed so that her wheels have a constant angular acceleration of 2.0 rad/s$^2$ around their axles. She accelerates until her wheels are rotating at 8.0 rad/s. If the radius of a tire is 0.30 meters, how far has the cyclist traveled?

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**Answer:** 4.8 m

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**Question 4:** A pair of pants is hanging on the clothesline when a tornado strikes. The pants are pulled off the clothesline by the tornado and accelerated in a circle of radius 44.0 m. The tangential acceleration is constant and the pants take 13.8 seconds to complete two revolutions. What is the magnitude of the average tangential acceleration during the two revolutions (assuming that they start with zero velocity?

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**Answer:** 5.81 m/s$^2$

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## Lesson 4: Torque

**Question 1:** You want to exert a torque of at least 35.0 N • m on a wrench whose handle is 0.150 m long. If you can provide a force of 355 N to the end of the wrench, what is the minimum angle at which you can apply the force in order to achieve the desired torque?

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**Answer:** 41.1 °

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**Question 2:** Bob and Ray push on a door from opposite sides. They both push perpendicular to the door. Bob pushes 0.63 m from the door hinge with a force of 89 N. Ray pushes 0.57 m from

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the door hinge with a force of 98 N, in a manner that tends to turn the door in a clockwise direction. What is the net torque on the door?

**Answer:** .21 N * m counterclockwise

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**Question 3:** The wheel on a car is held in place by four nuts. Each nut should be tightened to 94.0 N • m of torque to be secure. If you have a wrench with a handle that is 0.250 m long, what minimum force do you need to exert perpendicular to the end of the wrench to tighten a nut correctly?

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**Answer:** 376 N

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**Question 4:** A 1.1 kg birdfeeder hangs from a horizontal tree branch. The birdfeeder is attached to the branch at a point that is 1.2 m from the trunk. What is the amount of torque exerted by the birdfeeder on the branch? The origin is at the pivot point, where the branch attaches to the trunk.

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**Answer:** 13 N * m

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**Question 5:** A 3.30 kg birdfeeder hangs from the tip of a 1.90 m pole that sticks up from the ground at a 65.0° angle. What is the magnitude of the torque exerted on the pole by the birdfeeder? Treat the bottom end of the pole as the pivot point.

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**Answer:** 26.0 N * m

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## Lesson 5: Torque and Angular Acceleration

**Question 1:** On which of the following does the moment of inertia depend?

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**Answer:** Shape of the object, Mass, Location of axis of rotation

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**Question 2:** What is the formula for the moment of inertia of a hollow sphere of mass M and radius R, rotated on an axis tangent to its surface?

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**Answer:** $(5/3)MR^2$

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**Question 3:** Find the angular acceleration created by a net torque of 288 N • m acting on a flywheel with moment of inertia 28.4 kg • $m^2$ .

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**Answer:** 10.1 rad/$s^2$

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**Question 4:** For a wheel with moment of inertia 49.3 kg • $m^2$ , what net torque is required to produce an angular acceleration of 3.05 rad/$s^2$ ?

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**Answer:** 150 N * m

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**Question 5:** Four small balls are arranged at the corners of a rigid metal square with sides of length 3.0 m. An axis of rotation in the plane of the square passes through the center of the square, and is parallel to two sides of the square. On one side of the axis, the two balls have masses 1.8 kg and 2.3 kg; on the other side, 1.5 kg and 2.7 kg. The mass of the square is negligible compared to the mass of the balls. What is the moment of inertia of the system for this axis?

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**Answer:** 19 kg * $m^2$

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## Lesson 6: Angular Momentum

**Question 1:** A spinning object makes 5.8 revolutions each second and has an angular momentum of 14 kg • $m^2$ /s. What is its moment of inertia?

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**Answer:** 1.2 kg * $m^2$

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**Question 2:** A steady wind exerts a torque of 0.35 N • m on a frictionless wind turbine for 55 s. Find the resulting change in the turbine's angular momentum.

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**Answer:** 19 kg * $m^2$/s

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**Question 3:** An ice skater spins on the tip of her skate and gradually pulls in her arms and leg to reduce her moment of inertia by a factor of 2.9. Ignoring external torques, by what factor does the skater's angular velocity increase?

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**Answer:** 2.9

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**Question 4:** What is the magnitude of angular momentum of a 1430 kg car going around a circular curve with a 15.0 m radius at 12.0 m/s? Assume the origin is at the center of the curve's arc.

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**Answer:** 257400 kg * $m^2$/2

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**Question 5:** The angular momentum of a spy satellite needs to be reduced by 130 kg • $m^2$ /s during a 12.0-s burn of the thruster rockets. Find the magnitude of the constant torque that the thruster rockets should exert to accomplish this.

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**Answer:** 10.8 N * m

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**Question 6:** A bicyclist rides down the street. From her point of view, what is the direction of the angular momentum vector due to her wheel rotation?

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**Answer:** To her left

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# Chapter 10

## Lesson 1: Fluids, Pressure and Density

**Question 1:** You have 62 g of a substance with density 1100 kg/m$^3$ . What is the volume in cubic centimeters?

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**Answer:** 56 cm$^3$

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**Question 2:** What perpendicular force acts on a 17.0-m$^2$ floor when the pressure on the floor is 990 Pa?

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**Answer:** 16830 N

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**Question 3:** A volume of 1.800 m$^3$ of a substance is found to possess a mass of 2726 kg. What is the substance’s density?

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**Answer:** 1514 kg/m$^3$

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**Question 4:** A spacecraft of weight 7.0 × 10$^4$ N rests on the surface of a planet and applies a pressure of 1800 Pa on the surface. What is the area of the spacecraft that is in contact with the surface?

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**Answer:** 39 m$^2$

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**Question 5:** An automobile has four tires, each one inflated to a gauge pressure of 24.0 psi, or 1.66 × 10$^5$ Pa. Each tire is slightly flattened by its contact with the ground, so that the area of contact is 17.5 cm by 12.0 cm. What is the weight of the automobile?

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**Answer:**1.39 x 10$^4$ N

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## Lesson 2: Pressure in Liquids

**Question 1:** What is the pressure at the bottom of the tank due to the weight of the water alone?

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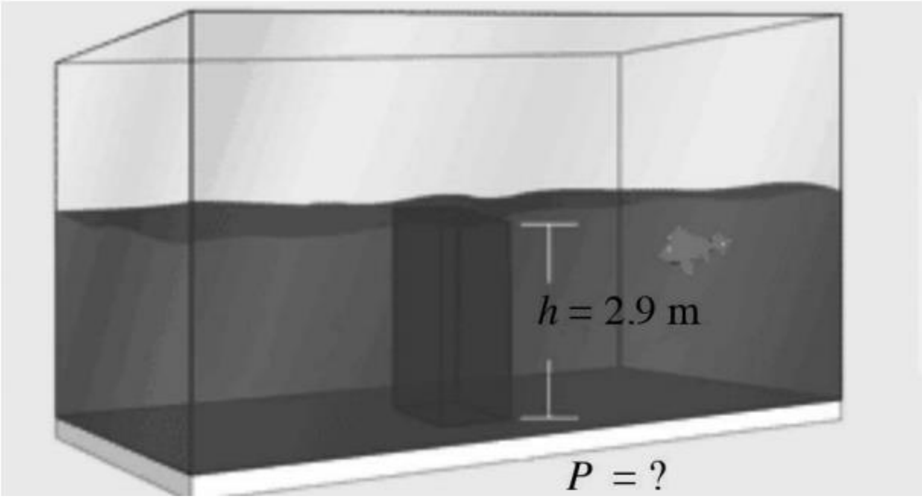


**Answer:** 28335 Pa

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**Question 2:** Robert Ballard's submersible robot is used for deep-sea exploration (like investigating the Titanic). It can dive up to 4350 meters deep. What pressures can it withstand? Assume that the average density of sea water is 1,030 kg/m$^3$ and ignore atmospheric pressure.

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**Answer:** 4.4 x 10$^7$

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**Question 3:** The density of mercury is 13,600 kg/m$^3$ and that of ethanol 790 kg/m$^3$ . Tanks of mercury and ethanol are open to the atmosphere. The depth in the mercury at which the pressure equals the pressure in the ethanol at a depth of 2.8 m is most nearly

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**Answer:** 0.16m

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**Question 4:** What is the gauge pressure exerted on the bottom of a beaker by mercury that fills the beaker to a height of 8.4 cm?

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**Answer:** 11196 Pa

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## Lesson 3: Pressure on Earth

**Question 1:** Find the absolute pressure at the bottom of a beaker filled with mercury to a height of 19 cm. The atmospheric pressure is $1.01 \times 10^5$ Pa.

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**Answer:** 126323 Pa

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**Question 2:** What is the absolute pressure, including atmospheric pressure, pressing down at the bottom of a water tank?

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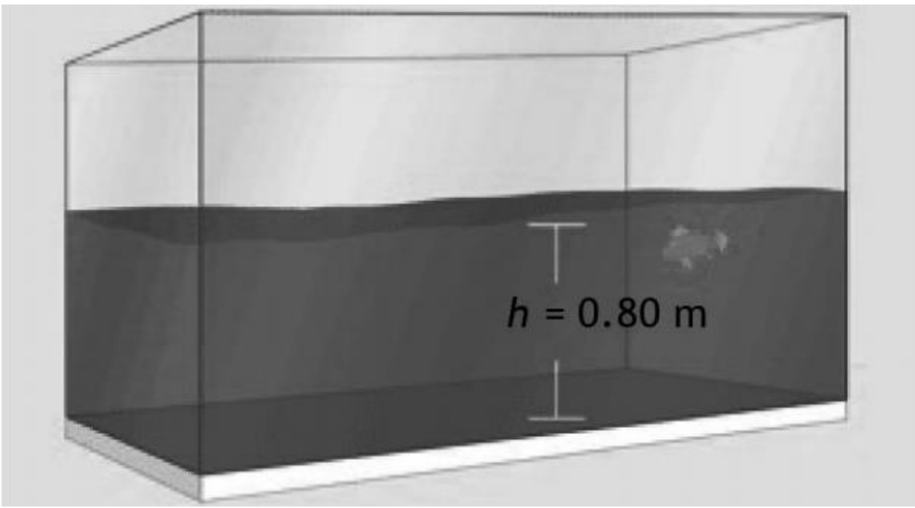


**Answer:** 108,816 Pa

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**Question 3:** What pressure acts on a sunken ship at the depth of 160 m? The atmospheric pressure is $1.01 \times 10^5$ Pa and the density of sea water is 1025 $kg/m^3$ .

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**Answer:** 1708200 Pa

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**Question 4:** Explain what properties of water allow some creatures (such as the aptly-named water striders, or fishing spiders) to “walk on water.”

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**Answer:** Surface tension. Due to attraction in water molecules, creatures below a certain weight don’t apply enough pressure to break the surface tension so they can walk across water.

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## Lesson 4: Archimedes’ Principle

**Question 1:** At a depth of 240.0 meters in a certain fluid, a cubic meter of lead experiences a buoyant force of 9700 N. Lead has a density of $1.135 \times 10^4$ $kg/m^3$ . At the same depth, what would be the buoyant force acting on a cubic meter of wood, which has a density of 745.0 $kg/m^3$?

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**Answer:** 9700 N

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**Question 2:** An empty boat is placed in a freshwater lake and a mark is painted on the hull at the waterline, a line corresponding to the surface of the water when the vessel is floating upright. The boat is then transported to the Dead Sea, where the liquid density is about 1.2 times that of fresh water due to the high concentration of salts. A waterline mark is noted in the Dead Sea. Compared to the first waterline mark, where is the new waterline mark located on the hull of the boat?

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**Answer:** Lower

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**Question 3:** An object is placed in each of three liquids. In liquid A it sinks, in liquid B it floats while partially submerged, and in liquid C it floats while wholly submerged. The densities of these liquids have the relationship

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**Answer:** $P_A < P_C < P_B$

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**Question 4:** In the motion picture Danny Deckchair, based on an actual event, a man attaches 42 helium-filled weather balloons to an aluminum deck chair, steps in, and takes off to experience a series of adventures. (Don't try this at home – or anywhere else!) The weight of the man plus the chair plus the balloons is 929 N. Each balloon is a sphere 1.60 meters in diameter. The density of air at sea level and 15.0°C is 1.23 kg/m$^3$ . What is the net upward force on Danny and his vehicle right after he leaves the ground? Ignore the volume of the man and of the deckchair.

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**Answer:** 159 N

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**Question 5:** A penguin with a volume of 0.0320 m$^3$ dives into the ocean (density 1030 kg/m$^3$ ) to catch an underwater lunch. Find the buoyant force on the penguin.

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**Answer:** 323 N

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## Lesson 5: Pascal's Principle and Fluid Continuity

**Question 1:** Find the volume flow rate of a fluid flowing at 3.3 m/s through a tube of circular crosssection, with diameter 5.4 cm

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**Answer:** $7.5 \times 10^{-3}$ m$^3$/s

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**Question 2:** An incompressible fluid flows through a circular pipe at a speed of 15.0 m/s. The radius of the pipe is 5.00 cm. There is a constriction of the pipe where the radius is only 3.20 cm. How fast must the fluid flow through the constricted region?

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**Answer:** 36.6 m/s

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**Question 3:** The open end of a garden hose is directed horizontally, at a height of 1.25 m above the ground. Water issues from the hose and follows a falling parabolic trajectory to strike the ground 2.41 m away. A gardener holding the hose wishes to water some plants that are 5.12 m distant. What fraction of the hose end should she cover with her thumb? Assume that she continues to hold the hose end horizontally at the same height, and be careful to tell the fraction **covered**, not the fraction left open.

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**Answer:** 263/500

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**Question 4:** A person with mass 61 kg sits on a piston (radius 0.13 m) of a hydraulic lift. A puppy sits on the other piston of the lift (radius 0.018 m). What is the mass of the puppy if the puppy on its piston balances the person on his piston?

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**Answer:** 1.2 kg

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**Question 5:** An incompressible fluid flows steadily upward through a circular pipe, as shown in the diagram in cross section. The diameter of the wide section is greater than that of the narrow section by a factor of 2.3. The ratio of flow speeds $v_n$ /$v_w$ is most nearly

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**Answer:** 5.3

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## Lesson 6: Bernoulli's Principle

**Question 1:** A stream of water is flowing through the horizontal configuration shown. The crosssectional areas of the left and right pipes are $A_1$ = 0.762 m$^2$ and $A_2$ = 0.115 m$^2$ , and the velocity $v_1$ is 0.534 m/s. The pressure P1 is 7.21 × 10$^4$ Pa. The density of water is 1,000 kg/m$^3$ . What is P2 ?

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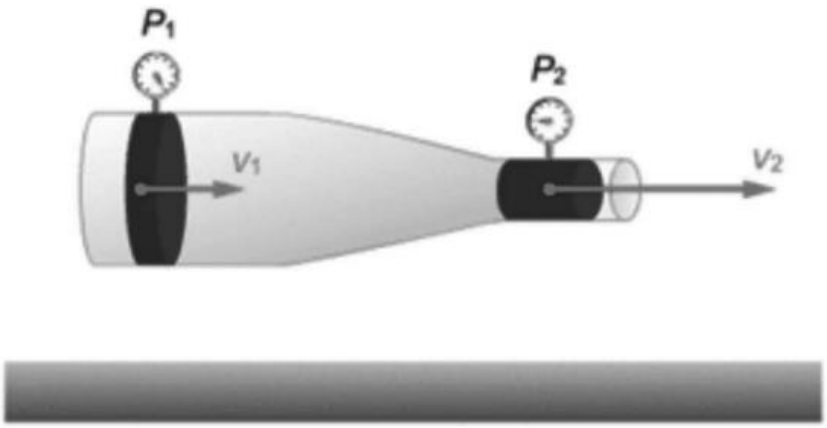


**Answer:** 6.6 x $10^4$ Pa

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**Question 2:** A stream of water is flowing through the horizontal configuration shown. The speeds $v_1$ and $v_2$ are 2.75 m/s and 5.35 m/s, respectively. The pressure P2 is 7.36 × $10^4$ Pa. The density of water is 1,000 kg/$m^3$ . What is P1 ? (Hint: the numbers on the pressure dials are not correct – that would be too easy!)

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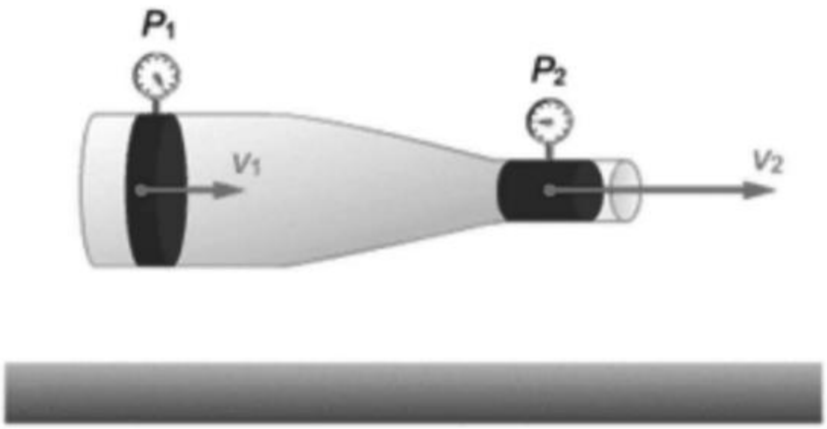


**Answer:** 8.4 x $10^4$ Pa

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**Question 3:** Water, with a density of 1,000 kg/$m^3$ , flows steadily from left to right through a circular pipe, as shown in the diagram, in cross section. The flow speed in the narrow section is 3.2 m/s and the diameter of the wide section is greater than that of the narrow section by a factor of 1.9. (If needed, take g = 10 m/$s^2$ .) The pressure difference pw – pn most nearly equals

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**Answer:** $4.7 \times 10^3$ Pa

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**Question 4:** An incompressible fluid flows steadily in a horizontal pipe and encounters a widening of the pipe's cross section. In the wider part of the pipe, compared to the narrower one, the fluid has

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**Answer:** Lower speed and increased pressure

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**Question 5:** Sea water (density = 1030 $kg/m^3$ ) flows through a horizontal pipe of varying diameter. Its gauge pressure in a wide segment is 3300 Pa, while in a narrow segment it is 540 Pa. The flow speed in the wide segment is 1.50 m/s. What is the flow speed in the narrow segment?

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**Answer:** 2.76 m/s

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# Chapter 11

## Lesson 1: Types of Matter and Thermal Energy

**Question 1:** Describe how the macroscopic properties of a thermodynamic system are related to the molecular level of matter, including kinetic or potential energy of atoms. Please submit your answer on paper.

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**Answer:** Higher temperature systems' molecules have greater kinetic energy.

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**Question 2:** Is the chemical potential energy of reactants increased by an exothermic reaction, or is it decreased? Explain.

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**Answer:** Decreased; energy is released.

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**Question 3:** Chemical warmers are used by skiers, hunters and other outdoor enthusiasts to supply heat to gloves and boots. Reactants in a wrapper are combined, to supply heat. Is the reaction exothermic, endothermic, or neither? Explain

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**Answer:** Exothermic; chemicals release chemical potential energy to heat up.

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## Lesson 3: Temperature Scales and Conversions

**Question 1:** How many kelvins correspond to the temperature −99.0°F?

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**Answer:** 200.4 K

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**Question 2:** Convert the temperature 164 K to degrees Celsius.

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**Answer:** -109.2ºC

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**Question 3:** Find the temperature −27.0°C on the Kelvin scale.

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**Answer:** 246.2 K

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**Question 4:** Express the temperature 116°F on the Celsius scale.

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**Answer:** 46.67ºC

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**Question 5:** What is the temperature 191 K expressed in degrees Fahrenheit?

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**Answer:** -115.9ºF

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## Lesson 4: Heat

**Question 1:** Find the amount of heat needed to raise the temperature of 6.5 kg of lead from −26°C to 72°C. The specific heat capacity for lead c = 129 J/(kg • C).

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**Answer:** 82173 J

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**Question 2:** You want to take a bath with the water temperature at 35.0°C. The water temperature is 38.0°C from the hot water tap and 11.0°C from the cold water tap. You fill the tub with a total of 169 kg of water. How many kilograms of water from the hot water tap do you use?

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**Answer:** 150 kg

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**Question 3:** Two blocks at different temperatures are placed next to each other in an insulated container, and allowed to reach thermal equilibrium. The first block's initial temperature is 45°C and its heat capacity is 4,500 J/K. The second block's initial temperature is 17°C and its heat capacity is 5,800 J/K. If the only heat transfer occurs between the two blocks, what is their temperature after reaching thermal equilibrium?

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**Answer:** 29ºC

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**Question 4:** A 2.4 kg iron ball is dropped from a height of 14 m onto a concrete roadway, and 2.5% of its kinetic energy at the time it reaches the ground is transformed into internal energy in the ball itself. (The rest of the energy is transmitted to the ground, converted into sound energy, and so on.) What is the ball's increase in temperature? The specific heat of iron is 449 J/(kg • K).

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**Answer:** 7.6 x $10^{-3}$ K

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## Lesson 5: State Changes

**Question 1:** How much energy is required to melt a 0.02020 kg gold ring? The latent heat of fusion for gold is $L_f = 6.3 \times 10^4$ J/kg.

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**Answer:** 1272.6 J

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**Question 2:** Calculate how much heat is required to vaporize 0.48 kg of mercury already at its boiling point. The latent heat of vaporization for mercury is $L_v = 2.95 \times 10^5$ J/kg.

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**Answer:** 141600 J

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**Question 3:** How much energy is required to take 63.9 kg of water from 26.0°C to 132°C? The specific heat capacity of water is $c_w = 4.178 \times 10^3$ J/(kg • C), the latent heat of vaporization of water is $L_v = 2.26 \times 10^6$ J/kg, and the specific heat capacity of water vapor is $c_v = 1.85 \times 10^3$ J/(kg • C). The boiling point for water is 100°C.

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**Answer:** 1.680 x $10^8$ J

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**Question 4:** Imagine that the specific heat of water suddenly decreased from its current value. How would that change a lake's ability to absorb heat?

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**Answer:** It would be worse at absorbing heat.

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**Question 5:** Explain how the energy required to change between states of matter relates to a polar icecap's ability to absorb heat.

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**Answer:** Seasonal polar ice melting moderates the Earth's temperature as atmospheric temperature increases by absorbing that energy.

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**Question 6:** A well-insulated container holds 1.50 kg of water at 22.0°C. A 2.98 kg copper block is heated in an oven, then completely submerged in the water. When the liquid water and the copper block reach thermal equilibrium, their common temperature is 42.0°C, but 0.0100 kg of

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the water has become water vapor at 100°C. What was the initial temperature of the copper block? The specific heat of water is 4178 J/(kg • K), the specific heat of copper is 385 J/(kg • K), and the latent heat of fusion of water is 2.26 J/kg.

**Answer:** 173ºC

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## Lesson 6: How Heat Transfers

**Question 1:** Which thermal energy transfer process involves electromagnetic waves? The movement of matter? Collisions of particles within matter? Please submit your answer on paper.

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**Answer:** Electromagnetic waves is radiation; movement of matter is convection; collisions is conduction.

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**Question 2:** Contrast different processes of thermal energy transfer, including conduction, convection, and radiation. Please submit your answer on paper.

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**Answer:** Conduction is the transfer of thermal energy within matter due to collisions of the particles that make up the matter. An example is the transfer of thermal energy to a thermometer that is placed in a liquid; liquid's molecules collide with the surface of the thermometer, transferring energy. Convection is the transfer of warmer matter from one location to another. An example is “hot air rises” – the air molecules are changing location. Radiation is the transfer of energy by electromagnetic radiation. Being warmed by the Sun is an example – the electromagnetic radiation strikes our body, and increases the thermal energy of some of the particles that make us up.

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**Question 3:** Heat is conducted at rate H along the length of a particular rod with circular cross section because of a temperature difference between the rod's ends. Let the rod be scaled up by a factor of two, i.e., its radius and length are each doubled. With the same temperature difference, the rate of heat transfer is now.

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**Answer:** 2H

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**Question 4:** Find the thickness in meters of a concrete slab, when a temperature difference of 133 K between its faces causes heat to flow through a 73.1 $m^2$ area of it at the rate of 593 W. The thermal conductivity coefficient for concrete is k = 0.8 W/(m • K).

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**Answer:** 13.1 m

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**Question 5:** Three equally thick slabs of wood, glass and concrete are assembled in that order. The slabs all have the same shape and area and are assembled so that their edges match up. Assume that all heat exchange with the surroundings occurs at the outside surfaces of the wood and concrete slabs. The temperature on the outside surface of the wood layer is maintained at

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constant 44°C, the outside surface of the concrete layer is a constant 16°C, and the system is in steady–state (the internal temperatures are not changing). What is the temperature at the middle of the glass layer? The thermal conductivity for wood is 0.157 W/(m • K), glass is 0.825 W/(m • K), and concrete is 1.10 W/(m • K).

**Answer:** 21ºC

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## Lesson 7: Thermal Expansion

**Question 1:** A metal rod is 2.673 m long at 23.25°C. When its temperature is increased to 168.4°C, the length of the rod is 2.681 m. What is the metal's coefficient of linear expansion? Express your answer to four significant digits.

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**Answer:** 2.062 x $10^{-5}$ 1/C°

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**Question 2:** A steel block is heated so that the length of each side increases 1%. What happens to its mass?

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**Answer:** It does not change

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**Question 3:** A solid copper ball with radius 1.35 cm increases in temperature from 15.0°C to 86.0°C. What is the change in its volume? The volume expansion coefficient for copper is 49.8 × $10^{-6}$ 1/°C.

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**Answer:** 0.0366 $cm^3$

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**Question 4:** The temperature of a block of lead is raised from 0°C to 100°C. What is the percentage change in its density? The density of lead at 0°C is 11,300 $kg/m^3$. Take the coefficient of volume expansion for lead to be 84 × $10^{-6}$ 1/°C.

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**Answer:** -0.830 %

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**Question 5:** The coefficient of linear expansion of aluminum is 2.3 × $10^{-5}$ $(C°)^{-1}$. An aluminum rod contracts by 5.6 mm when it is cooled by 5.6°C. The initial length of the rod is most nearly

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**Answer:** 43 m

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# Chapter 12: Thermodynamics and Engines

## Lesson 1: First Law of Thermodynamics

**Question 1:** The environment does 44 J of work on a system, while the system's internal energy increases by 27 J. Find how much heat flows into the system (positive) or out of it (negative).

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**Answer:** 71 J

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**Question 2:** During a process, 70 J of work is done on a system and the system's thermal energy increases by 41 J. How much heat flows in or out of the system? Let the sign indicate the direction of heat flow.

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**Answer:** 111 J

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**Question 3:** Gas in an engine absorbs 471 J of heat and its thermal energy increases by 74.0 J. How much work (including its sign) does the gas perform during the process?

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**Answer:** 397 J

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**Question 4:** The amount of heat shown is transferred to the gas. The gas's thermal energy increases by 75.0 J. How much work does the gas do?

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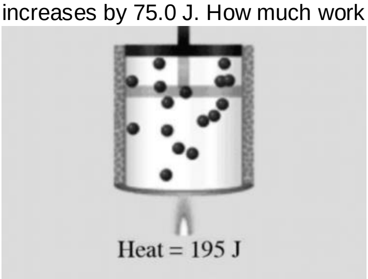


**Answer:** *W*= 120 J

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## Lesson 2: Heat Engines

**Question 1:** A heat engine does $2.4 \times 10^5$ J of work during each cycle. If the engine loses $1.8 \times 10^5$ J of heat to the cold reservoir in each cycle, how much heat is transferred from the hot reservoir during the cycle?

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**Answer:** $4.2 \times 10^5$ J

**Question 2:** A heat engine performs 247 J of work during a complete cycle while 813 J of heat flow into it from a hot reservoir. Find the amount of heat discharged by the engine.

**Answer:** 566 J

**Question 3:** During a complete cycle of a heat engine, the engine absorbs 6300 J and discharges 2200 J of heat. How much work does the engine perform each cycle?

**Answer:** 4100 J

**Question 4:** Analyze and explain how a geothermal heat pump conforms to the law of conservation of energy. Please submit your answer on

**Answer:** The total energy does not change. The pump can move it from one location to another, but not change the total.

## Lesson 3: Heat Engine Process in Detail

**Question 1:** Find the work (including its sign) that a gas performs in an isobaric process at pressure $3.30 \times 10^5$ Pa, when its volume changes from $5.50 \times 10^{-4}$ m$^3$ to $8.70 \times 10^{-4}$ m$^3$.

**Answer:** 105.6 J

**Question 2:** A gas is enclosed in a container whose walls are made of a material that is flexible and which acts as a perfect insulator for all practical purposes. A thermal process takes place on the gas. What would be the best model for the type of process?

**Answer:** Adiabatic

**Question 3:** A gas undergoes a constant-volume process during which its internal energy increases by $4.9 \times 10^4$ J. How much heat flows into the gas (positive) or out of it (negative)?

**Answer:** $4.9 \times 10^4$ J

**Question 4:** A gas does 887 J of work when it expands at a constant pressure of $7.71 \times 10^4$ Pa from its initial volume of 0.00135 m$^3$. What is its final volume?
**Answer:** 0.0129 m$^3$

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**Question 5:** In a heat engine, 1800 J of heat are added to the gas at constant pressure, while its internal energy increases 3300 J and its volume decreases from 0.032 $m^3$ to 0.019 $m^3$. What is the constant gas pressure?

**Answer:** $1.2 \times 10^5$ Pa

## Lesson 4: Gas Laws

**Question 1:** A particular quantity of gas undergoes a process in which no work is performed. What kind of process is it?

**Answer:** isochoric (constant-volume)

**Question 2:** A sample of gas is held at a constant pressure of $3.4 \times 10^4$ Pa, as its volume is doubled from an initial value of 0.088 $m^3$ by heating. Then, while a constant volume is maintained, the gas is cooled back to its initial temperature. The work that the gas does on the environment during the entire process is most nearly

**Answer:** $3.0 \times 10^3$ J

**Question 3:** The volume and pressure of a gas, in $m^3$ and Pa, are related by the equation PV = 7400 Pa • $m^3$. Find how much work the gas does as it expands from a volume of 0.003500 $m^3$ to 0.007800 $m^3$.

**Answer:** 9091 J

## Lesson 5: Advanced: Pressure-Volume Graphs

**Question 1:** 0.5 mol of an ideal gas fills a volume of 0.85 $m^3$ at a temperature of 420 K. The pressure of the gas is most nearly

**Answer:** $2.1 \times 10^3$ Pa

**Question 2:** A sample of ideal gas fills a volume of 0.00810 $m^3$ at the pressure and temperature of $6.10 \times 10^5$ Pa and 242 K. How many moles does the sample contain?

**Answer:** 2.46 mol

**Question 3:** A sample of monatomic ideal gas fills a volume of 0.00880 $m^3$ at the pressure and temperature of $3.82 \times 10^5$ Pa and 257 K. How many atoms does the sample contain?

Boltzmann's constant is $k = 1.38 \times 10^{-23}$ J/K.

**Answer:** $9.48 \times 10^{23}$

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**Question 4:** At what pressure do $2.20 \times 10^{22}$ atoms of a monatomic ideal gas fill a volume of $0.280\ m^3$ at 337 K? Boltzmann's constant is $k = 1.38 \times 10^{-23}$ J/K.

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**Answer:** 3654 Pa

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**Question 5:** A gas is compressed at constant temperature from its initial volume and pressure of $0.54\ m^3$ and $4.6 \times 10^6$ Pa to a volume of $0.15\ m^3$. What is the final pressure of the gas?

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**Answer:** $1.7 \times 10^7$ Pa

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**Question 6:** The pressure of a constant-volume gas thermometer is found to be 354.0 Pa at the triple point of water. What pressure does the thermometer have at a temperature of 638.0 K?

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**Answer:** 827 Pa

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## Lesson 6: Second Law of Thermodynamics

**Question 1:** Two identical containers hold the same type of gas, at the same pressure and volume. The rms molecular speed for the gas in the first container is 637 m/s. The second container has twice as many molecules as the first. What is the rms molecular speed for the second container?

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**Answer:** 450 m/s

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**Question 2:** On a particular afternoon in Houston, the nitrogen ($N_2$) molecules in the air have an rms speed of 515 m/s. What is the rms speed of the carbon dioxide ($CO_2$) molecules?

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**Answer:** 411 m/s

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**Question 3:** Find the rms speed of a molecule of diatomic oxygen $O_2$ at 254 K. The molar mass of diatomic oxygen is 32 g.

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**Answer:** 445 m/s

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**Question 4:** What is the rms speed for a molecule of ozone gas ($O_3$) at standard temperature (273 K)?

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**Answer:** 377 m/s

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**Question 5:** A sample of ideal gas is at a temperature of 580 K. Calculate the average kinetic energy of each of its molecules. Boltzmann's constant is k = 1.38 × $10^{-23}$ J/K

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**Answer:** 1.2 x $10^{-20}$ J

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## Lesson 7: Entropy, um, Entropy

**Question 1:** Find the maximum possible efficiency of a heat engine operating between reservoirs at temperatures 744 K and 156 K.

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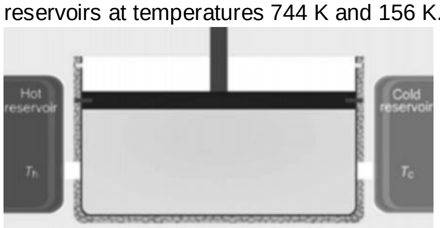


**Answer:** 0.79

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**Question 2:** Both the hot- and cold-reservoir temperatures of a Carnot engine are raised by exactly the same number of kelvins. As a result, the efficiency of the engine

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**Answer:** decreases

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**Question 3:** An engine applies a force of 53.50 N through a displacement of 6.960 m. The heat supplied to the engine is 3100 joules. What is the engine's efficiency?

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**Answer:** 0.12

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**Question 4:** An engine operates at an efficiency of 0.53. If 5.9 × $10^{6}$ J of heat is transferred to it during each cycle, how much heat is expelled?

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**Answer:** 2.7 x $10^{6}$ J

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**Question 5:** How much work does an engine perform during a cycle, when it takes in 694 J of heat and has an efficiency of 0.0480?

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**Answer:** 33 J

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## Lesson 8: Advanced: Kinetic Theory of Gas

**Question 1:** What is the change in the entropy of the block? Ignore any slight change in temperature.

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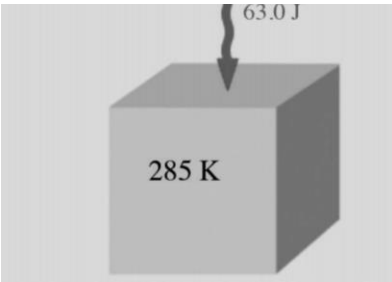



**Answer:** $\Delta S$ = 0.22 J/K

**Question 2:** Machine X is 40% efficient, and machine Y is 25% efficient. Both machines are supplied with 2,000 kWh of energy. Which one will “produce” more entropy?

**Answer:** Machine Y.

**Question 3:** Would an engineer want to design a heat engine whose cycle maximized or minimized the change in entropy? Explain.

**Answer:** Minimized. Ideally a small input of heat into an efficient machine results in larger changes in temperature.

**Question 4:** An amount of gas in a well-insulated container is compressed reversibly and adiabatically to half its initial volume. Does the entropy of the gas increase, decrease, or stay the same?

**Answer:** Stays the same

**Question 5:** An ideal gas expands isothermally at 64.0°C in a reversible process, and its entropy increases 2.70 J/K. What amount of heat is transferred to the gas in the process?

**Answer:** 910 J

**Question 6:** In a reversible thermodynamic process, a system’s entropy is unchanged, while its temperature increases. What type of process is this?

**Answer:** Adiabatic

**Question 7:** 360 J of heat are removed from a system in a reversible process at the temperature 260 K. Find the change in the system’s entropy (including its sign).

**Answer:** -1.4 J/K

# Chapter 13: SHM and Waves

## Lesson 1: Simple Harmonic Motion

**Question 1:** If an oscillator's period is 0.760 seconds, what is its frequency?

**Answer:** 1.32 Hz

**Question 2:** A cell phone operates at the frequency 1381 MHz. What is the period of the radio wave in seconds?

**Answer:** $7.241 \times 10^{-10}$ s

**Question 3:** A pendulum completes 13.0 cycles in 89.0 seconds. What is its period?

**Answer:** 6.8 s

**Question 4:** A weight on a spring oscillates between position 1.9 m and position 3.2 m. What is the amplitude of its motion?

**Answer:** 0.65 m

**Question 5:** A computer microprocessor has a frequency of 1.03 gigahertz. What is its period in seconds?

**Answer:** $9.7 \times 10^{-10}$ s

## Lesson 3: SHM in the World

**Question 1:** Discuss how you can investigate resonance in waves in a bathtub or sink in your home. Please submit your answer on paper.

**Answer:** Answers may vary.

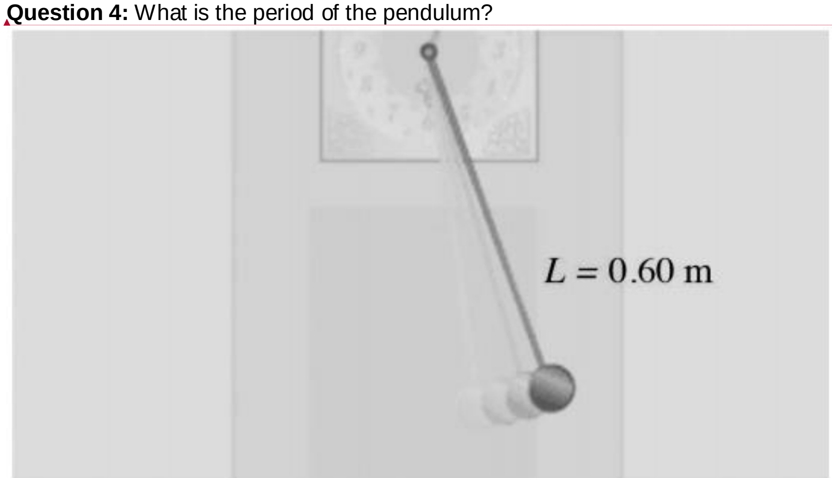
**Question 2:** One of the ways to calculate a planet's properties is through a measurement of its gravitational acceleration g. For this, the period of oscillations of a pendulum consisting of mass 1.1 kg on a rope of length 3.2 m was measured and found to be 2.0 s. What is the planet's gravitational acceleration?

**Answer:** 32 m/s$^2$

**Question 3:** A hiker's lunch bag of mass 1.5 kg swings back and forth on the end of a rope of length 2.4 m tied to a tree branch. A bear follows this oscillation with its nose, hoping to catch a meal. How many seconds does it take for the bear to move its nose from the lunch's leftmost position to its rightmost position during a single swing?

**Answer:** 1.6 s

**Question 4:** What is the period of the pendulum?




**Answer:** T = 1.6 s

## Lesson 4: Wave Basics

**Question 1:** The period of a wave is 0.50 s. What is its frequency?

**Answer:** 2 Hz

**Question 2:** A sound wave takes 0.235 seconds to complete 121 cycles. What is its frequency?

**Answer:** 515 Hz

**Question 3:** In a foggy harbor, a tugboat sounds its foghorn. Bobbie stands on shore, 750 m away. The foghorn's sound wave completes 1,100 cycles on its way to Bobbie. What is the wavelength of the sound wave?

**Answer:** 0.682 m

**Question 4:** A wave has a frequency of 487 Hz. What is its period?

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**Answer:** 0.00205 s

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**Question 5:** A rubber duck is bobbing up and down in a water-filled bathtub as waves pass by. The highest point that it reaches is 1.6 centimeters above its lowest point. What is the amplitude of the duck's motion, in centimeters?

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**Answer:** 0.8 cm

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## Lesson 6: Wave Speed

**Question 1:** A material wave has a wavelength of 8.30 cm and a frequency of 420 Hz. What is the wave speed in meters per second?

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**Answer:** 34.9 m/s

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**Question 2:** Two waves travel in the same medium at the same speed. One wave has frequency $5.72 \times 10^5$ Hz and wavelength 0.533 m. The other wave has frequency $6.13 \times 10^5$ Hz. What is the second wave's wavelength?

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**Answer:** 0.497 m

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**Question 3:** A wave has a speed of 351 m/s and a wavelength of 1.80 meters. What is its period?

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**Answer:** 0.005 s

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**Question 4:** A student connects a rope to a support. She shakes one end of it to create waves of wavelength 5.9 m. If she shakes the rope at 3.4 Hz, what is the speed of the wave?

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**Answer:** 20 m/s

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**Question 5:** Find the wavelength in nanometers of visible light of frequency $5.00 \times 10^{14}$ Hz in a vacuum. The speed of light in a vacuum is $3.00 \times 10^8$ m/s.

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**Answer:** 600 nm

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**Question 6:** The wavelength of a tone produced by a violin is 0.1965 m. What is its frequency? The speed of sound is 343 m/s.

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**Answer:** 1746 Hz

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# Chapter 14: Sound

## Lesson 1: Sound Waves

**Question 1:** Compare the oscillatory motion in a wave in a string and a sound wave. What is similar? What is different? Please submit your answer on paper.

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**Answer:** In both cases, the particles that make up the wave move back and forth, but return to their original position A wave in a string has the oscillation perpendicular to the motion of the wave. A sound wave has oscillatory motion parallel to the direction of the wave.

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## Lesson 2: Sound Intensity

**Question 1:** A sound source radiates acoustic energy at a rate of 3.6 W uniformly in all directions. Find the sound intensity, in microwatts per square meter, at a distance of 2.3 km.

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**Answer:** 0.054 μW/m$^2$

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**Question 2:** 15.0 meters from a sound source that radiates freely in all directions, the intensity is 8.00 × 10$^{-4}$ W/m$^2$. What is the rate at which the source is emitting sound energy?

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**Answer:** 2.26 W

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**Question 3:** Sound spreads radially in all directions from a source with power 15.3 W. If the intensity you experience is 3.00 × 10$^{-6}$ W/m$^2$, how far away are you from the source?

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**Answer:** 637m

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**Question 4:** For the sound level produced by loudspeakers to be increased by 22.0 dB, by what factor must the power supplied to the speakers be increased?

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**Answer:** 158

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**Question 5:** Sound at the intensity of 1 W/m$^2$ is known as the threshold of pain. What is the minimum power of headphones that can do damage to a listener's ear at a distance of 0.012 m from it?

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**Answer:** 0.002 W

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## Lesson 3: Doppler Effect

**Question 1:** A small plane is taxiing directly away from you down a runway. The noise of the engine, as the pilot hears it, has a frequency 1.13 times the frequency that you hear. The speed of sound in the air is 343 m/s. What is the speed of the plane?

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**Answer:** 44.6 m/s

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**Question 2:** A train approaches a station at the speed of 41.0 m/s and sounds a warning whistle. A person on the station platform hears a frequency of 753 Hz. What is the actual frequency of the train's whistle? The speed of sound is 343 m/s.

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**Answer:** 663 Hz

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**Question 3:** A fire truck sounds its siren at frequency fs as it speeds down a street and passes a person standing on the sidewalk. The frequencies that the person hears as the truck approaches and as it recedes are

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**Answer:** $f_{approaching} > f_s$ **and** $f_{receding} < f_s$

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**Question 4:** As you run toward a stationary trumpet player at 5.10 m/s, you hear a tone at a frequency of 550 Hz. Find the frequency you would hear if you stood still. Take 341 m/s for the speed of sound in air.

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**Answer:** 542 Hz

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**Question 5:** An approaching police car emits a sound of frequency 1500 Hz. A student measures its frequency as 1630 Hz. What is the car's speed? The speed of sound is 343 m/s.

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**Answer:** 27.4 m/s

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## Lesson 4: Combining Waves

**Question 1:** Speaker 1 is positioned at the origin and speaker 2 is at the position (0, 4.00) meters. They emit identical sound waves of wavelength 1.55 m, in phase. If you stand on the x axis at (x, 0) meters, what is the smallest positive value for x for which you experience complete destructive interference?

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**Answer:** 0.127 m

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**Question 2:** The speed of transverse waves in a 1.90 m long stretched string is 84.0 m/s. A standing wave having five nodes (including the two at the ends) is created in the string. What is the wave's frequency?

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**Answer:** 88.4 Hz

**Question 3:** A simple harmonic wave on the surface of a lake has an amplitude of 0.089 m. This wave meets a similar wave moving in the opposite direction and their interference creates a standing wave. Find the amplitude of the standing wave.

**Answer:** 0.089 m

**Question 4:** The distance between a node and an adjacent antinode of a standing wave in a vibrating string is 0.083 m. What is the wavelength of the interfering traveling waves?

**Answer:** 0.332 m

## Lesson 5: Harmonics and Musical Instruments

**Question 1:** A simple handmade whistle with both ends open produces a sound with a frequency of approximately 341 Hz. Its length is 0.525 m. What harmonic is this sound for the whistle? The speed of sound is 343 m/s

**Answer:** 1

**Question 2:** The speed of transverse waves in a stretched string depends only on the linear mass density (mass per unit length) of the string and the tension in the string. For a length L of a particular kind of string at some tension the frequency of the third harmonic is $f_3$. Now change the length of the same kind of string at the same tension so that the frequency of the new third harmonic is $f_3/2$ . The new length of the string is

**Answer:** 2L

**Question 3:** The propagation speed of transverse waves in a stretched string is 50 m/s. If the string's fourth harmonic is 500 Hz, the length of the string is most nearly

**Answer:** 0.2 m

**Question 4:** Find the speed of transverse waves in a stretched wire of length 0.380 m that is needed in order to obtain a fundamental frequency of 490 Hz.

**Answer:** 93.1 m/s

**Question 5:** What is the third harmonic frequency for a musical instrument string of length 1.11 m? Use 319 m/s for the speed of wave propagation in the string.

**Answer:** 372 Hz

# Chapter 15: Electric Charge

## Lesson 1: Electric Charge

**Question 1:** A metallic sphere has a net charge of $+5.4 \times 10^{-8}$ C. How many more protons than electrons does it contain?

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**Answer:** $3.3 \times 10^{11}$

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**Question 2:** A high-energy gamma ray, which is electrically neutral, strikes a neutral piece of material. As a result, 48 electrons and some number of protons are emitted. After the process the material remains neutral. How many protons are emitted?

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**Answer:** 48

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**Question 3:** Rubbing an initially neutral balloon causes it to gain $5.8 \times 10^{6}$ electrons. What is the balloon's net charge?

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**Answer:** $-9.28 \times 10^{-13}$ C

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**Question 4:** An iron arrowhead has an initial charge of $2.10 \times 10^{-6}$ C. How many electrons are required to give it a charge of −2.82 μC?

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**Answer:** $3.1 \times 10^{13}$ electrons

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## Lesson 2: Electric Force

**Question 1:** Calculate the magnitude of the electrical force between an electron and a proton separated by a distance of 25 nanometers.

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**Answer:** $3.7 \times 10^{-13}$ N

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**Question 2:** Two point charges of $7.50 \times 10^{-6}$ C, on the left, and $-4.20 \times 10^{-6}$ C, directly to its right, are separated by 0.0880 m. Find the electrostatic force acting on the charge on the left. A force to the right is taken as positive, while one directed to the left is negative.

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**Answer:** -36.6 N

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**Question 3:** A point charge of charge +2.40 × $10^{–6}$ C is 0.0129 m to the left of a –7.20 × $10^{–8}$ C charge. What force acts on the charge on the left? Use a positive number for a force to the right and a negative number for one to the left.

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**Answer:** -9.34 N

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**Question 4:** Two point charges, 0.0030 m apart, are attracted to each other with a force of 3.9 N. One of the charges is +8.2 × $10^{–8}$ C. What is the other, including its sign?

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**Answer:** 4.8 x $10^{-8}$ C

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**Question 5:** An electron at rest is held in equilibrium at the surface of Earth by a charge located 380 m directly above it. (Use g = 10 m/$s^2$ .) This charge is most nearly

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**Answer:** 9.1 x $10^{-16}$ C

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**Question 6:** A mad scientist is designing a trap for intruders that will lift them up into the air and hold them helpless. The device consists of an equilateral triangle, 10.0 meters to a side, embedded in his floor. When he flips a switch, the corners of the triangle will be charged equally by a generator and any negatively charged object above the center of the triangle will be lifted upwards by the electric force. A computer-controlled system of giant fans keeps the intruder from straying horizontally from the center of the triangle. While he is testing the system, his cat walks into the trap. She has a net charge of −1.00 nanocoulombs due to electrons that rubbed off from the carpet. The cat, which has a mass of 5.00 kg, begins to hover 3.00 meters up in the air. Find the charge on each corner of the triangle.

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**Answer:** -166 C

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## Lesson 3: Electric Fields

**Question 1:** Charges of ±8.5 × $10^{–8}$ C and point P are arranged along a straight line as shown in the picture. The electric field at P is most nearly

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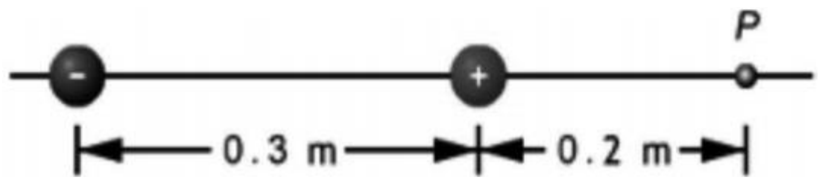


**Answer:** 1.6 x $10^4$ N/C to the right

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**Question 2:** A point charge of −9.600 μC is located on the x-axis at −3.400 m, while a point charge of 1.500 μC is positioned at 5.700 m on the same axis. What is the net electric field produced at the origin by both charges? Use a positive value to indicate a field in the positive x direction and a negative value for the negative x direction.

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**Answer:** -7220 N/C

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**Question 3:** Find the magnitude of the electric field produced by a point charge of 7.000 × $10^{-6}$ C at a location 3.572 m from the charge.

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**Answer:** 4932 N/C

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**Question 4:** An electric field of 5.6 × $10^{-7}$ N/C is produced by a charge, at a distance of 2.9 m from it. The electric field lines point away from the charge. Find the charge, including its sign.

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**Answer:** +5.3e-16 C

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**Question 5:** An arrangement of four point charges gives a field strength of 201 N/C in the +y direction at point P = (4, 1) m. If another charge of +7.80 μC is added at (−2, 5) m, what is the new field strength at point P?

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**Answer:** 1.25e3 N/C

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**Question 6:** A proton with mass 1.67 × $10^{-27}$ kg and charge 1.60 × $10^{-19}$ C is traveling at 6.00 × $10^5$ m/s in the positive direction when it enters a uniform electric field with a strength of 1250 N/C in the negative direction. The opposing electric force brings the proton to rest. Calculate the displacement of the proton while it is coming to rest.

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**Answer:** 1.5 m

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## Lesson 4: Electric Potential Energy

**Question 1:** What is the electric potential energy of a point charge of $–6.4 \times 10^{–8}$ C when it is located at a position where the electric potential is –35 V?

**Answer:** $2.2 \times 10^{-6}$ J

**Question 2:** A charged particle of mass $8.39 \times 10^{–4}$ kg starts from rest and accelerates through a potential difference of +25,000 V to reach a speed of 1180 m/s. What is the charge on this particle?

**Answer:** 0.023 C

**Question 3:** A point charge has an electric potential energy of –0.60 J at a location where the electric potential is 6800 V. What is the charge?

**Answer:** $-8.8 \times 10^{-5}$ C

**Question 4:** A uniform electric field of $2.0 \times 10^{5}$ N/C is oriented in the negative x direction. How much work must be done to move an electron 3.0 m in the positive x direction, if it begins and ends at rest?

**Answer:** $-9.6 \times 10^{-14}$ J

**Question 5:** In a typical television or in an older computer monitor's cathode ray tube (CRT), electrons are accelerated from rest through a potential difference of $2.5 \times 10^{4}$ V, steered by magnetic fields, and finally strike particular spots on the screen at the front of the tube to create an image. What is the kinetic energy of the electrons after the accelerating process, as they are moving toward the screen?

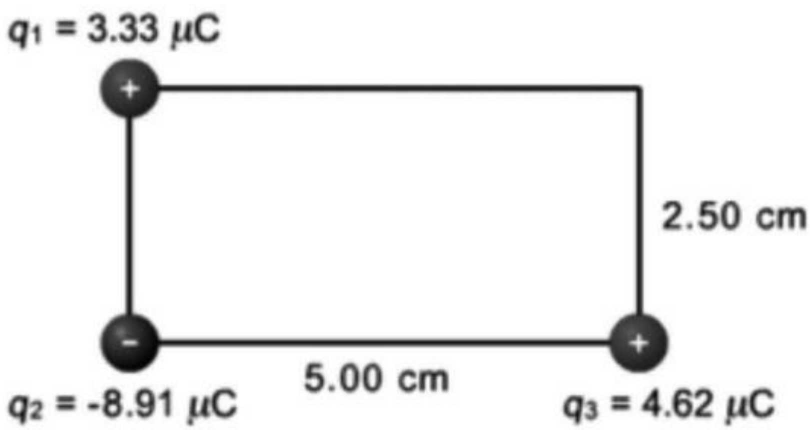
**Answer:** $4 \times 10^{-15}$ J

## Lesson 5: Advanced Topics in Coulomb's Law

**Question 1:** What is the point charge that causes an electric potential of –7.4 V at a distance of 4.4 m from it?

**Answer:** $-3.6 \times 10^{-9}$ C

**Question 2:** Three charges are arranged at the corners of a rectangle as shown in the diagram. What is the electric potential at the corner of the rectangle that does not have a charge?




**Answer:** 8.27e5 V

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**Question 3:** Four charges are located at the corners of a square with side a = 0.8 m, as shown. The values of the charges are $Q_1 = Q_2 = 5$ μC and $Q_3 = Q_4 = -5$ μC. The potential at the center of the square is most nearly

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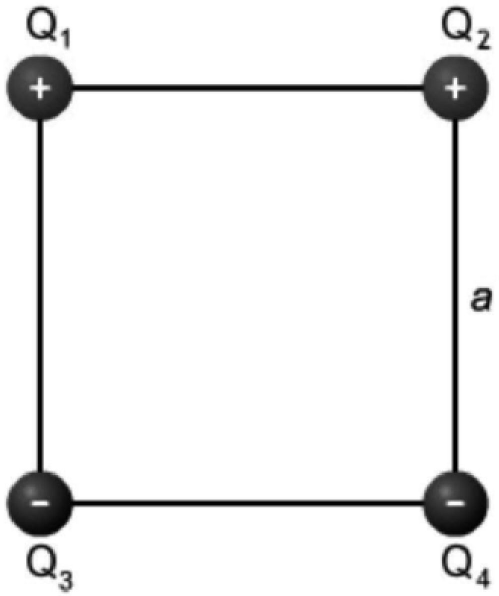


**Answer:** 0 V

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**Question 4:** Points 1 and 2 are located in a uniform electric field of strength 325 N/C. The displacement vector from point 1 to point 2 points in the same direction as the field, and has a length of 15.4 cm. The electric potential at point 1 is 9.25 V. What is the potential at point 2?

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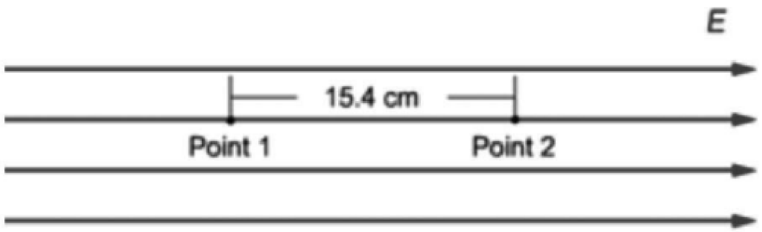


**Answer:** -40.5 V

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**Question 5:** Two identical insulating spheres are separated by 1.25 m in a stationary configuration. The spheres carry opposite charges of magnitude 3.75 mC which are uniformly distributed in the spheres. Each ball has a radius 1.38 cm, and a mass of 0.0207 kg. In a space-station experiment where gravity can be ignored, the spheres are allowed to drift together and “crash”. What is their total kinetic energy just when they hit?

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**Answer:** 4.48e6 J

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# Chapter 16: Electric Circuits

## Lesson 1: Electric Current and Resistance

**Question 1:** A resistor has 2.0 A of current flowing through it when the potential difference across it is 6.5 V. When the potential difference is increased to 19.5 V, the current increases to 5.5 A. What kind of material is this?

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**Answer:** Non-ohmic

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**Question 2:** You find a used battery and discover that it is no longer strong enough to power your CD player. Out of curiosity, you decide to find out what potential difference it actually supplies. You connect it to a 1.25 kΩ resistor and an ammeter (a device that measures current) and discover that the current through the circuit is 1.03 mA . What is the potential difference?

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**Answer:** 1.29 V

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**Question 3:** An old battery labeled as 9.0 volts has an internal resistance of 0.50 ohms. If 1.3 A of current is flowing through it, what is the actual potential difference across the terminals of the battery?

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**Answer:** 0.65 V

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**Question 4:** A current of 2.5 A flows through a battery. How many coulombs of charge pass through the battery in 9.0 seconds?
**Answer:** 23 C

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**Question 5:** An electric wire has resistance R between its ends. The wire is scaled down by a factor of two, i.e., its radius and length are both halved. The new resistance is

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**Answer:** 2R

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## Lesson 2: Electric Power and Capacitors

**Question 1:** An automobile lamp operates at a 12 V potential difference by being connected to the terminals of the car battery. The lamp produces heat and light at the rate of 34 W. What is its resistance?

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**Answer:** 4.2 Ω

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**Question 2:** A resistor R1= 12 Ω, another resistor R2= 6.0 Ω, and a 24 V battery are all connected in parallel. What is the power consumed by the 6.0 Ω resistor?

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**Answer:** 96 W

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**Question 3:** Suppose you disassemble a cell phone and remove a capacitor inside labeled “7.3 $\times 10^{-11}$ F.” If you apply a potential difference of 5.0 volts across the capacitor, how much charge would you expect to be on the positive plate?

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**Answer:** $3.7 \times 10^{-10}$ C

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**Question 4:** A capacitor is charged with 0.0083 C and has a potential difference of 0.54 V between its plates. How much electric potential energy is stored in this capacitor?

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**Answer:** $2.2 \times 10^{-3}$ J

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**Question 5:** With a charge of ±0.38 C on its plates, what is the potential difference between the plates of a 0.16-F capacitor?

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**Answer:** 2.4 V

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## Lesson 3: Electric Circuits

**Question 1:** A battery with an emf of 8.9 V and internal resistance of 0.070 Ω forms part of a circuit and produces a current of 6.4 A. Find the potential difference between its terminals.

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**Answer:** 8.452 V

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**Question 2:** A battery with an emf of 1.5 V and a 12 Ω resistor are the only two components in a circuit. You measure the current flowing through the circuit to be 0.091 A. What is the internal resistance of the battery?

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**Answer:** 4.5 Ω

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**Question 3:** A battery is modeled as an ideal emf together with an internal resistance of 0.0270 ohms. A voltmeter says the potential difference across its terminals is 8.87 V. 4.50 A of current flows through the battery. What is the emf of the battery?

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**Answer:** 8.99 V

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**Question 4:** You want 5.0 A to flow through the upper battery which is “dead”. What should the emf of the lower power source be? Assume that the batteries have negligible internal resistance.

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**Answer:** 15 V

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## Lesson 4: Series and Parallel Wiring

**Question 1:** A 12 V battery, with $R_1$ = 4.0 Ω and $R_2$ = 2.0 Ω are all connected in series. What is the current through the resistors?

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**Answer:** 2.0 A

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**Question 2:** Three resistors $R_1$, $R_2$, $R_3$ are connected in series. The current through $R_1$ is 7.0 amperes. What is the current in $R_3$?

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**Answer:** 7 A

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**Question 3:** Two resistors are connected in parallel. The potential difference across $R_1$ is 8.0 V. What is the potential difference across $R_2$?

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**Answer:** 8.0 V

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**Question 4:** What is the equivalent resistance of the resistors?

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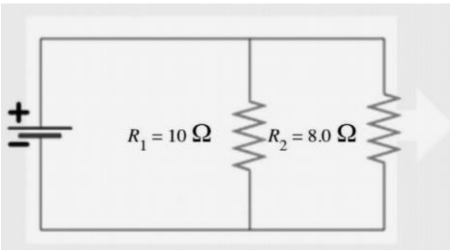


**Answer:** $R_{equiv} = 4.4\ \Omega$

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**Question 5:** The total potential difference across two resistors in series is 34.0 V. The current through them is 6.50 A. One resistor's resistance is 2.00 Ω. What is the other resistor's resistance?

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**Answer:** 3.23 Ω

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## Lesson 5: Mixed Circuits

**Question 1:** The battery in the circuit shown has zero internal resistance. The current in the 9.0 Ω resistor is most nearly

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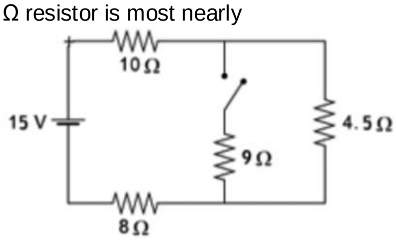


**Answer:** 0.24 A

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**Question 2:** The equivalent resistance of the combination of resistors shown in the figure is 13.0 Ω, while $R_2$ = 430 Ω and $R_3$ = 260 Ω. Find the value of $R_1$

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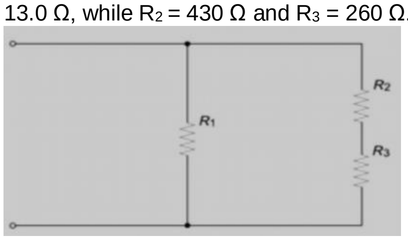


**Answer:** 13 Ω

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**Question 3:** Of the three currents flowing into or out of a junction, a 69 A current flows in and a 33 A current flows out. Find the third current, indicating an outward flow by a negative value and an inward flow by a positive value

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**Answer:** -36 A

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**Question 4:** What current flows through the 5.00 Ω resistor? Express your answer to the nearest 0.01 amperes

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**Answer:** 5.81 A

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## Lesson 6: Advanced Topics in Capacitors

**Question 1:** Three capacitors, with capacitances 0.0079 F, 0.0021 F, and 0.0088 F, are connected in parallel. What is their equivalent capacitance?

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**Answer:** 0.019 F

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**Question 2:** The plates of a $4.50 \times 10^{-9}$ F parallel-plate capacitor are separated by 1.20 mm. What is the area of each plate?

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**Answer:** 0.61 $m^2$

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**Question 3:** A 665 pF parallel-plate capacitor has rectangular plates that measure 0.550 m by 0.440 m. Find the distance between the plates.

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**Answer:** 0.00322 m

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**Question 4:** A trio of capacitors, of capacitance 10.0, 20.0 and 30.0 picofarads, are wired in series. What is their equivalent capacitance?

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**Answer:** $5.45 \times 10^{-12}$ F

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**Question 5:** A 26.4 pF cylindrical capacitor has an outer radius of 11.0 cm and is 36.2 cm long. What is the radius of the inner cylinder?

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**Answer:** 0.0513 m

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**Question 6:** You have a 12 V battery and a $1.1 \times 10^{-4}$ F capacitor in series. You want the potential difference across the capacitor to be 9.0 V. What capacitance should be placed in series with this capacitor to obtain the desired potential difference across it?

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**Answer:** 3.3 x $10^{-4}$ F

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**Question 7:** Twelve identical 5.00 μF capacitors are joined and used to form the edges of a cube. What is the equivalent capacitance between diagonally opposite vertices?

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**Answer:** 6.00 x $10^{-6}$ F

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# Chapter 17: Magnets and Charge

## Lesson 1: Magnetic Fields and Charged Particles

**Question 1:** Identify two examples of magnetic force that you experience every day. Please submit your answer on paper.

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**Answer:** Answers may vary, but two examples include a compass pointing toward the north and a magnet attached to a refrigerator door.

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**Question 2:** What is the strength of the uniform magnetic field in which a particle carrying a 0.088 μC charge and moving perpendicularly to the field at a speed of 820 m/s is acted on by a force of 2.8 × $10^{-6}$ N?

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**Answer:** 0.039 T

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**Question 3:** A boy shuffles across an outdoor nylon carpet, acquiring a positive static charge, and then fires a BB gun in the direction of the setting sun. The BB travels horizontally at a speed of 105 m/s, carrying away a charge of +3.43 μC. If the Earth's local magnetic field is perpendicular to the velocity of the BB, and it exerts a force of 1.80 × $10^{-8}$ N on it, what is the magnitude of the magnetic field at his location?

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**Answer:** 5.0 x $10^{-5}$ T

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**Question 4:** Find the speed of a particle with charge –0.460 μC that is acted on by a force of 0.511 N when it moves perpendicularly to a uniform 0.740 T magnetic field.

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**Answer:** 1.50 x $10^{6}$ m/s

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**Question 5:** An electrically charged bullet of mass 0.010 kg leaves the barrel of a gun traveling parallel to the ground and perpendicular to the Earth's magnetic field at 1500 m/s. In theory, what charge could the bullet carry in order to remain at a constant height? Assume that the Earth is flat, and that the magnetic field ($0.5 \times 10^{-4}$ T) is horizontal and points left if you are looking in the direction of the bullet's motion.

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**Answer:** 1.31 C

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## Lesson 3: Electromagnetic Induction

**Question 1:** A conducting loop is positioned in a uniform magnetic field of B = 2.0 T and oriented so its normal makes an angle of 50° with the field direction, as shown (where for clarity only a few field lines are indicated). The area of the loop is A = 0.063 $m^2$ . During 6.0 s the field strength decreases to 0. In that interval the average emf induced in the loop is most nearly

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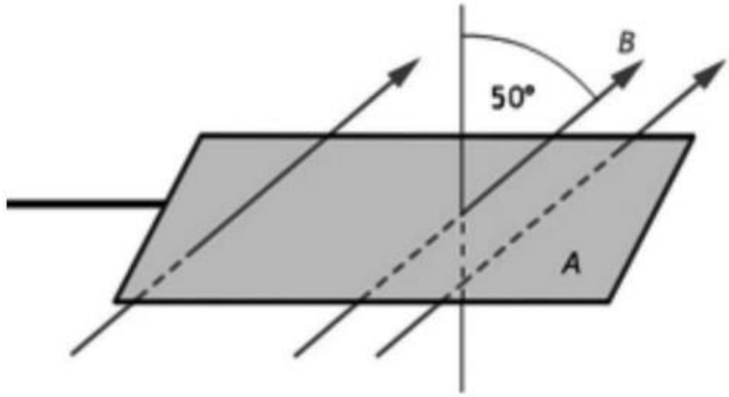


**Answer:** 13 mV

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**Question 2:** What is the inductance of a solenoid that produces an induced emf of −3.4 V when the current flowing through it is changing at the rate of 0.15 A/s?

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**Answer:** 23 H

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**Question 3:** A magnetic field is varied from −7.0 T to 4.0 T, and passes through a loop with area 0.024 $m^2$ . To obtain an emf of magnitude 8.0 volts in the loop, over how many seconds must the magnetic field change from one extreme value to the other?

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**Answer:** 0.033 s

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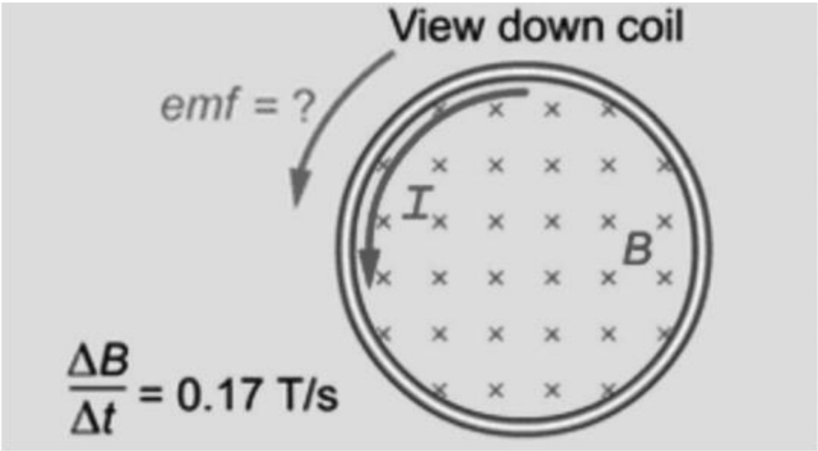
**Question 4:** Suppose a positive charge is at the center of a cube. Another positive charge is outside the cube, on a line perpendicular to a face of a cube, that passes through its center. Which face of the cube has the greatest (positive) net flux through it?

**Answer:** The face farthest from the external charge

**Question 5:** A changing magnetic field passes through a loop of area 2.9 $m^2$ . What is the induced emf? Remember to include the sign of the induced emf.




**Answer:** -0.49 T

**Question 6:** A wire has a resistance of 60.0 ohms, and is bent into a square loop with sides of length 15.0 cm. The loop is perpendicular to a magnetic field which is changing at a rate of 0.00900 T/s. What is the current induced in the wire?

**Answer:** 3.4 x $10^{-6}$ A

## Lesson 4: Applications of Magnetic Fields

**Question 1:** A 15.0 ampere current flows through a 6.00 m section of wire, perpendicular to a 0.250 T magnetic field. What is the magnitude of the force exerted by the field on the wire section?

**Answer:** 22.5 N

**Question 2:** A straight 4.7 m segment of wire is located in a uniform magnetic field of 0.40 T and carries a current of 8.0 A. The strongest magnetic force that can act on the wire in this situation is most nearly

**Answer:** 15 N

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**Question 3:** What is the current in a straight 0.66 m section of wire, when a 0.047 N magnetic force acts on the wire in a uniform 0.86 T magnetic field while the wire is perpendicular to the field?

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**Answer:** 0.083 A

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**Question 4:** An electron moves up the page in a magnetic field that points out of the page, as shown. The electron's trajectory

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**Answer:** Curves to the left

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**Question 5:** A segment of insulated wire 0.032 m long carries a current perpendicular to a uniform magnetic field. The strength of the field is 0.0055 T. The wire is attached to a spring that lies in a direction perpendicular to both the wire and the field. When a current is passed through the wire, it stretches the spring by an additional amount $\Delta x = 4.6 \times 10^{-4}$ m. The spring constant is 0.87 N/m. What current is passing through the wire?

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**Answer:** 2.27 A

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## Lesson 5: Non-Perpendicular Magnetic Fields

**Question 1:** Find the magnitude of the magnetic force acting on a particle carrying a charge of −7.30 mC and moving at a speed of 210 m/s in a uniform 0.0110 T magnetic field. The angle between the particle's velocity vector and the field vector is 139°.

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**Answer:** 0.011 N

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**Question 2:** A circular wire loop of area 0.061 $m^2$ is immersed in a uniform magnetic field. Find the minimum magnetic field strength required for the magnetic flux through the loop to equal 41 mWb.

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**Answer:** 0.069 T

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**Question 3:** A thick book is suspended in a uniform nonzero electric field. The field is parallel to the plane of the book’s front cover, and the flux through the spine (which has less area than the cover) is positive. Which is greater: the flux through the spine, or the flux through the front cover?

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**Answer:** The flux through the spine

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**Question 4:** The area of the loop formed by a wire coat hanger is 0.232 $m^2$ . The coat hanger is immersed in a uniform electric field of 1120 N/C and the flux through the coat hanger is 85.0 (N/C) • $m^2$ . Determine the angle between the the electric field and the area vector of the plane of the wire.

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**Answer:** 70.9 degrees

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**Question 5:** An alpha particle (m = $6.68 \times 10^{-27}$ kg, q = $3.20 \times 10^{-19}$ C) is moving perpendicularly to a uniform magnetic field at a speed of $7.88 \times 10^{6}$ m/s. Because of the force exerted on it by the magnetic field, it is accelerating at $5.67 \times 10^{12}$ m/$s^2$ . What is the strength of the magnetic field?

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**Answer:** 0.0150

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**Question 6:** The flux passing through a part of the surface of a sphere, of area 0.010 $m^2$ , is 4.0 (N/C) • $m^2$ . The sphere has radius 5.0 cm and is centered on a point charge. There are no other charges present. Determine the charge enclosed by the sphere.

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**Answer:** $1.1 \times 10^{-10}$

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## Lesson 6: More Topics in Induction

**Question 1:** An electric current flows in the outer wire, as shown, and is increasing in magnitude. The current that is induced in the inner loop

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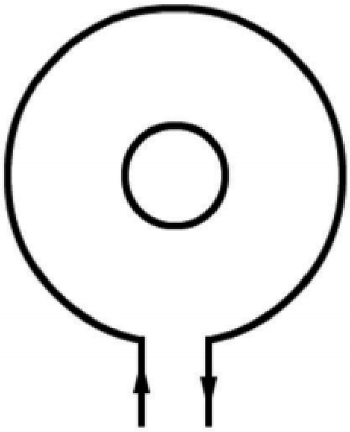

**Answer:** Flows counterclockwise

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**Question 2:** A conducting loop is located in a magnetic field pointing out of the page with its plane perpendicular to the field, as shown. It is then withdrawn to a region with zero magnetic field. During the withdrawal the current induced in the loop

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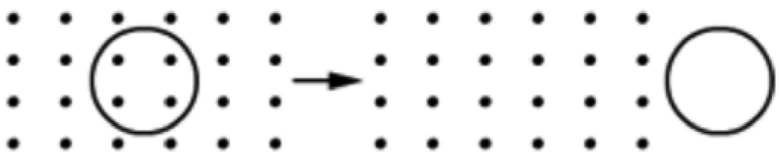

**Answer:** flows counterclockwise

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## Lesson 7: Mutual Induction

**Question 1:** A transformer has 180.0 loops in its secondary winding and is designed to accept an input AC potential difference of 710.0 V and produce an output of 290.0 V. How many loops does the transformer's primary winding contain?

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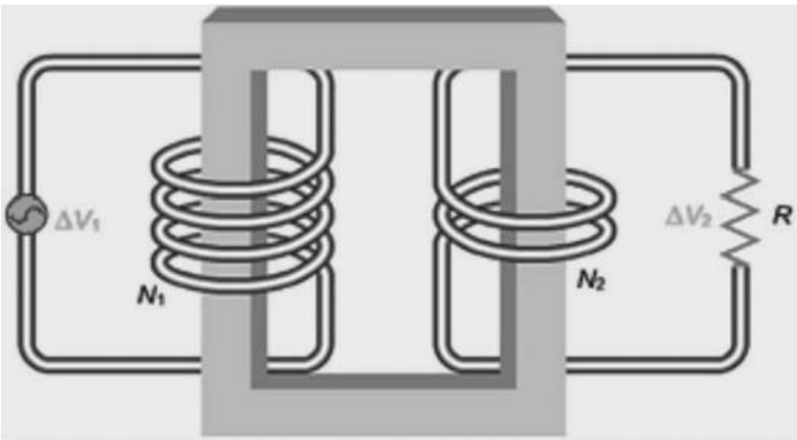


**Answer:** 441

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**Question 2:** A machine that makes transformers can only wind the coils with a single specific number density. The number of turns is therefore controlled by the length of the coils. A transformer is designed to transform a 120 V input potential difference to a 9.0 V output. If the input coil is 2.8 cm in length, what is length of the output coil?

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**Answer:** 0.0021 m

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**Question 3:** The electricity supplied through a city power line is transmitted at 14,300 V. On each city block there are one or more neighborhood transformers on utility poles that transform the potential difference to 120 V, as used in homes and businesses (240 V outlets are supplied by two 120 V lines). What is the ratio of primary to secondary windings in a neighborhood transformer like the one shown in the photograph?

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**Answer:** 119

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**Question 4:** A transformer with an input current of 0.500 A has 6000 primary turns. How many secondary turns must the transformer have if an output current of 9.000 A is desired?

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**Answer:** 333.3

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## Lesson 8: History of Two Forces

**Question 1:** Research the historical development of the concept of electromagnetic forces. Use the textbook as a starting point. You might consider some research prior to Faraday. Consider how Maxwell used observational data to formulate his equations. How did the data support his equations? Please submit your answer on paper.

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**Answer:** Answers may vary.

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# Chapter 18: Interference and Diffraction

## Lesson 1: Interference

**Question 1:** Two beams of light, initially in phase, follow the paths shown. In terms of the wavelength λ, what is the minimum length d that will result in complete destructive interference between the two beams?

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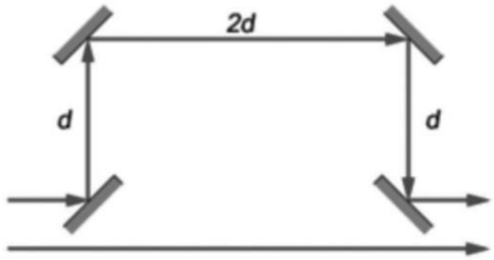


**Answer:** lambda/4

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**Question 2:** Two loudspeakers emit sound waves at the same frequency, amplitude, and phase constant. The waves reach the same listener. The second smallest non-zero path length difference for which the listener perceives constructive interference is 3.4 m. Find the wavelength of the waves.

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**Answer:** 1.7 m

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**Question 3:** Two loudspeakers emit sound waves at the same frequency, amplitude, and phase constant. The waves reach the same listener. For a wavelength of 0.72 m, what is the second smallest difference of path lengths for the listener to perceive destructive interference?

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**Answer:** 1.08 m

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**Question 4:** A Fabry-Perot interferometer consists of two parallel partially-reflecting plates placed a distance d from each other as shown. The beam that passes straight through interferes with the beam that reflects once off each of the mirrored surfaces. (The reflected beams are

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essentially perpendicular to the mirrors. The angles of reflection are exaggerated − and unequal to the angles of incidence − in this diagram.) For light of wavelength 622 nm, what is the smallest, nonzero value of d that results in constructive interference?

**Answer:** $3.11 \times 10^{-7}$ m

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## Lesson 2: Calculating Band Locations

**Question 1:** The first-order bright fringe appears 0.350 cm from the centerline when a light is passed through a double-slit apparatus. The distance between the centers of the slits is 0.450 mm and the screen is 2.71 m from the pair of slits. Find the wavelength of the light.

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**Answer:** $5.81 \times 10^{-7}$ m

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**Question 2:** In a double-slit experiment, an observer wants to see the first bright band making the angle 1.6 degrees with the normal. What must be the slit separation in nanometers, if she uses light of 592 nm wavelength?

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**Answer:** $2.1 \times 10^{4}$ nm

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**Question 3:** Electromagnetic radiation passes through a pair of narrow slits separated by 1.50 $\times 10^{6}$ nm. The fourth bright band makes an angle of 16.8° with the normal. What is the electromagnetic radiation wavelength?

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**Answer:** $1.1 \times 10^{5}$ nm

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**Question 4:** A pair of very flat glass plates, 17 cm long, touch at one end and are separated at the other end by a piece of paper, $6.3 \times 10^{-5}$ m thick. The pair lies with the lower plate on a horizontal surface. An air wedge is formed between the glass plates by this support. Light of wavelength 430 nm shines perpendicularly from above. What is the distance between the observed bright fringes?

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**Answer:** $5.8 \times 10^{-4}$ m

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**Question 5:** A beam of light whose wavelength is 595 nm falls on a barrier containing a pair of long, narrow slits of width 0.0231 mm whose centers are separated by 0.103 mm. Taking diffraction into account, what is the ratio of the intensity at an angle of 0.235° from the centerline to the intensity at the peak of the central maximum?

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**Answer:** 0.345

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## Lesson 3: Diffraction: Light

**Question 1:** What wave characteristic is limiting the density of transistors in microprocessors and why? Please submit your answer on paper.

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**Answer:** Diffraction, as it causes “blurring” which makes for less distinct circuits.

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## Lesson 5: Resolution

**Question 1:** Find the angle to the first diffraction minimum for light of wavelength 566 nm passing through a circular aperture with diameter 0.00440 mm.

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**Answer:** 0.16°

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**Question 2:** A small circular pinhole of radius 0.125 mm is melted at the very top of an igloo. Sunlight (assume a wavelength of 5.50 × 10−7 m, which is approximately the central wavelength of visible light) streams down through the hole to the floor, which is 1.95 m below the pinhole. What is the diameter of the circular spot of sunlight on the floor? (That is, what is the diameter of the central maximum?)

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**Answer:** 0.0105 m

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# Chapter 19: Light

## Lesson 1: Radiation

**Question 1:** What is the frequency in hertz of microwave radiation with wavelength of 4.0 cm?

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**Answer:** 7.5 x 10^9 Hz

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**Question 2:** An electromagnetic wave in a vacuum has an instantaneous magnetic field strength of $7.90 \times 10^{-7}$ T at a certain point. What is the instantaneous electric field strength of the wave at this point?

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**Answer: 237** V/m

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**Question 3:** Compare the characteristics of transverse waves, including electromagnetic waves, and longitudinal waves, including sound waves. Please submit your answer on paper.

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**Answer:** A key difference is the direction of oscillation. Transverse waves oscillate perpendicular to the direction of the wave, while longitudinal waves oscillate parallel to that direction. With electromagnetic waves, the oscillation is the direction of the magnetic and electric fields. A common characteristic is that the particles in both wave types oscillate, but do not ultimately move in the direction of the wave.

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**Question 4:** Describe how waves from two different regions of the electromagnetic spectrum are used in communication or in medicine.

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**Answer:** Communication: Radio waves, microwaves, infrared and visible light can all be used for communication. Radio waves – are used to transmit television and radio programs. Microwaves – are used to transmit satellite television and for mobile phones. Infrared – is used to transmit information from remote controls.
Medicine: X-rays - are used to observe internal bone structure. Gamma rays - are used in sterilizing food and medical equipment and detection of cancer and its treatment.

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**Question 5:** What characteristic of electromagnetic radiation is used in studying proteins? Why are certain frequencies of radiation relevant? Please submit your answer on paper.

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**Answer:** Diffraction with X−ray radiation. The frequency is important because radiation of a certain frequency has a specific wavelength. The wavelength of X−rays, for example, is about the size of protein molecules.

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## Lesson 2: Light Intensity

**Question 1:** What is the power in kilowatts of a source of electromagnetic radiation, when the radiation intensity is 8.5 W/m$^2$ at a distance of 7.9 m from the source? The source radiates isotropically.

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**Answer:** 6.7 kW

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**Question 2:** The SMART-1 lunar orbiter, launched by the European Space Agency, reached the Moon in November 2004 after a 13-month voyage from the Earth. It used an ion propulsion system powered by two winglike solar panel assemblies, one of which you see deployed for testing in the photograph. The assembly consists of lithium photovoltaic cells and it measures 14.0 m wide by 115 cm tall. In flight, when the panels are adjusted to directly face the Sun, each assembly produces 1.90 kW of power. It was shown in the text that the intensity of sunlight is 1380 W/m$^2$ at the distance of the Earth’s (and the Moon’s) orbit. What is the efficiency, expressed as a percentage, of the SMART-1 solar panels at converting sunlight power into electric power?

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**Answer:** 8.55%

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**Question 3:** A light-sensitive sensor needs at least 1.62 watts per square meter to trigger a response. A light source that is 4.64 meters away triggers the sensor. What is the minimum power of the light source?

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**Answer:** 438 W

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**Question 4:** Suppose a blue-giant star is located 10.7 light-years from the solar system and radiates energy at a rate 135 times that of the Sun. What would be the intensity of the starlight reaching the Earth from this star? (Treat this as an ideal problem, and ignore any absorption due to interstellar dust or the Earth's atmosphere.)

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**Answer:** $4.12 \times 10^{-7}$ W/m$^2$

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**Question 5:** How can solar radiation be used to power a spaceship?

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**Answer:** Either using solar panels to harvest sunlight and turn it into electrical energy for propulsion, or using solar sails which utilize the pressure exerted by solar radiation to push the spacecraft forward.

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**Question 6:** A spacecraft with a mass of only 10.0 kg is driven using light pressure from a powerful laser that reflects off a circular mirror mounted on its base. What must be the light intensity in order to accelerate the craft at 14.0 m/s$^2$? The light wavelength is 630 nm and the mirror has a radius of 1.00 m.

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**Answer:** $1.14 \times 10^{10}$ W/m$^2$

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# Chapter 20: Reflection

## Lesson 1: Reflection

**Question 1:** As you get ready for your early morning physics class, you comb your hair in front of a planar mirror. You know that you are 4.75 m in front of the mirror. How far away from you is your image?

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**Answer:** 9.5 m

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**Question 2:** Find the angle of incidence of a light ray that is reflected from a plane mirror at a 69° angle of reflection.

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**Answer:** 69°

**Question 3:** A light ray strikes a plane mirror at a 30° angle of incidence. At what angle of reflection does the ray leave the mirror?

**Answer:** 30°

**Question 4:** Two parallel planar mirrors face each other. An object is placed between them at a distance x from one and 3x from the other. If the images created of the object are “first-order” images, and those created of the first-order images are “second-order” images, how far away are the second-order images from the object, in terms of x?

**Answer:** 8x

**Question 5:** Two 3.0 meter-tall planar mirrors are placed facing and parallel to each other 0.75 m apart. If a ray of light just passes the bottom edge of one mirror and strikes the other at an incident angle of 10°, how many reflections will the light make before exiting this “hall”?

**Answer:** 22

## Lesson 2: Spherical and Parabolic Mirrors

**Question 1:** An object is placed in front of a convex mirror. Draw a ray diagram to determine the nature of the image. Check all the boxes that describe the image.

**Answer:** Virtual, Smaller, Upright

**Question 2:** An object is placed between a concave mirror and its focal point. Draw a ray diagram to determine the nature of the image. Check all the boxes that describe the image.

**Answer:** Virtual, Larger, Upright

**Question 3:** If you want to create a real image, which object location and mirror combinations could you use? Check all that apply.

**Answer:** Object at distance over twice the focal length from concave mirror, object between focal point and center of curvature of concave mirror

**Question 4:** An object is placed between the focal point and center of curvature of a concave mirror. Draw a ray diagram to determine the nature of the image. Check all the boxes that describe the image

**Answer:** Real, Larger, Inverted

## Lesson 3: Mirror Equations

**Question 1:** The focal length of a spherical mirror is 39 cm. Find the mirror’s (positive) radius of curvature in meters.

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**Answer:** 0.72 m

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**Question 2:** The radius of curvature of a convex spherical mirror is 1.6 m. What is the mirror’s focal length?

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**Answer:** 0.8 m

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**Question 3:** A spherical mirror has a focal length of −0.97 m. For an object located 0.94 m in front of the mirror, what is the image distance (including its sign)?

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**Answer:** -0.48 m

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**Question 4:** A frog is positioned at 30 cm from a convex mirror with the focal length of 45 cm. An image is produced behind the mirror. What is the image distance?

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**Answer:** d=-18cm

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**Question 5:** A 1.03 m tall girl is looking at herself in a plane mirror. What is the height of her image?

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**Answer:** 1.03 m

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**Question 6:** For an object positioned 1.2 m in front of a spherical mirror, the image distance is 8.6 m. Find the focal length (including its sign) of the mirror.

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**Answer:** 1.05 m

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# Chapter 21: Refraction and Lenses

## Lesson 1: Snell’s Law

**Question 1:** When a diver observes the liquid surface from below, she sees a circle of light transmitted from the sky. Thus, the light rays reaching her eye from the sky form a cone, as

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shown in the diagram, in cross section. For a liquid with index of refraction 1.4, the vertex angle of this cone, θ, is most nearly

**Answer:** 91 degrees

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**Question 2:** At what speed does light of wavelength 589 nm travel in flint glass? Flint glass has an index of refraction of 1.61 for that wavelength

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**Answer:** 1.86 x $10^8$ m/s

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**Question 3:** A beam of light travels from a medium with an index of refraction of 1.75 to a medium with an index of refraction of 1.30. If the beam refracts at an angle of 23.5° from the normal, at what angle to the normal did it enter the second medium?

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**Answer:** 17.2°

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**Question 4:** A beam of light travels from one medium to another, with the incident beam making an angle of 19.0° from the normal. The beam then refracts at an angle of 32.0°. How many times faster does the light travel in the second medium than the first?

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**Answer:** 1.63

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**Question 5:** A narrow ray of white light traveling in air enters a glass block at an incident angle of 40.00°. The white light consists of a range of wavelengths. For these colors, the indices of refraction for the glass range from 1.512 to 1.531. Find the angular width of the ray inside the block.

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**Answer:** 0.33°

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## Lesson 2: More on Refraction

**Question 1:** When a light ray passes from a medium with low index of refraction to one with high index of refraction,

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**Answer:** the angle of refraction is smaller than the angle of incidence.

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**Question 2:** A beam of light crosses an interface between two media, its wavelength increasing by a factor of 1.40. If the second medium has an index of refraction of 1.34, what is the index of refraction of the first medium?

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**Answer:** 1.88

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**Question 3:** As light travels between media with different indices of refraction, which of the following wave properties changes: speed, frequency, wavelength?

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**Answer:** Speed and wavelength.

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**Question 4:** A light wave passes from a medium with index of refraction $n_1 = 1.3$ into one with $n_2 = 1.1$, as shown. The light's wavelength in the first medium is $\lambda_1 = 420$ nm. Its wavelength in the second medium, $\lambda_2$ , is most nearly

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**Answer:** 500 nm

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## Lesson 3: Total Internal Reflection

**Question 1:** You are constructing a fiber optic cable. You wish to surround the core of the cable with a cladding material such that the critical angle to go from the core to the cladding is 73.0°. If the index of refraction of the core material is 1.61, what must the index of refraction of the cladding material be?

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**Answer:** 1.54

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**Question 2:** The critical angle for light traveling from a certain plastic into air is 36.5°. What is the index of refraction of the plastic?

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**Answer:** 1.68

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**Question 3:** In which case does total internal reflection occur: when light is moving from a slower to a faster medium or from a faster to a slower?

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**Answer:** Slower to faster

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**Question 4:** A point source of light is at the bottom of a koi pond, at a depth of 0.525 meters. What is the radius of the circle of light formed on the water's surface? Take the index of refraction of water to be 1.33. Hint: Some of the light emitted experiences total internal reflection inside the water.

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**Answer:** 0.599 m

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**Question 5:** A light ray enters the center of one end of a thin cylinder of glass at an incident angle of 55.0°. The cylinder has a diameter of 4.30 mm and a length of 595 mm. How many times will the light ray reflect off the inside surface of the cylinder before exiting? The glass has an index of refraction of 1.50.

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**Answer:** 90

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## Lesson 5: Lenses: Ray Tracing

**Question 1:** An object is placed between a converging lens and its focal point. Draw a ray diagram to determine the nature of the image and describe the image.

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**Answer:** Virtual; larger; upright

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**Question 2:** An object is placed between the focal point of a converging lens and a distance twice the focal length from the lens. Draw a ray diagram to determine the nature of the image and describe the image.

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**Answer:** Real; larger; inverted

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**Question 3:** An object is placed in front of a diverging lens. Draw a ray diagram to determine the nature of the image.

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**Answer:** Virtual; smaller; upright

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**Question 4:** An object is placed 4.0 cm in front of a converging mirror, whose radius of curvature is 26 cm. The image the mirror forms can best be described as

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**Answer:** Virtual, enlarged, upright

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**Question 5:** A child requires eyeglasses with diverging lenses, but is concerned that they will look too thick. The radius of curvature of the near surface of the lenses has a magnitude of 55.0 cm and the radius of curvature of the far surface has a magnitude of 35.0 cm. If the lenses are circular with a diameter of 5.00 cm and a thickness at the center of 0.100 cm, how thick are the glasses at the edge?

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**Answer:** .246 cm

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## Lesson 7: Thins Lens Equation

**Question 1:** An image is formed by a lens with a focal length of −40 cm. The distance between the image and the lens is 8.0 cm. The object is positioned in front of the lens at a distance that is most nearly

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**Answer:** 10cm

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**Question 2:** For an object positioned 2.9 m in front of a lens, the image distance is 5.4 m. Find the focal length (including its sign) of the lens.

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**Answer:** 1.89 m



**Question 3:** You are making a thin lens. The near surface (the surface on the object side) has a radius of curvature of +5.00 cm and the far surface has a radius of curvature of +6.00 cm. What is the focal length of the lens if the index of refraction of the material is 1.60?



**Answer:** 50.0 cm



**Question 4:** An entomologist examining an insect adjusts the position of her magnifying glass so that the image of the insect is at her near point, which is 29.0 cm from her eye. If the angular magnifying power of the magnifying glass is 3.75, what is the approximate distance between the insect and the magnifying glass?



**Answer:** 7.73 cm



**Question 5:** You are using a magnifying glass with a focal length of 4.85 cm to examine a rare coin. You place the magnifying glass so that the image of the coin is at your near point of 25.0 cm. What is the approximate angular magnifying power of the magnifying glass?



**Answer:** 6.15



**Question 6:** A lens has a focal length of −67 cm. An object of height 3.0 cm is located 34 cm in front of the lens. What is the height (including its sign) of the object's image?



**Answer:** 1.99 cm



# Chapter 22: Nuclear Physics

## Lesson 1: Elements and Atoms

**Question 1:** The isotope argon-40, which is stable, has a nuclear mass of 39.9525 u. What is its mass excess in atomic mass units? The atomic number of argon is 18.



**Answer:** 0.37 u



**Question 2:** A researcher searching for new isotopes is determining the possible combinations of protons and neutrons. If the isotope he is considering has a mass number of 103 and an atomic number of 52, how many neutrons does its nucleus contain?

**Answer:** 51 neutrons

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**Question 3:** What scientific evidence did Bohr offer for his explanation of the “missing energy”? And what evidence did those who argued for Pauli’s explanation? Please submit your answer on paper.

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**Answer:** Bohr showed that there was less mass. Pauli supporters looked for the neutrino.

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## Lesson 2: Forces and the Nucleus

**Question 1:** Calculate the mass equivalent in kilograms of 1.4 kJ of energy.

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**Answer:** $1.56 \times 10^{-14}$ kg

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**Question 2:** Describe evidence for the weak nuclear force in nature. Please submit your answer on paper.

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**Answer:** The neutrino and beta radiation.

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**Question 3:** Describe effects of the strong nuclear forces in nature. Please submit your answer on paper.

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**Answer:** It holds together the nucleus. Fusion is an effect.

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**Question 4:** Research the strong and weak forces in today’s news. What experiments are being conducted to further understand these forces? Please submit your answer on paper.

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**Answer:** Answers may vary. Potential answer: They are experiments in which particles are made to collide with very high energies and the results of the collision are detected and analyzed. The high energies are achieved by accelerating particles, such as protons or electrons, to very high speeds.

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**Question 5:** Research the historical development of the concept of strong nuclear force. What researching is occurring now? Please submit your answer on paper.

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**Answer:** Answers may vary.

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**Question 6:** Express the mass of a 64.9 kg person in atomic mass units.

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**Answer:** $3.9 \times 10^{28}$ u

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**Question 7:** Apply the mass-energy equivalence in explanations of phenomena. Please submit your answer on paper.

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**Answer:** It explains the energy release in both fission and fusion. Matter is converted to energy as part of these processes. The tremendous amount of energy represented by a small amount of mass explains the huge amounts of energy released by these processes.

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**Question 8:** Describe the significance of mass-energy equivalence. Please submit your answer on paper.

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**Answer:** It shows the fundamental relationship between mass and energy. It is used to describe critical phenomena such as fission and fusion.

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## Lesson 3: Radioactive Decay

**Question 1:** Alpha decay is a type of radioactivity in which a nucleus emits a helium nucleus (4 He, consisting of two protons and two neutrons). Compared to the original nucleus, the new one has

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**Answer:** Atomic number smaller by two and mass number smaller by four

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**Question 2:** The radioactive isotope barium-144 has a half-life of 11.9 s. Find the fraction of Ba-144 atoms remaining in a sample after 148 s have passed.

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**Answer:** $1.8 \times 10^{-4}$ %

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**Question 3:** Carbon-14 has a half-life of 5730 years. After four half-lives have elapsed, what percentage of an initially pure sample would remain unchanged?

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**Answer:** 6.25 percent

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**Question 4:** It is found that after one hour and 15.0 minutes, 22.0% remains of the original sample of a radioactive isotope. What is the half-life of this isotope expressed in minutes?

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**Answer:** 34.3 minutes

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## Lesson 4: Fission and Fusion

**Question 1:** In the sun, 4 hydrogen nuclei undergo a multi-step process and eventually form a helium-4 nucleus (plus some positrons, neutrinos and gamma rays, all of negligible mass). What is this an example of?

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**Answer:** Nuclear fusion

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**Question 2:** Give examples of applications of atomic and nuclear phenomena. Please submit your answer on paper.

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**Answer:** Atomic bombs and carbon dating are two examples.

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# Chapter 23: Quantum Physics

## Lesson 1: Quantum

**Question 1:** How does the energy of a photon of electromagnetic radiation change as the frequency increases? As the wavelength increases?

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**Answer:** Energy increases as frequency increases, decreases as wavelength increases.

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**Question 2:** “The wavelength of red light is greater than that of violet light, so its energy is always greater,” said Serafina. Do you agree with this statement?

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**Answer:** False. Greater wavelength equates to lower frequency and thus **lower** energy.

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**Question 3:** “AM and FM radio signals travel at the same speed through the atmosphere, so they have the same amount of energy.” Do you agree with this statement? Explain.

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**Answer:** False. Waves can have the same speed, but different frequencies and wavelengths and thus energy.

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**Question 4:** Find the energy in joules of a single photon of microwave radiation with the wavelength of 0.53 cm.

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**Answer:** $3.75 \times 10^{-23}$ J

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**Question 5:** If a photon has energy of $5.0 \times 10^{-20}$ J, what is its frequency?

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**Answer:** $7.5 \times 10^{13}$ Hz

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**Question 6:** The gap between two energy levels in neutral helium atom is 23.4 eV. What frequency photon must be emitted when an electron makes a transition from upper to lower state?

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**Answer:** $5.65 \times 10^{15}$ Hz

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## Lesson 2: Evidence of Quantum

**Question 1:** What is the energy in electron volts of the 7th energy level of the hydrogen atom according to the Bohr model? Express your answer to the nearest hundredth of an electron volt.

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**Answer:** -0.3 eV

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**Question 2:** Provide an example of when light is typically described as a wave, and one where it is typically described as a particle. Please submit your answer on paper.

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**Answer:** Wave examples include refraction and diffraction. Particle examples include the photoelectric effect and momentum transfer.

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**Question 3:** An electron starts with energy $5.3 \times 10^{-20}$ J and it moves to a state with energy $6.5 \times 10^{-20}$ J. What is the change in energy?

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**Answer:** $1.2 \times 10^{-20}$ J

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**Question 4:** Compare the emission spectra produced by various atoms. Please submit your answer on paper.

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**Answer:** They have lines of different colors. The lines may have some overlap, but atoms have a specific combination.

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## Lesson 3: Semiconductors and Lasers

**Question 1:** A laser emits light at the wavelength of 779 nm when electrons in the lasing material drop from one energy level to another. What is the energy difference in electron volts between the levels?

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**Answer:** 1.59 eV

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**Question 2:** Light is amplified in a laser. Consider photons with characteristics that are specific to the laser medium, that is, the laser will emit light at the frequency of the photons. What property of these photons initially increases during the amplification process?

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**Answer:** Number of photons

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**Question 3:** Give examples of applications of quantum phenomena. Please submit your answer on paper.

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**Answer:** Transistors, diodes, lasers and photovoltaic cells.

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## Lesson 4: Matter Waves

**Question 1:** What is the momentum of an electron that has a de Broglie wavelength of 1.56 nm?

**Answer:** 4.25 x $10^{-25}$ kg m/s

**Question 2:** Find the de Broglie wavelength in nanometers of neutrons moving at 2190 m/s.

**Answer:** 0.18 nm

**Question 3:** What is the momentum of a photon of visible light with wavelength 555 nm?

**Answer:** 1.19 x $10^{-27}$ kg m/s

**Question 4:** Protons are given a kinetic energy of 604 eV. What is their wavelength in meters?

**Answer:** 1.46 x $10^{17}$ m

**Question 5:** Calculate the total energy, in MeV, of a proton that has a de Broglie wavelength of 0.500 femtometer (1 fm = $10^{-15}$ m). The rest energy of a proton ($mc^2$ ) is 938 MeV. Hint: This requires a relativistic calculation.

**Answer:** 2650 MeV

# Chapter 24: Advances in Physics

## Lesson 1: Special Relativity

**Question 1:** The average lifetime of muons at rest is 2.2 × $10^{-6}$ s. High-speed muons moving through the atmosphere are observed to have an average lifetime of 3.4 × $10^{-6}$ s. Find their speed.

**Answer:** 2.2 x $10^{8}$ m/s

**Question 2:** A clock is designed to tick every second. When the clock is moving past an observer at 89% of the speed of light, how much time does the observer measure between ticks?

**Answer:** 2.1 s

**Question 3:** In the electromagnetic spectrum emitted by a receding galaxy, a 448 nm line is found to be redshifted to 566 nm. How fast in meters per second is the galaxy moving away from Earth?

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**Answer:** $6.9 \times 10^7$ m/s

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**Question 4:** A space torpedo, launched at an Intergalactic Federation spacecraft at 0.320 of the speed of light with respect to the spacecraft, just misses it. As the torpedo passes by, a physicist in the spacecraft measures the torpedo's length and finds 4.34 m. Calculate the proper length of the torpedo.

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**Answer:** 4.58 m

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**Question 5:** A spaceship skims the atmosphere of The Dark Planet at a speed of 0.61c with respect to the planet. While doing so, it sends ahead a scout craft at 0.58c relative to itself. At what fraction of the speed of light is the scout craft moving, according to the Dark Planetarians?

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**Answer:** 0.97

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**Question 6:** Jana and Shashi are engaged in a contest to see who can first hit Pluto with a laser beam. At precisely 12 noon, Jana fires her laser from the Earth. In an attempt to beat her, Shashi races by the Earth at 0.50c (as measured by Jana), toward Pluto, and fires his beam just as he passes her. Who will win the contest? Ignore any effects of the Earth's atmosphere.

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**Answer:** It's a tie!

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**Question 7:** A spaceship is flying directly away from Earth at a speed of 0.700c, and the captain's family at home on Earth broadcasts their well wishes on the Family Radio System frequency of 462.5625 Mhz. To what frequency must the homesick captain tune the ship's radio to receive the broadcast? (Round your answer to three significant figures.)

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**Answer:** 194 MHz

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**Question 8:** The Green Planet is attacked by a spaceship flying toward it at a speed of 0.22c and firing its forward laser cannon. The laser is designed to operate at a frequency of $5.9 \times 10^{14}$ Hz. Find the frequency of the laser radiation as observed by the Greenies.

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**Answer:** $4.7 \times 10^{14}$ Hz

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## Lesson 2: Standard Model

**Question 1:** Why have scientific theories about the beginning of the Universe developed and changed so much in the past 60 years or so? Please submit your answer on paper.

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**Answer:** One reason is technological advances, such as particle accelerators. This in turn has furthered much more scientific research in the area.

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**Question 2:** Why is so much effort being expended to find the Higgs boson? Explain your answer using the concepts of hypothesis and theory. Please submit your answer on paper.

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**Answer:** It is required to turn the Standard Model from a hypothesis to a theory supported by observations.

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**Question 3:** What empirical evidence have scientists offered for the scientific explanations supplied by the Standard Model? Please submit your answer on paper.

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**Answer:** They have discovered both particles and forces that support the model.

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## Lesson 3: Particle Accelerators

**Question 1:** How have technology advances in particle accelerators allowed scientific theories to be created and changed? How have they allowed new areas of science to be developed? Please submit your answer on paper.

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**Answer:** They allow scientists to “peer within” the atom, due to higher energy levels and better analytic tools. This has led to theories such as the Standard Model.

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# Chapter 25: Tools for Physics

## Lesson 1: Models and Laws

**Question 1:** “The universe is mostly empty space.” What type of model would describe this statement?

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**Answer:** Conceptual model: An idea that explains observations.

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**Question 2:** “Air resistance is proportional to the cube of an object’s velocity.” What kind of model describes this statement?

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**Answer:** Mathematical: equation to define relationships

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**Question 3:** “The speed of light is constant – the motion of its source or observer does not change its speed.” What kind of model describes this statement?

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**Answer:** Physical: Describes properties and relationships

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**Question 4:** In answering a query about why gravity exists, a physicist wrote (and we paraphrase): “In Newtonian physics, there’s no reason – there’s just the law to calculate its strength. With Einstein’s theory of General Relativity, matter curves spacetime around it, resulting in an explanation for gravity, but there’s no explanation for why matter curves spacetime. In quantum theory, it’s because matter exchanges gravitons, but there’s no explanation for why gravitons with those properties exist.” Discuss how this explanation illustrates the strengths and limits of scientific inquiry.



**Answer:** Answers may vary.



## Lesson 2: Graphing and Analyzing Data

**Question 1:** Does your physics course explain why Newton’s laws of motion and gravity are true? Explain why or why not.



**Answer:** yes/no



**Question 2:** An ancient Greek believed that her gods controlled the motion of the stars. Is this considered science?



**Answer:** No.



**Question 3:** Tedric asks six of his neighbors whether they believe that an object moving at high velocity relative to an observer would have its length measured as less than if it were stationary relative to the observer. All six agree that this sounds like utter nonsense. Tedric concludes it is nonsense. Is Tedric performing science? Explain.



**Answer:** No.



**Question 4:** Two scientists both agree that gravitational force is proportional to the product of the masses of two bodies, and inversely proportional to the distance between them. The scientists disagree on why this relationship holds. What kind(s) of debate are they having?



**Answer:** theoretical debate



**Question 5:** “The universe is composed mostly of empty space” is a statement which can be described as what kind of model?



**Answer:** Conceptual model.



**Question 6:** “The acceleration is proportional to the force and inversely proportional to the mass” is a statement which can be described as what kind of model?



**Answer:** Mathematical model.