

# Solved Practice Problems: Entire Course of Physics 2001

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# Units and Measurement

1. How many significant figures are in the number 0.00450?

- A) 2
- B) 3
- C) 4
- D) 5

**Solution:** B. Leading zeros are only placeholders, so they do not count as significant figures. The digits 4, 5, and the trailing 0 after the decimal are significant, so there are 3 significant figures.

2. What is the result of  $12.5 + 3.25$  respecting significant figures?

- A) 15.75
- B) 15.8
- C) 15.7
- D) 16.0

**Solution:** B. First add the numbers:  $12.5 + 3.25 = 15.75$ . For addition, the result must be rounded to the least number of decimal places, which is one decimal place here, so the answer is 15.8.

3. Which of the following is a base SI unit?

- A) Newton
- B) Joule
- C) Kilogram
- D) Velocity

**Solution:** C. Kilogram is one of the base SI units and is used for mass. Newton and joule are derived units, and velocity is a physical quantity rather than a unit.

4. Convert 50 km/h to m/s.

- A) 13.9 m/s
- B) 180 m/s
- C) 500 m/s
- D) 8.3 m/s

**Solution:** A. Convert kilometers to meters and hours to seconds by multiplying by  $\frac{1000}{3600}$ . This gives  $50 \times \frac{1000}{3600} = 13.88\dots$ , which rounds to 13.9 m/s.

5. The number  $3.45 \times 10^3$  is equivalent to:

- A) 345
- B) 3450
- C) 0.00345
- D) 34.5

**Solution:** B. A positive exponent means the decimal point moves to the right. Moving it 3 places gives 3450.

6. Calculate the area of a rectangle with sides 2.0 m and 3.00 m (sig figs).

- A) 6 m<sup>2</sup>
- B) 6.0 m<sup>2</sup>
- C) 6.00 m<sup>2</sup>
- D) 6.000 m<sup>2</sup>

**Solution:** B. First multiply the two lengths:  $2.0 \times 3.00 = 6.00 \text{ m}^2$ . For multiplication, keep the fewest significant figures, which is 2, so the final answer is 6.0 m<sup>2</sup>.

7. Which measurement has the highest uncertainty?

- A) 1.00 m
- B) 1.0 m
- C) 1 m
- D) 1.000 m

**Solution:** C. A measurement written with fewer digits is less precise and therefore has greater uncertainty. Since 1 m has the fewest reported digits, it has the highest uncertainty.

8. Convert 250 cm to meters.

- A) 0.25 m
- B) 2.5 m
- C) 25 m
- D) 2500 m

**Solution:** B. There are 100 cm in 1 m, so divide by 100 to convert centimeters to meters. Thus  $250 \div 100 = 2.5 \text{ m}$ .

9. A highway speed limit is 65 mph (approx 105 km/h). What is this in m/s?

- A) 18 m/s
- B) 29 m/s
- C) 65 m/s

D) 105 m/s

**Solution:** B. Convert km/h to m/s by multiplying by  $\frac{1000}{3600}$ , or dividing by 3.6. That gives  $105/3.6 \approx 29.2$  m/s, so the closest answer is 29 m/s.

10. **A typical human heart beats 72 times per minute. What is the frequency in Hz (beats per second)?**

A) 0.83 Hz

B) 1.2 Hz

C) 72 Hz

D) 60 Hz

**Solution:** B. Frequency means number of cycles per second, so convert beats per minute to beats per second. Dividing 72 by 60 gives 1.2 Hz.

11. **A smartphone screen is 6.1 inches diagonally. If 1 inch = 2.54 cm, what is this in cm?**

A) 2.4 cm

B) 15.5 cm

C) 8.6 cm

D) 12.2 cm

**Solution:** B. Use the conversion 1 inch = 2.54 cm and multiply by 6.1. This gives  $6.1 \times 2.54 \approx 15.49$  cm, which rounds to 15.5 cm.

12. **How many significant figures are in the number 0.070?**

A) 1

B) 2

C) 3

D) 4

**Solution:** B. The zeros before the 7 are placeholders, so they are not significant. The final zero after the decimal is significant, so the number has 2 significant figures.

13. **How many significant figures are in the number 1020?**

A) 2

B) 3

C) 4

D) 1

**Solution:** B. The zero between 1 and 2 is significant because it lies between nonzero digits. The final zero is not usually counted without a decimal point, so the number has 3 significant figures.

14. **When multiplying or dividing measured quantities, the result should be rounded to:**

- A) The most decimal places of any factor
- B) The fewest significant figures of any factor
- C) The most significant figures of any factor
- D) The fewest decimal places of any factor

**Solution:** B. For multiplication and division, the limiting rule is significant figures rather than decimal places. The final result should match the quantity with the fewest significant figures.

15. **Precision in a measurement refers to:**

- A) How close a measurement is to the true value
- B) How close repeated measurements are to each other
- C) The number of decimal places reported
- D) The size of the unit used

**Solution:** B. Precision is about consistency from one measurement to the next. If repeated measurements cluster closely together, they are precise even if they are not accurate.

16. **Accuracy in a measurement refers to:**

- A) How close repeated measurements are to each other
- B) How many significant figures are reported
- C) How close a measurement is to the accepted value
- D) The smallest division on the instrument

**Solution:** C. Accuracy tells you how close a measurement is to the true or accepted value. A measurement can be accurate even if repeated measurements are not tightly grouped.

17. **Which of the following is a derived (not base) SI unit?**

- A) Meter
- B) Second
- C) Kilogram
- D) Newton

**Solution:** D. A newton is built from base units, since  $1 \text{ N} = 1 \text{ kg} \cdot \text{m}/\text{s}^2$ . Meter, second, and kilogram are base SI units, but the newton is derived from them.

18. **The SI prefix “kilo” represents a factor of:**

- A) 10
- B) 100
- C) 1000
- D) 1,000,000

**Solution:** C. The prefix kilo means  $10^3$ . That is equal to 1000 times the base unit.

19. **A student measures a table length five times and gets: 1.52 m, 1.51 m, 1.53 m, 1.52 m, 1.52 m. The actual length is 1.80 m. These measurements are:**

- A) Both accurate and precise
- B) Accurate but not precise
- C) Precise but not accurate
- D) Neither accurate nor precise

**Solution:** C. The measurements are tightly grouped around 1.52 m, so they are precise. However, they are far from the true value of 1.80 m, so they are not accurate.

20. **Which of the following is a fundamental (base) SI quantity?**

- A) Area
- B) Speed
- C) Force
- D) Time

**Solution:** D. Time is a base SI quantity and is measured in seconds. Area, speed, and force are all derived from other base quantities.

21. **Express 45,000 in proper scientific notation.**

- A)  $4.5 \times 10^3$
- B)  $4.5 \times 10^4$
- C)  $45 \times 10^3$
- D)  $0.45 \times 10^5$

**Solution:** B. Proper scientific notation requires exactly one nonzero digit before the decimal point. Since 45,000 becomes 4.5 when the decimal moves 4 places, the number is  $4.5 \times 10^4$ .

22. **Convert 72 km/h to m/s.**

- A) 10 m/s
- B) 20 m/s
- C) 36 m/s
- D) 72 m/s

**Solution:** B. Convert km/h to m/s by dividing by 3.6. So  $72/3.6 = 20$  m/s.

23. **Convert 2.5 hours to seconds.**

- A) 150 s
- B) 1500 s
- C) 9000 s
- D) 25000 s

**Solution:** C. There are 3600 seconds in 1 hour. Multiplying  $2.5 \times 3600$  gives 9000 s.

24. **A student measures  $g = 9.5 \text{ m/s}^2$ . The accepted value is  $10.0 \text{ m/s}^2$ . What is the percent error?**

- A) 0.5%
- B) 2%
- C) 5%
- D) 10%

**Solution:** C. Percent error is found from  $\frac{|\text{measured} - \text{accepted}|}{\text{accepted}} \times 100\%$ . Here the difference is 0.5, so  $\frac{0.5}{10.0} \times 100\% = 5\%$ .

25. **Convert 0.75 kg to grams.**

- A) 7.5 g
- B) 75 g
- C) 750 g
- D) 7500 g

**Solution:** C. One kilogram equals 1000 grams. Multiplying  $0.75 \times 1000$  gives 750 g.

## One-Dimensional Motion

26. The slope of a position-time graph represents:

- A) Displacement
- B) Velocity
- C) Acceleration
- D) Distance

**Solution:** B. On a position-time graph, slope tells how quickly position changes with time. That quantity is velocity.

27. If an object has constant negative velocity and positive acceleration, it is:

- A) Speeding up
- B) Slowing down
- C) Moving at constant speed
- D) Stopped

**Solution:** B. When velocity and acceleration point in opposite directions, the object's speed decreases. Here the velocity is negative and the acceleration is positive, so the object is slowing down.

28. An object in free fall (neglecting air resistance) has an acceleration of:

- A)  $0 \text{ m/s}^2$
- B)  $9.8 \text{ m/s}^2$  downwards
- C) Increasing as it falls
- D) Decreasing as it falls

**Solution:** B. In ideal free fall, gravity is the only force acting on the object. Near Earth's surface, that gives a constant downward acceleration of about  $9.8 \text{ m/s}^2$ .

29. At the peak of a vertical toss, the velocity is:

- A) Maximum
- B) Zero
- C)  $9.8 \text{ m/s}$
- D) Negative

**Solution:** B. At the highest point, the object changes direction from upward to downward. Its instantaneous velocity is therefore zero at that moment, even though gravity still acts on it.

30. Displacement is a:

- A) Scalar
- B) Vector
- C) Neither
- D) Force

**Solution:** B. Displacement describes the change in position from start to finish. Because it includes both magnitude and direction, it is a vector.

31. **Can an object have zero velocity and non-zero acceleration?**

- A) Yes
- B) No
- C) Only in vacuum
- D) Only in space

**Solution:** A. Yes, this happens at turning points such as the top of a vertical toss. The object is momentarily at rest there, but gravity still gives it a non-zero acceleration downward.

32. **A car traveling on a highway maintains a speed of 20 m/s for 5 seconds. What distance does it cover?**

- A) 4 m
- B) 25 m
- C) 100 m
- D) 10 m

**Solution:** C. For motion at constant speed, distance is found from  $d = vt$ . Substituting  $v = 20$  m/s and  $t = 5$  s gives  $d = 100$  m.

33. **A car at a stoplight accelerates from rest to 20 m/s in 4 seconds. What is the acceleration?**

- A) 2 m/s<sup>2</sup>
- B) 4 m/s<sup>2</sup>
- C) 5 m/s<sup>2</sup>
- D) 80 m/s<sup>2</sup>

**Solution:** C. Acceleration is the change in velocity divided by the time taken. The velocity changes from 0 to 20 m/s in 4 s, so  $a = 20/4 = 5$  m/s<sup>2</sup>.

34. **An object falls from rest for 3 seconds. How far does it fall? ( $g = 10$  m/s<sup>2</sup>)**

- A) 15 m

- B) 30 m
- C) 45 m
- D) 90 m

**Solution:** C. Since the object starts from rest, use  $d = \frac{1}{2}gt^2$ . Substituting  $g = 10 \text{ m/s}^2$  and  $t = 3 \text{ s}$  gives  $d = 45 \text{ m}$ .

35. **A ball is thrown up with  $v_0 = 30 \text{ m/s}$ . How long to reach the top? ( $g = 10 \text{ m/s}^2$ )**

- A) 1 s
- B) 2 s
- C) 3 s
- D) 4 s

**Solution:** C. At the top of the motion, the final velocity is zero. Using  $v = v_0 - gt$ , we get  $0 = 30 - 10t$ , so the time to reach the top is 3 s.

36. **What is the final velocity of an object dropped from 20 m? ( $g = 10 \text{ m/s}^2$ )**

- A) 10 m/s
- B) 20 m/s
- C) 30 m/s
- D) 40 m/s

**Solution:** B. Because the object is dropped, its initial speed is zero. Using  $v^2 = v_0^2 + 2gd$  gives  $v^2 = 2(10)(20) = 400$ , so the final speed is 20 m/s.

37. **A runner accelerates from 2 m/s to 8 m/s over 20 m. What is the acceleration?**

- A) 1.5 m/s<sup>2</sup>
- B) 3.0 m/s<sup>2</sup>
- C) 0.5 m/s<sup>2</sup>
- D) 2.0 m/s<sup>2</sup>

**Solution:** A. Use  $v^2 = v_0^2 + 2ax$  because the time is not given. Substituting  $v = 8 \text{ m/s}$ ,  $v_0 = 2 \text{ m/s}$ , and  $x = 20 \text{ m}$  gives  $64 = 4 + 40a$ , so  $a = 1.5 \text{ m/s}^2$ .

38. **A driver sees a deer and hits the brakes. The reaction time is 0.8 s. If traveling at 20 m/s, how far does the car travel before the brakes are applied?**

- A) 16 m
- B) 20 m

- C) 25 m
- D) 10 m

**Solution:** A. During the reaction time, the car continues moving at its original speed because the brakes have not acted yet. So the distance is  $d = vt = 20 \times 0.8 = 16$  m.

39. **You drop a rock into a well and hear the splash 2 seconds later. Ignoring sound travel time, how deep is the well? ( $g = 10 \text{ m/s}^2$ )**

- A) 10 m
- B) 20 m
- C) 40 m
- D) 5 m

**Solution:** B. If sound travel time is ignored, the full 2 s is the time of fall. Using  $d = \frac{1}{2}gt^2$  gives  $d = \frac{1}{2}(10)(2^2) = 20$  m.

40. **A jet takes off from an aircraft carrier, accelerating from 0 to 70 m/s in 2 seconds. What is the acceleration in g's? ( $1g \approx 10 \text{ m/s}^2$ )**

- A) 1.5 g
- B) 3.5 g
- C) 7 g
- D) 10 g

**Solution:** B. First find the acceleration in  $\text{m/s}^2$ :  $a = \Delta v/t = 70/2 = 35 \text{ m/s}^2$ . Since  $1g \approx 10 \text{ m/s}^2$ , this corresponds to  $35/10 = 3.5g$ .

41. **The area under a velocity-time graph represents:**

- A) Acceleration
- B) Force
- C) Displacement
- D) Speed

**Solution:** C. The area under a velocity-time graph is velocity multiplied by time. Since the units are  $\text{m/s}$  times  $\text{s}$ , the result is displacement in meters.

42. **If a position-time graph is a straight line with a positive slope, the object has:**

- A) Constant positive acceleration
- B) Constant positive velocity
- C) Increasing velocity

D) Zero velocity

**Solution:** B. A straight line means the slope does not change, so the velocity is constant. Because the slope is positive, the velocity is in the positive direction.

43. **If a position-time graph is a parabola (curve) opening upward, the object has:**

- A) Constant velocity
- B) Zero acceleration
- C) Constant positive acceleration
- D) Decreasing speed

**Solution:** C. A curved parabolic position-time graph shows that the slope is changing with time. That is the signature of constant acceleration, and opening upward corresponds to positive acceleration.

44. **The average velocity for a complete round trip (returning to the starting point) is:**

- A) Equal to the average speed
- B) Always positive
- C) Zero
- D) Equal to the maximum velocity

**Solution:** C. Average velocity depends on displacement, not on total distance traveled. In a complete round trip the displacement is zero, so the average velocity must also be zero.

45. **Distance traveled can never be:**

- A) Greater than displacement
- B) Equal to displacement
- C) Positive
- D) Negative

**Solution:** D. Distance measures the total path length traveled by an object. Since path length cannot be less than zero, distance can never be negative.

46. **Speed is the magnitude of:**

- A) Acceleration
- B) Displacement
- C) Velocity
- D) Force

**Solution:** C. Velocity includes direction, while speed does not. That means speed is simply the magnitude of velocity.

47. **On a velocity-time graph, a horizontal line indicates:**

- A) The object is at rest
- B) The object has constant acceleration
- C) The object has constant velocity
- D) The object is decelerating

**Solution:** C. A horizontal line means the velocity value stays the same as time passes. So the object has constant velocity and zero acceleration.

48. **On a velocity-time graph, a straight line with positive slope indicates:**

- A) Constant velocity
- B) Constant positive acceleration
- C) Decreasing speed
- D) Zero displacement

**Solution:** B. The slope of a velocity-time graph represents acceleration. A straight line with positive slope therefore means constant positive acceleration.

49. **An object in free fall near Earth's surface has the same acceleration regardless of its:**

- A) Height
- B) Mass
- C) Shape
- D) All of the above (neglecting air resistance)

**Solution:** D. In ideal free fall, gravity gives all objects the same acceleration  $g$ . Mass, shape, and height do not change that result as long as air resistance is neglected.

50. **Deceleration means the object's:**

- A) Acceleration is always negative
- B) Speed is decreasing
- C) Velocity is negative
- D) Acceleration is zero

**Solution:** B. Deceleration means the object's speed is getting smaller. The acceleration does not have to be negative; it just has to oppose the motion.

51. **Instantaneous velocity at a point on a position-time graph is the slope of the:**

- A) Secant line
- B) Horizontal axis
- C) Tangent line at that point
- D) Vertical line at that point

**Solution:** C. Instantaneous velocity means the velocity at one exact moment. On a position-time graph, that is given by the slope of the tangent line at that point.

52. **A ball thrown straight up takes 3 seconds to reach the top. The total time in the air (returning to the same height) is:**

- A) 3 s
- B) 4.5 s
- C) 6 s
- D) 9 s

**Solution:** C. For motion that returns to the same height, the time going up equals the time coming down. Since it takes 3 s to rise, the total time in the air is 6 s.

53. **If two objects are dropped simultaneously from different heights, the one dropped from the lower height hits the ground:**

- A) Last
- B) First
- C) At the same time
- D) It depends on their masses

**Solution:** B. Both objects have the same downward acceleration if air resistance is ignored. The one that has less distance to fall reaches the ground first.

54. **An object moving along a straight line reverses direction. At the turning point, its velocity is zero and its acceleration is:**

- A) Also zero
- B) Non-zero
- C) Undefined
- D) Equal to its speed

**Solution:** B. To reverse direction, the velocity must be changing, which requires acceleration. So even though the velocity is momentarily zero at the turning point, the acceleration is not zero.

55. A car travels 360 km in 4 hours. What is its average speed in m/s?

- A) 15 m/s
- B) 25 m/s
- C) 90 m/s
- D) 100 m/s

**Solution:** B. Convert 360 km to 360,000 m and 4 h to 14,400 s. Then the average speed is  $360,000/14,400 = 25$  m/s.

56. A car decelerates from 30 m/s to rest in 6 seconds. What is the magnitude of the deceleration?

- A) 2 m/s<sup>2</sup>
- B) 5 m/s<sup>2</sup>
- C) 6 m/s<sup>2</sup>
- D) 36 m/s<sup>2</sup>

**Solution:** B. The speed changes from 30 m/s to 0 in 6 s. Using  $|a| = \Delta v/t$ , the magnitude of the deceleration is  $30/6 = 5$  m/s<sup>2</sup>.

57. A ball is thrown upward with  $v_0 = 20$  m/s. What is the maximum height? ( $g = 10$  m/s<sup>2</sup>)

- A) 10 m
- B) 20 m
- C) 40 m
- D) 200 m

**Solution:** B. At the highest point, the vertical velocity is zero. Using  $v^2 = v_0^2 - 2gh$  gives  $0 = 20^2 - 2(10)h$ , so the maximum height is 20 m.

58. An object falls from rest for 4 seconds. What is its speed just before hitting the ground? ( $g = 10$  m/s<sup>2</sup>)

- A) 20 m/s
- B) 40 m/s
- C) 80 m/s
- D) 160 m/s

**Solution:** B. For free fall from rest, the speed after time  $t$  is  $v = gt$ . Substituting  $g = 10$  m/s<sup>2</sup> and  $t = 4$  s gives 40 m/s.

59. A runner covers the first 100 m at 5 m/s and the next 100 m at 10 m/s. What is the average speed for the entire 200 m?

- A) 6.7 m/s
- B) 7.5 m/s
- C) 8.0 m/s
- D) 10 m/s

**Solution:** A. First find the time for each segment:  $100/5 = 20$  s and  $100/10 = 10$  s. The total distance is 200 m and the total time is 30 s, so the average speed is about 6.67 m/s.

60. **A car traveling at 25 m/s brakes with a deceleration of 5 m/s<sup>2</sup>. What distance does it need to stop?**

- A) 50 m
- B) 62.5 m
- C) 125 m
- D) 250 m

**Solution:** B. Since the final speed is zero, use  $v^2 = v_0^2 + 2ax$  with  $v = 0$ . Substituting gives  $0 = 25^2 + 2(-5)x$ , so the stopping distance is 62.5 m.

61. **A ball is dropped from a height of 80 m. How long does it take to reach the ground? ( $g = 10$  m/s<sup>2</sup>)**

- A) 2 s
- B) 4 s
- C) 8 s
- D) 16 s

**Solution:** B. For an object dropped from rest, use  $d = \frac{1}{2}gt^2$ . Substituting  $80 = 5t^2$  gives  $t^2 = 16$ , so the time is 4 s.

62. **An object starts with velocity 10 m/s and accelerates at 2 m/s<sup>2</sup>. What is its velocity after 5 s?**

- A) 12 m/s
- B) 15 m/s
- C) 20 m/s
- D) 60 m/s

**Solution:** C. Use the kinematics relation  $v = v_0 + at$ . With  $v_0 = 10$  m/s,  $a = 2$  m/s<sup>2</sup>, and  $t = 5$  s, the final velocity is 20 m/s.

63. **An object has initial velocity 15 m/s and acceleration  $-3$  m/s<sup>2</sup>. After how many seconds does it momentarily stop?**

- A) 3 s
- B) 5 s
- C) 12 s
- D) 45 s

**Solution:** B. The object stops when its velocity becomes zero. Setting  $0 = 15 - 3t$  in  $v = v_0 + at$  gives  $t = 5$  s.

64. **How far does a freely falling object (from rest) travel during the 3rd second of its fall? ( $g = 10 \text{ m/s}^2$ )**

- A) 15 m
- B) 20 m
- C) 25 m
- D) 30 m

**Solution:** C. Find the total distance after 3 s and subtract the total distance after 2 s. That gives  $45 - 20 = 25$  m traveled during the 3rd second alone.

65. **A car starts from rest and accelerates at  $4 \text{ m/s}^2$  for 5 seconds. How far does it travel?**

- A) 20 m
- B) 50 m
- C) 100 m
- D) 10 m

**Solution:** B. Because the car starts from rest, the distance is  $d = \frac{1}{2}at^2$ . Substituting  $a = 4 \text{ m/s}^2$  and  $t = 5$  s gives 50 m.

## Vectors and Projectile Motion

66. Which of the following is a vector quantity?

- A) Speed
- B) Mass
- C) Temperature
- D) Velocity

**Solution:** D. A vector must have both magnitude and direction. Velocity satisfies that requirement, while speed, mass, and temperature do not.

67. The horizontal component of a projectile's velocity (ignoring air resistance):

- A) Increases
- B) Decreases
- C) Remains constant
- D) Is zero

**Solution:** C. If air resistance is ignored, there is no horizontal force on the projectile. With no horizontal acceleration, the horizontal component of velocity remains constant.

68. At the top of a projectile's path, the vertical acceleration is:

- A) Zero
- B)  $g$  downwards
- C)  $g$  upwards
- D) Depends on mass

**Solution:** B. Gravity acts throughout the entire flight, even at the highest point. So the vertical acceleration is still  $g$  downward there.

69. Two vectors of magnitude 3 and 4 can have a maximum resultant of:

- A) 1
- B) 5
- C) 7
- D) 12

**Solution:** C. The maximum resultant occurs when the two vectors point in the same direction. In that case their magnitudes add directly, giving 7.

70. A ball is dropped and another fired horizontally from the same height. Which hits the ground first?

- A) Dropped ball
- B) Fired ball
- C) Both at same time
- D) Depends on mass

**Solution:** C. Both objects start with the same vertical velocity and have the same downward acceleration due to gravity. Since horizontal motion does not affect fall time, they hit the ground together.

71. Find the  $x$ -component of a vector with magnitude 10 at  $60^\circ$  to the  $x$ -axis.

- A) 5.0
- B) 8.7
- C) 10
- D) 0

**Solution:** A. The horizontal component is found with  $v_x = v \cos \theta$ . Using  $v = 10$  and  $\theta = 60^\circ$  gives  $v_x = 5.0$ .

72. A vector has components  $x = 3$ ,  $y = 4$ . Its magnitude is:

- A) 5
- B) 7
- C) 12
- D) 25

**Solution:** A. Use the Pythagorean theorem because the components are perpendicular. The magnitude is  $\sqrt{3^2 + 4^2} = 5$ .

73. A ball is thrown horizontally at 10 m/s from a height of 20 m. Time to hit ground? ( $g = 10 \text{ m/s}^2$ )

- A) 1 s
- B) 2 s
- C) 3 s
- D) 4 s

**Solution:** B. The time depends only on the vertical drop, not on the horizontal speed. Using  $20 = \frac{1}{2}(10)t^2$  gives  $t = 2$  s.

74. In the previous problem, how far horizontally does it travel?

- A) 10 m
- B) 20 m

- C) 30 m
- D) 40 m

**Solution:** B. Once the flight time is known, the horizontal motion is simple constant-speed motion. So  $x = v_x t = 10 \times 2 = 20$  m.

75. **A projectile is launched at  $30^\circ$  with  $v = 40$  m/s. Vertical component of velocity?**

- A) 20 m/s
- B) 34.6 m/s
- C) 40 m/s
- D) 0 m/s

**Solution:** A. The vertical component is found with  $v_y = v \sin \theta$ . Substituting  $v = 40$  m/s and  $\theta = 30^\circ$  gives 20 m/s.

76. **A quarterback throws a football at a  $45^\circ$  angle. To maximize range, he should throw it:**

- A) At  $30^\circ$
- B) At  $45^\circ$
- C) At  $60^\circ$
- D) Horizontally

**Solution:** B. For a projectile launched and landing at the same height, the range is greatest at  $45^\circ$ . That angle balances horizontal and vertical components most effectively for maximum distance.

77. **A boat heads directly north across a river flowing east. The boat's resultant velocity is:**

- A) North
- B) East
- C) Northeast
- D) Northwest

**Solution:** C. The boat's northward velocity combines with the river's eastward velocity. Adding those vectors gives a resultant toward the northeast.

78. **A relief package is dropped from a plane flying horizontally. To an observer on the ground, the package follows a:**

- A) Straight line down
- B) Parabolic path

- C) Circular path
- D) Straight line backwards

**Solution:** B. The package keeps the plane's horizontal velocity while also accelerating downward due to gravity. That combination produces a parabolic path.

79. **The minimum resultant of two vectors with magnitudes 5 and 3 is:**

- A) 0
- B) 2
- C) 3
- D) 8

**Solution:** B. The minimum resultant occurs when the vectors point in opposite directions. Then the magnitude is the difference,  $|5 - 3| = 2$ .

80. **If a projectile is launched at  $30^\circ$  and another at  $60^\circ$  with the same speed on flat ground, their ranges are:**

- A) Equal
- B) Greater for  $30^\circ$
- C) Greater for  $60^\circ$
- D) Zero for both

**Solution:** A. On level ground, the range depends on  $\sin(2\theta)$ . Since  $\sin(60^\circ)$  and  $\sin(120^\circ)$  are equal, launch angles of  $30^\circ$  and  $60^\circ$  give the same range.

81. **Can a component of a vector be larger than the vector's magnitude?**

- A) Yes, always
- B) No, never
- C) Only at  $90^\circ$
- D) Only at  $0^\circ$

**Solution:** B. A component is only part of the full vector, not something larger than it. Since sine and cosine are never greater than 1, a component can never exceed the vector's magnitude.

82. **The time of flight of a projectile launched at an angle depends primarily on:**

- A) The horizontal component of velocity
- B) The vertical component of velocity
- C) Both components equally

D) The mass of the projectile

**Solution:** B. Gravity acts vertically, so the time in the air is controlled by the up-and-down motion. That means the vertical component of velocity determines the time of flight.

83. **The horizontal and vertical components of projectile motion are:**

- A) Dependent on each other
- B) Independent of each other
- C) Always equal
- D) Both zero at the top

**Solution:** B. Projectile motion can be split into two separate motions: horizontal and vertical. These components are independent, except that they happen over the same time interval.

84. **If a vector points entirely in the negative  $x$ -direction, its  $x$ -component is:**

- A) Positive
- B) Negative
- C) Zero
- D) Equal to its  $y$ -component

**Solution:** B. Components carry signs based on their direction along the axis. A vector pointing entirely along negative  $x$  must therefore have a negative  $x$ -component.

85. **The launch angle that gives the maximum vertical height (for a given speed) is:**

- A)  $0^\circ$
- B)  $30^\circ$
- C)  $45^\circ$
- D)  $90^\circ$

**Solution:** D. Maximum height depends on the initial vertical component of the launch speed. That component is largest when the object is launched straight up at  $90^\circ$ .

86. **When a projectile lands at the same height it was launched, its speed at landing equals:**

- A) Zero
- B) Its launch speed
- C) Half its launch speed
- D) Twice its launch speed

**Solution:** B. Ignoring air resistance, mechanical energy is conserved. If the projectile lands at the same height, it returns with the same speed it had at launch.

87. **A vector has components  $x = 6$ ,  $y = 8$ . Its magnitude is:**

- A) 10
- B) 14
- C) 48
- D) 100

**Solution:** A. Use the Pythagorean theorem for the perpendicular components. That gives  $\sqrt{6^2 + 8^2} = 10$ .

88. **A projectile is launched at 50 m/s at  $37^\circ$  above horizontal. What is the horizontal component of velocity? ( $\cos 37^\circ \approx 0.8$ )**

- A) 30 m/s
- B) 40 m/s
- C) 50 m/s
- D) 25 m/s

**Solution:** B. The horizontal component is found from  $v_x = v \cos \theta$ . With  $v = 50$  m/s and  $\cos 37^\circ \approx 0.8$ , the result is 40 m/s.

89. **A ball is kicked horizontally off a 45 m high cliff. How long does it take to hit the ground? ( $g = 10$  m/s<sup>2</sup>)**

- A) 2 s
- B) 3 s
- C) 4.5 s
- D) 9 s

**Solution:** B. The fall time depends only on the vertical drop. Using  $45 = \frac{1}{2}(10)t^2$  gives  $t^2 = 9$ , so the time is 3 s.

90. **A projectile is launched at 20 m/s at  $45^\circ$  on flat ground. What is its range? ( $g = 10$  m/s<sup>2</sup>)**

- A) 20 m
- B) 40 m
- C) 80 m
- D) 200 m

**Solution:** B. For a projectile landing at the same height, use  $R = \frac{v^2 \sin(2\theta)}{g}$ . Substituting  $v = 20$  m/s and  $\theta = 45^\circ$  gives  $R = 40$  m.

## Newton's Laws

91. Inertia is a measure of an object's:

- A) Velocity
- B) Force
- C) Mass
- D) Acceleration

**Solution:** C. Inertia is an object's resistance to changes in its motion. Mass measures how much inertia the object has.

92. If the net force on an object is zero, it must be:

- A) At rest
- B) Moving with constant velocity
- C) Accelerating
- D) Falling

**Solution:** B. Zero net force means zero acceleration by Newton's 2nd law. So the object either remains at rest or continues moving with constant velocity.

93. Action and reaction forces always act on:

- A) The same object
- B) Different objects
- C) The ground
- D) Stationary objects

**Solution:** B. Newton's 3rd law says forces come in equal and opposite pairs. Those two forces always act on different objects, not on the same one.

94. The weight of an object depends on:

- A) Mass only
- B) Gravity only
- C) Mass and Gravity
- D) Volume

**Solution:** C. Weight is the gravitational force on an object, given by  $W = mg$ . It depends on both the object's mass and the local gravitational field strength.

95. To keep an object moving at constant velocity on a frictionless surface requires:

- A) A constant force
- B) A decreasing force
- C) Zero net force
- D) An increasing force

**Solution:** C. Newton's 1st law says an object keeps moving at constant velocity unless a net force acts on it. On a frictionless surface, zero net force is enough to maintain that motion.

96. **If you push a wall, the wall pushes back with:**

- A) Less force
- B) More force
- C) Equal force
- D) Zero force

**Solution:** C. By Newton's 3rd law, the wall exerts a force equal in magnitude and opposite in direction to your push. That is why you feel the wall pushing back.

97. **An object in deep space (no gravity) has:**

- A) No mass
- B) No weight
- C) No inertia
- D) No volume

**Solution:** B. Weight is the force due to gravity, so without gravity the object has no weight. Its mass and inertia still remain because those are intrinsic properties.

98. **The normal force on a book resting on a flat table is equal to:**

- A) Its mass
- B) Its weight
- C) Friction
- D) Zero

**Solution:** B. If the book is at rest and no other vertical forces act, the net vertical force must be zero. So the table's normal force balances the book's weight.

99. **Doubling the net force on an object will:**

- A) Double the acceleration
- B) Halve the acceleration
- C) Quadruple the acceleration

D) Not change acceleration

**Solution:** A. Newton's 2nd law gives  $a = F/m$ . If the mass stays the same and the net force doubles, the acceleration also doubles.

100. **Which law explains why passengers lurch forward when a bus stops?**

A) 1st Law

B) 2nd Law

C) 3rd Law

D) Law of Gravity

**Solution:** A. Passengers tend to keep their state of motion when the bus stops suddenly. That is inertia, which is described by Newton's 1st law.

101. **A 5 kg box on a frictionless surface is pushed to accelerate at 3 m/s<sup>2</sup>. What force is applied?**

A) 1.6 N

B) 8 N

C) 15 N

D) 0.6 N

**Solution:** C. Use Newton's 2nd law,  $F = ma$ . With  $m = 5$  kg and  $a = 3$  m/s<sup>2</sup>, the applied force is 15 N.

102. **You push a 2 kg object with a force of 10 N. What is the acceleration?**

A) 0.2 m/s<sup>2</sup>

B) 5 m/s<sup>2</sup>

C) 20 m/s<sup>2</sup>

D) 8 m/s<sup>2</sup>

**Solution:** B. Rearranging Newton's 2nd law gives  $a = F/m$ . Dividing 10 N by 2 kg gives an acceleration of 5 m/s<sup>2</sup>.

103. **What is the weight of a 10 kg mass on Earth? ( $g = 9.8$  m/s<sup>2</sup>)**

A) 10 N

B) 98 N

C) 1.02 N

D) 980 N

**Solution:** B. Weight is found from  $W = mg$ . Multiplying 10 kg by 9.8 m/s<sup>2</sup> gives 98 N.

104. **An object weighs 50 N. What is its mass? ( $g = 10 \text{ m/s}^2$ )**

- A) 5 kg
- B) 50 kg
- C) 500 kg
- D) 0.5 kg

**Solution:** A. Rearranging the weight formula gives  $m = W/g$ . Substituting 50 N and  $10 \text{ m/s}^2$  gives a mass of 5 kg.

105. **Two forces, 3 N and 4 N, act in the same direction. Net force is:**

- A) 1 N
- B) 5 N
- C) 7 N
- D) 12 N

**Solution:** C. Forces in the same direction add together. So the net force is  $3 + 4 = 7$  N.

106. **Two forces, 10 N right and 4 N left, act on a 2 kg box. Acceleration?**

- A)  $3 \text{ m/s}^2$
- B)  $7 \text{ m/s}^2$
- C)  $14 \text{ m/s}^2$
- D)  $2 \text{ m/s}^2$

**Solution:** A. First find the net force: 10 N right minus 4 N left gives 6 N to the right. Then use  $a = F/m = 6/2 = 3 \text{ m/s}^2$ .

107. **A 1000 kg car stops from 20 m/s in 5 s. Average force?**

- A) 2000 N
- B) 4000 N
- C) 5000 N
- D) 10000 N

**Solution:** B. The car's speed changes by 20 m/s in 5 s, so the acceleration magnitude is  $4 \text{ m/s}^2$ . Using  $F = ma$ , the average force has magnitude  $1000 \times 4 = 4000$  N.

108. **If mass is doubled while force is constant, acceleration becomes:**

- A) Double
- B) Half

- C) Quadruple
- D) Unchanged

**Solution:** B. Since  $a = F/m$ , acceleration is inversely proportional to mass when force is fixed. Doubling the mass cuts the acceleration in half.

109. **A 50 kg person pushes a 5000 kg wall with 100 N. Force on person?**

- A) 0 N
- B) 100 N
- C) 5000 N
- D) 50 N

**Solution:** B. By Newton's 3rd law, the wall pushes back on the person with an equal and opposite force. So the person experiences 100 N.

110. **Net force on a 2 kg object moving at constant 5 m/s is:**

- A) 0 N
- B) 2.5 N
- C) 10 N
- D) 5 N

**Solution:** A. Constant velocity means there is no acceleration. With  $a = 0$ , Newton's 2nd law gives a net force of 0 N.

111. **When a car turns a corner sharply, passengers slide to the outside. This is due to:**

- A) Centrifugal force
- B) Inertia
- C) Gravity
- D) Friction

**Solution:** B. The passengers' bodies tend to keep moving in a straight line while the car turns underneath them. That effect is inertia.

112. **An elevator accelerates upward. The normal force (apparent weight) on a passenger is:**

- A) Less than actual weight
- B) Greater than actual weight
- C) Equal to actual weight
- D) Zero

**Solution:** B. Because the elevator accelerates upward, the net force on the passenger must be upward. That means  $N - mg = ma > 0$ , so the normal force must be larger than the actual weight.

113. **In a tug-of-war, Team A pulls with 1000 N and Team B pulls with 1000 N. The tension in the rope is:**

- A) 0 N
- B) 1000 N
- C) 2000 N
- D) 500 N

**Solution:** B. Each team pulls with 1000 N, so the rope carries that amount of tension. Equal pulls do not make the tension 2000 N; they keep it at 1000 N.

114. **A net force of 12 N acts on a 4 kg object. What is the acceleration?**

- A) 3 m/s<sup>2</sup>
- B) 8 m/s<sup>2</sup>
- C) 16 m/s<sup>2</sup>
- D) 48 m/s<sup>2</sup>

**Solution:** A. Apply Newton's 2nd law in the form  $a = F/m$ . Dividing 12 N by 4 kg gives 3 m/s<sup>2</sup>.

115. **What is the weight of an 8 kg mass on Earth? ( $g = 10 \text{ m/s}^2$ )**

- A) 8 N
- B) 18 N
- C) 80 N
- D) 800 N

**Solution:** C. Weight is calculated using  $W = mg$ . With  $m = 8 \text{ kg}$  and  $g = 10 \text{ m/s}^2$ , the weight is 80 N.

# Momentum

116. **Momentum is the product of:**

- A) Mass and acceleration
- B) Mass and velocity
- C) Force and time
- D) Force and distance

**Solution:** B. Momentum is defined as mass multiplied by velocity. That is why the correct relation is  $p = mv$ .

117. **Impulse is equal to:**

- A) Change in energy
- B) Change in momentum
- C) Force  $\times$  distance
- D) Mass  $\times$  acceleration

**Solution:** B. The impulse-momentum theorem states that impulse equals the change in momentum. In symbols,  $J = \Delta p$ .

118. **In an inelastic collision, which is conserved?**

- A) Kinetic Energy
- B) Momentum
- C) Both
- D) Neither

**Solution:** B. In an isolated collision, momentum is conserved whether the collision is elastic or inelastic. Kinetic energy is not conserved in an inelastic collision.

119. **A rubber ball bounces; a clay ball sticks. Which receives a larger impulse?**

- A) Rubber ball
- B) Clay ball
- C) Same
- D) Depends on mass

**Solution:** A. Impulse depends on the change in momentum. Because the rubber ball reverses direction when it bounces, its momentum changes by a larger amount than the clay ball's.

120. **For momentum to be conserved, the system must be:**

- A) Isolated (no external forces)
- B) Moving constant speed
- C) At rest
- D) Massless

**Solution:** A. Momentum is conserved only when the system is isolated from external influences. That means the net external force on the system must be zero.

121. **A soccer ball with mass 2 kg is moving at 3 m/s. What is its momentum?**

- A) 1.5 kg·m/s
- B) 5 kg·m/s
- C) 6 kg·m/s
- D) 0.6 kg·m/s

**Solution:** C. Use the definition of momentum,  $p = mv$ . Multiplying 2 kg by 3 m/s gives 6 kg·m/s.

122. **During a collision, a 10 N force acts on an object for 2 s. What is the impulse?**

- A) 5 N·s
- B) 12 N·s
- C) 20 N·s
- D) 0.2 N·s

**Solution:** C. Impulse is force multiplied by the time interval over which it acts. So  $J = F\Delta t = 10 \times 2 = 20$  N·s.

123. **A 2 kg object changes speed from 2 m/s to 5 m/s. Change in momentum?**

- A) 3 kg·m/s
- B) 6 kg·m/s
- C) 10 kg·m/s
- D) 14 kg·m/s

**Solution:** B. Compute the change in momentum with  $\Delta p = m(v_f - v_i)$ . Using 2 kg, 5 m/s, and 2 m/s gives  $\Delta p = 6$  kg·m/s.

124. **A 1 kg cart ( $v = 4$ ) hits a 1 kg stationary cart and sticks. Final velocity?**

- A) 1 m/s
- B) 2 m/s
- C) 4 m/s

D) 0 m/s

**Solution:** B. Because the carts stick together, momentum is conserved in a perfectly inelastic collision. The initial momentum is  $4 \text{ kg}\cdot\text{m/s}$  and the combined mass is  $2 \text{ kg}$ , so the final velocity is  $2 \text{ m/s}$ .

125. **A 3 kg object slides at 2 m/s and then comes to rest. What is the impulse magnitude?**

A) 2 N·s

B) 3 N·s

C) 5 N·s

D) 6 N·s

**Solution:** D. The impulse equals the change in momentum. Here  $\Delta p = 3(0 - 2) = -6 \text{ kg}\cdot\text{m/s}$ , so the magnitude is  $6 \text{ N}\cdot\text{s}$ .

126. **A 50 kg skater throws a 5 kg ball at 2 m/s. Skater's recoil speed?**

A) 0.1 m/s

B) 0.2 m/s

C) 2 m/s

D) 10 m/s

**Solution:** B. The system starts with zero total momentum, so the skater's momentum must balance the ball's momentum. Since the ball has  $10 \text{ kg}\cdot\text{m/s}$  forward, the skater must recoil at  $10/50 = 0.2 \text{ m/s}$  backward.

127. **What force is needed to stop an object with momentum 10 kg·m/s in 2 seconds?**

A) 5 N

B) 10 N

C) 20 N

D) 2 N

**Solution:** A. Average force is the rate of change of momentum. Dividing  $10 \text{ kg}\cdot\text{m/s}$  by  $2 \text{ s}$  gives  $5 \text{ N}$ .

128. **Airbags reduce injury in a crash by:**

A) Reducing the change in momentum

B) Increasing the time of impact

C) Decreasing the impulse

D) Increasing the force

**Solution:** B. In a crash, the change in momentum is essentially fixed. Airbags increase the stopping time, which reduces the average force on the person.

129. **An astronaut floating in space throws a wrench forward. The astronaut moves:**

- A) Forward
- B) Backward
- C) Stays still
- D) Upward

**Solution:** B. The total momentum of the astronaut-wrench system must remain constant. If the wrench moves forward, the astronaut recoils backward.

130. **A bug hits a windshield. Which force is greater?**

- A) Force on bug
- B) Force on windshield
- C) They are equal
- D) Depends on speed

**Solution:** C. Newton's 3rd law says interacting objects exert equal and opposite forces on each other. So the bug and windshield experience forces of equal magnitude.

131. **In a perfectly elastic collision, which quantities are conserved?**

- A) Only momentum
- B) Only kinetic energy
- C) Both momentum and kinetic energy
- D) Neither momentum nor kinetic energy

**Solution:** C. Elastic collisions conserve momentum like all isolated collisions. They also conserve kinetic energy, which is what makes them elastic.

132. **A system of two objects has zero total momentum. If one object moves to the left, the other must:**

- A) Also move to the left
- B) Move to the right with equal magnitude of momentum
- C) Be at rest
- D) Move upward

**Solution:** B. Zero total momentum means the momenta must cancel. So if one object has momentum to the left, the other must have equal momentum to the right.

133. **Impulse has the same units as:**

- A) Energy
- B) Momentum
- C) Force
- D) Acceleration

**Solution:** B. Since impulse equals change in momentum, they must have the same units. Those units are  $\text{kg}\cdot\text{m}/\text{s}$ , which is equivalent to  $\text{N}\cdot\text{s}$ .

134. **When catching a ball, pulling your hands back during the catch reduces the:**

- A) Impulse on your hands
- B) Change in momentum of the ball
- C) Average force on your hands
- D) Speed of the ball

**Solution:** C. The ball still has to undergo essentially the same change in momentum. Pulling your hands back increases the stopping time, so the average force becomes smaller.

135. **A firework at rest explodes into several pieces. The total momentum of all the pieces is:**

- A) Greater than zero
- B) Less than zero
- C) Zero
- D) Impossible to determine

**Solution:** C. The firework starts at rest, so its total initial momentum is zero. If external forces are negligible, the total momentum after the explosion must still be zero.

136. **Two identical objects moving toward each other at equal speeds collide and stick together. Their final velocity is:**

- A) Equal to the original speed
- B) Half the original speed
- C) Zero
- D) Double the original speed

**Solution:** C. The two objects have equal and opposite momenta, so the total initial momentum is zero. After they stick together, the combined object must therefore have zero velocity.

137. Which has more momentum: a 2000 kg truck moving at 2 m/s or a 0.01 kg bullet moving at 500 m/s?
- A) The bullet
  - B) The truck
  - C) They have equal momentum
  - D) Cannot determine without more information

**Solution:** B. Calculate both momenta: the truck has  $2000 \times 2 = 4000$  kg·m/s, while the bullet has  $0.01 \times 500 = 5$  kg·m/s. The truck therefore has much more momentum.

138. A 4 kg ball moving at 5 m/s bounces off a wall and returns at 3 m/s. What is the magnitude of the impulse?
- A) 8 kg·m/s
  - B) 12 kg·m/s
  - C) 20 kg·m/s
  - D) 32 kg·m/s

**Solution:** D. Because the ball reverses direction, its final velocity is negative relative to the initial direction. Using  $\Delta p = m(v_f - v_i)$  gives  $4(-3 - 5) = -32$ , so the impulse magnitude is 32 kg·m/s.

139. A 0.5 kg ball hits a wall at 6 m/s and bounces back at 4 m/s. If contact time is 0.1 s, what is the average force?
- A) 10 N
  - B) 25 N
  - C) 50 N
  - D) 100 N

**Solution:** C. Reversing direction means the change in velocity is 10 m/s in magnitude. The impulse is  $0.5 \times 10 = 5$  kg·m/s, and dividing by 0.1 s gives an average force of 50 N.

140. A 3 kg object moving at 4 m/s collides with a 2 kg object moving at -1 m/s. They stick together. What is the final velocity?
- A) 1 m/s
  - B) 2 m/s
  - C) 3 m/s
  - D) 5 m/s

**Solution:** B. First add the initial momenta to get 10 kg·m/s. Since the objects stick, the combined mass is 5 kg, so the final velocity is  $10/5 = 2$  m/s.

## Thermodynamics and Calorimetry

141. **Temperature is a measure of the average \_\_\_\_\_ of the particles in a substance.**

- A) Potential Energy
- B) Kinetic Energy
- C) Total Energy
- D) Momentum

**Solution:** B. Temperature tells us about the average kinetic energy of the particles in a substance. Faster microscopic motion corresponds to a higher temperature.

142. **Heat always flows naturally from:**

- A) Cold to Hot
- B) Hot to Cold
- C) High pressure to low pressure
- D) Low density to high density

**Solution:** B. Heat is energy in transit caused by a temperature difference. It naturally flows from the hotter object to the colder one.

143. **Heat is best described as:**

- A) A measure of temperature
- B) A transfer of energy
- C) The total energy of a system
- D) The kinetic energy of particles

**Solution:** B. Heat is not something stored inside an object like temperature. It is the transfer of energy from one object to another because of a temperature difference.

144. **Two objects are in thermal equilibrium when:**

- A) They have the same mass
- B) They are at the same temperature
- C) Heat flows between them
- D) They have the same volume

**Solution:** B. Thermal equilibrium means there is no net heat flow between the objects. That happens when they are at the same temperature.

145. **The specific heat capacity of a substance is the energy required to:**

- A) Heat any amount by any temperature

- B) Raise the temperature of 1 kg by 1°C
- C) Change its phase
- D) Bring it to thermal equilibrium

**Solution:** B. Specific heat capacity tells how much energy is needed per kilogram per degree of temperature change. By definition, it is the energy required to raise 1 kg by 1°C.

146. **If you place a hot metal spoon in cold water, what happens?**

- A) Heat flows from water to spoon
- B) Heat flows from spoon to water
- C) No heat flows
- D) Temperature stays constant

**Solution:** B. The spoon starts at a higher temperature than the water. Heat therefore flows from the spoon to the water until they approach thermal equilibrium.

147. **When two objects at different temperatures are in contact, heat transfer stops when:**

- A) The hotter object loses all its heat
- B) They reach thermal equilibrium
- C) The colder object reaches room temperature
- D) Never

**Solution:** B. Heat continues to flow while there is a temperature difference. Once both objects reach the same temperature, net heat transfer stops.

148. **Which has a higher average molecular kinetic energy: boiling water or ice?**

- A) Boiling water
- B) Ice
- C) They are the same
- D) Cannot be determined

**Solution:** A. Average molecular kinetic energy increases with temperature. Since boiling water is much hotter than ice, it has the greater average kinetic energy.

149. **A material with a high specific heat capacity requires \_\_\_\_\_ energy to change its temperature.**

- A) Less
- B) More

- C) No
- D) The same

**Solution:** B. A high specific heat means the temperature changes slowly for a given energy input. So more energy is required to produce the same temperature change.

150. **Why does water take longer to heat up than cooking oil (assuming equal masses)?**

- A) Water is denser
- B) Water has a higher specific heat capacity
- C) Oil conducts heat better
- D) Water is transparent

**Solution:** B. Water's specific heat capacity is larger than that of cooking oil. That means it takes more energy to raise water's temperature by the same amount.

151. **How much heat is required to raise the temperature of 2 kg of water by 10°C? ( $c_{water} = 4186 \text{ J/kg}\cdot\text{°C}$ )**

- A) 8372 J
- B) 41860 J
- C) 83720 J
- D) 837 J

**Solution:** C. Use the calorimetry relation  $Q = mc\Delta T$ . Substituting 2 kg, 4186 J/kg·°C, and 10°C gives 83,720 J.

152. **You heat a 0.5 kg metal block and find it requires 2000 J to raise its temperature by 10°C. What is its specific heat capacity?**

- A) 200 J/kg·°C
- B) 400 J/kg·°C
- C) 1000 J/kg·°C
- D) 4000 J/kg·°C

**Solution:** B. Rearranging the heat formula gives  $c = Q/(m\Delta T)$ . Using 2000 J, 0.5 kg, and 10°C gives 400 J/kg·°C.

153. **How much energy is needed to heat 5 kg of aluminum from 20°C to 100°C? ( $c_{Al} = 900 \text{ J/kg}\cdot\text{°C}$ )**

- A) 360,000 J
- B) 450,000 J
- C) 90,000 J

D) 720,000 J

**Solution:** A. First find the temperature change, which is  $80^{\circ}\text{C}$ . Then apply  $Q = mc\Delta T$  to get  $5 \times 900 \times 80 = 360,000$  J.

154. **A 3 kg iron block ( $c_{\text{iron}} = 450 \text{ J/kg}\cdot^{\circ}\text{C}$ ) cools from  $150^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ . How much heat is released?**

A) 13,500 J

B) 67,500 J

C) 135,000 J

D) 202,500 J

**Solution:** C. The temperature drops by  $100^{\circ}\text{C}$ , so the block releases heat. Using  $Q = mc\Delta T$  gives  $3 \times 450 \times 100 = 135,000$  J.

155. **If 10,000 J of heat is added to 2 kg of a substance with specific heat capacity  $1000 \text{ J/kg}\cdot^{\circ}\text{C}$ , what is the temperature change?**

A)  $2^{\circ}\text{C}$

B)  $5^{\circ}\text{C}$

C)  $10^{\circ}\text{C}$

D)  $20^{\circ}\text{C}$

**Solution:** B. Solve the calorimetry equation for temperature change:  $\Delta T = Q/(mc)$ . Substituting the given values gives  $10,000/(2 \times 1000) = 5^{\circ}\text{C}$ .

156. **During a phase change (e.g., melting or boiling), the temperature of a substance:**

A) Increases rapidly

B) Decreases rapidly

C) Remains constant

D) Fluctuates

**Solution:** C. During a phase change, the added energy changes the arrangement of the particles rather than their average kinetic energy. That is why the temperature stays constant.

157. **Which substance has a higher specific heat capacity?**

A) Iron ( $c = 450 \text{ J/kg}\cdot^{\circ}\text{C}$ )

B) Water ( $c = 4186 \text{ J/kg}\cdot^{\circ}\text{C}$ )

C) Copper ( $c = 390 \text{ J/kg}\cdot^{\circ}\text{C}$ )

D) Aluminum ( $c = 900 \text{ J/kg}\cdot^{\circ}\text{C}$ )

**Solution:** B. Comparing the given values shows that water has the largest specific heat capacity. That means water needs the most energy per kilogram for each degree of temperature change.

158. **Coastal cities tend to have milder temperatures than inland cities because:**

- A) The ocean reflects sunlight
- B) Water has a high specific heat capacity and moderates temperature changes
- C) Coastal winds are always cool
- D) Saltwater freezes at a lower temperature

**Solution:** B. Large bodies of water warm up and cool down slowly because water has a high specific heat capacity. This reduces extreme temperature swings near the coast.

159. **Two identical blocks of equal mass, one aluminum ( $c = 900$ ) and one iron ( $c = 450$ ), each receive 9000 J of heat. Which has a larger temperature increase?**

- A) Aluminum
- B) Iron
- C) Same for both
- D) Cannot determine

**Solution:** B. Since both blocks receive the same heat and have the same mass, the one with smaller specific heat must undergo the larger temperature change. Iron has the smaller  $c$ , so it heats up more.

160. **A thermos bottle keeps drinks hot (or cold) by minimizing:**

- A) The mass of the liquid
- B) Heat transfer by conduction, convection, and radiation
- C) The temperature of the surroundings
- D) Gravity's effect on the liquid

**Solution:** B. A thermos is designed to reduce conduction, convection, and radiation as much as possible. That slows the transfer of heat into or out of the drink.

161. **Equal masses (1 kg each) of water at  $80^{\circ}\text{C}$  and  $20^{\circ}\text{C}$  are mixed in an insulated container. What is the final temperature?**

- A)  $40^{\circ}\text{C}$
- B)  $50^{\circ}\text{C}$
- C)  $60^{\circ}\text{C}$
- D)  $100^{\circ}\text{C}$

**Solution:** B. In an insulated container, the heat lost by the hot water equals the heat gained by the cold water. Because the masses and specific heats are equal, the final temperature is the average,  $50^{\circ}\text{C}$ .

162. **How much heat is needed to raise 500 g of water by  $20^{\circ}\text{C}$ ? ( $c_{\text{water}} = 4186 \text{ J/kg}\cdot^{\circ}\text{C}$ )**

- A) 8372 J
- B) 20930 J
- C) 41860 J
- D) 83720 J

**Solution:** C. First convert 500 g to 0.5 kg so the units match the specific heat. Then use  $Q = mc\Delta T$  to get 41,860 J.

163. **A 2 kg substance absorbs 16,000 J of heat and its temperature rises by  $20^{\circ}\text{C}$ . What is its specific heat capacity?**

- A) 200 J/kg $\cdot^{\circ}\text{C}$
- B) 400 J/kg $\cdot^{\circ}\text{C}$
- C) 800 J/kg $\cdot^{\circ}\text{C}$
- D) 1600 J/kg $\cdot^{\circ}\text{C}$

**Solution:** B. Rearranging  $Q = mc\Delta T$  gives  $c = Q/(m\Delta T)$ . Using the given numbers gives  $16,000/(2 \times 20) = 400 \text{ J/kg}\cdot^{\circ}\text{C}$ .

164. **How much heat is released when 4 kg of water cools from  $70^{\circ}\text{C}$  to  $20^{\circ}\text{C}$ ? ( $c_{\text{water}} = 4186 \text{ J/kg}\cdot^{\circ}\text{C}$ )**

- A) 83,720 J
- B) 209,300 J
- C) 418,600 J
- D) 837,200 J

**Solution:** D. The water cools by  $50^{\circ}\text{C}$ , so it releases heat. Using  $Q = mc\Delta T$  gives  $4 \times 4186 \times 50 = 837,200 \text{ J}$ .

165. **How much heat is needed to raise 0.5 kg of copper ( $c = 390 \text{ J/kg}\cdot^{\circ}\text{C}$ ) from  $25^{\circ}\text{C}$  to  $75^{\circ}\text{C}$ ?**

- A) 975 J
- B) 9750 J
- C) 19500 J
- D) 97500 J

**Solution:** B. The temperature change is  $50^{\circ}\text{C}$ . Applying  $Q = mc\Delta T$  gives  $0.5 \times 390 \times 50 = 9,750 \text{ J}$ .

## Rotational Dynamics (Torque)

166. Torque is the rotational analog of:

- A) Mass
- B) Velocity
- C) Force
- D) Momentum

**Solution:** C. Force changes translational motion, while torque changes rotational motion. That is why torque is often described as the rotational analog of force.

167. If the line of action of a force passes through the pivot, the torque is:

- A) Maximum
- B) Zero
- C) Negative
- D) Infinite

**Solution:** B. Torque depends on the perpendicular distance from the pivot to the force's line of action. If the force passes through the pivot, that distance is zero, so the torque is zero.

168. The lever arm is the \_\_\_\_\_ distance from the pivot to the force.

- A) Straight
- B) Perpendicular
- C) Parallel
- D) Longest

**Solution:** B. The lever arm is not the raw distance along the object. It is the perpendicular distance from the pivot to the line of action of the force.

169. By convention, counter-clockwise torque is considered:

- A) Positive
- B) Negative
- C) Zero
- D) Neutral

**Solution:** A. In the usual sign convention for planar rotation, counter-clockwise torques are taken as positive. Clockwise torques are then negative.

170. You apply a 10 N force perpendicular to a wrench at a distance of 2 m from the pivot. What is the torque?

- A) 5 N·m
- B) 12 N·m
- C) 20 N·m
- D) 100 N·m

**Solution:** C. Because the force is perpendicular, the torque magnitude is simply  $\tau = rF$ . Multiplying 2 m by 10 N gives 20 N·m.

171. **A 20 N force is applied at 0.5 m from a pivot at a 30° angle. What is the torque?**

- A) 5 N·m
- B) 8.6 N·m
- C) 10 N·m
- D) 20 N·m

**Solution:** A. Use the torque formula  $\tau = rF \sin \theta$  because the force is applied at an angle. Substituting 0.5 m, 20 N, and  $\sin 30^\circ = 0.5$  gives 5 N·m.

172. **Two children balance on a seesaw. Child A (300 N) is 2 m from pivot. Child B (600 N) should be where?**

- A) 0.5 m
- B) 1 m
- C) 2 m
- D) 4 m

**Solution:** B. A balanced seesaw has equal torques on both sides. Setting  $300 \times 2 = 600 \times d$  gives  $d = 1$  m.

173. **Net torque: 10 N·m CW and 15 N·m CCW. Resultant?**

- A) 25 N·m CW
- B) 5 N·m CW
- C) 5 N·m CCW
- D) 25 N·m CCW

**Solution:** C. The torques act in opposite directions, so subtract their magnitudes. Since 15 CCW is larger than 10 CW, the net torque is 5 N·m CCW.

174. **Why is it easier to open a door by pushing near the handle rather than the hinges?**

- A) Less friction

- B) Larger lever arm
- C) Less mass
- D) More gravity

**Solution:** B. Torque increases with the lever arm distance from the pivot. Pushing near the handle gives a larger lever arm, so the same force produces more torque.

175. **To loosen a tight lug nut on a tire, you should use a wrench that is:**

- A) Shorter
- B) Longer
- C) Heavier
- D) Lighter

**Solution:** B. A longer wrench gives a larger lever arm. That allows the same applied force to create a greater torque.

176. **When holding a heavy box close to your chest vs. at arm's length, the torque on your shoulder is:**

- A) Greater at arm's length
- B) Greater at chest
- C) The same
- D) Zero

**Solution:** A. Holding the box farther away increases the distance from the pivot point at your shoulder. A larger lever arm means a larger torque.

177. **For an object in rotational equilibrium, the net torque acting on it is:**

- A) Maximum
- B) Equal to its weight
- C) Zero
- D) Equal to the applied force

**Solution:** C. Rotational equilibrium means the object is not speeding up or slowing down in rotation. That requires the sum of all torques to be zero.

178. **If the force applied to a wrench doubles while the lever arm also doubles, the torque becomes:**

- A) Twice as large
- B) Three times as large
- C) Four times as large

D) Unchanged

**Solution:** C. Torque is proportional to both lever arm and force. Doubling each multiplies the torque by  $2 \times 2 = 4$ .

179. **A force applied parallel to the lever arm (along the line from the pivot) produces a torque of:**

A) Maximum value

B)  $rF$

C)  $rF \cos \theta$

D) Zero

**Solution:** D. Only the component of force perpendicular to the lever arm produces torque. If the force is parallel to the lever arm, that perpendicular component is zero.

180. **For a given force and distance from the pivot, the torque is maximum when the angle between the force and the lever arm is:**

A)  $0^\circ$

B)  $30^\circ$

C)  $45^\circ$

D)  $90^\circ$

**Solution:** D. The torque formula is  $\tau = rF \sin \theta$ . This is largest when  $\sin \theta = 1$ , which happens at  $90^\circ$ .

181. **To balance a heavier child on a seesaw, a lighter child must sit:**

A) Closer to the pivot

B) Farther from the pivot

C) At the same distance

D) On the same side

**Solution:** B. Balance requires equal torques on both sides of the pivot. Since the lighter child has less force, that child must sit farther away to compensate.

182. **The SI unit of torque is:**

A) Newton (N)

B) Joule (J)

C) Newton-meter (N·m)

D) Kilogram (kg)

**Solution:** C. Torque equals force times distance from the pivot. Its SI unit is therefore the newton-meter, written N·m.

183. **Torque depends on all of the following EXCEPT:**

- A) The magnitude of the force
- B) The distance from the pivot
- C) The angle at which the force is applied
- D) The mass of the object

**Solution:** D. The torque formula contains lever arm, force, and the angle between them. Mass does not appear directly unless it helps determine the force.

184. **A force applied at an angle less than  $90^\circ$  to the lever arm produces:**

- A) More torque than at  $90^\circ$
- B) Less torque than at  $90^\circ$
- C) The same torque as at  $90^\circ$
- D) Zero torque

**Solution:** B. Torque depends on  $\sin\theta$ , and this value is less than 1 for angles below  $90^\circ$ . So the torque is smaller than the maximum possible torque.

185. **A force of 15 N is applied perpendicular to a wrench at a distance of 3 m from the pivot. What is the torque?**

- A) 5 N·m
- B) 18 N·m
- C) 45 N·m
- D) 60 N·m

**Solution:** C. Because the force is perpendicular, use  $\tau = rF$ . Multiplying 3 m by 15 N gives 45 N·m.

186. **A 50 N force is applied at 0.4 m from a pivot at a  $60^\circ$  angle. What is the torque? ( $\sin 60^\circ \approx 0.87$ )**

- A) 10 N·m
- B) 17.3 N·m
- C) 20 N·m
- D) 50 N·m

**Solution:** B. Use  $\tau = rF\sin\theta$  because the force is not perpendicular. Substituting the values gives about  $0.4 \times 50 \times 0.87 = 17.4$  N·m, which rounds to 17.3 N·m.

187. **Child A (400 N) sits 1.5 m from the pivot of a seesaw. Where must Child B (200 N) sit to balance?**

- A) 1 m
- B) 2 m
- C) 3 m
- D) 4 m

**Solution:** C. For balance, the torque from Child B must equal the torque from Child A. Solving  $400 \times 1.5 = 200d$  gives  $d = 3$  m.

188. **Net torque: 25 N·m CW and 40 N·m CCW. Resultant?**

- A) 65 N·m CW
- B) 65 N·m CCW
- C) 15 N·m CW
- D) 15 N·m CCW

**Solution:** D. Subtract the smaller clockwise torque from the larger counter-clockwise torque. The result is 15 N·m CCW.

189. **A seesaw is balanced. On the left, a force of 8 N acts at 3 m from the pivot. What force at 4 m on the right is needed to maintain balance?**

- A) 2 N
- B) 6 N
- C) 8 N
- D) 12 N

**Solution:** B. A balanced seesaw has equal torques on each side of the pivot. Solving  $8 \times 3 = 4F$  gives a required force of 6 N.

190. **A force of 12 N is applied at a  $45^\circ$  angle, 0.8 m from the pivot. What is the torque? ( $\sin 45^\circ \approx 0.71$ )**

- A) 4.3 N·m
- B) 6.8 N·m
- C) 9.6 N·m
- D) 12 N·m

**Solution:** B. Apply the angled-force torque formula  $\tau = rF \sin \theta$ . With 0.8 m, 12 N, and  $\sin 45^\circ \approx 0.71$ , the torque is about 6.8 N·m.

## Oscillations and Waves

191. The time for one complete cycle is called:

- A) Frequency
- B) Period
- C) Amplitude
- D) Wavelength

**Solution:** B. The period is the time needed for one complete cycle of motion. It is measured in seconds.

192. Frequency is measured in:

- A) Seconds
- B) Meters
- C) Hertz
- D) Joules

**Solution:** C. Frequency counts how many cycles occur each second. Its SI unit is hertz, abbreviated Hz.

193. In a transverse wave, particles move \_\_\_\_\_ to the wave direction.

- A) Parallel
- B) Perpendicular
- C) Opposite
- D) Randomly

**Solution:** B. In a transverse wave, the particles move at right angles to the direction the wave travels. That means the motion is perpendicular to the wave direction.

194. Sound waves are:

- A) Transverse
- B) Longitudinal
- C) Electromagnetic
- D) Standing

**Solution:** B. Sound waves in air travel through compressions and rarefactions of the medium. That makes them longitudinal waves.

195. A sound wave travels at 340 m/s with a frequency of 170 Hz. What is its wavelength?

- A) 0.5 m
- B) 2 m
- C) 510 m
- D) 57800 m

**Solution:** B. Use the wave relation  $\lambda = v/f$ . Dividing 340 m/s by 170 Hz gives a wavelength of 2 m.

196. **The distance between two consecutive crests is:**

- A) Amplitude
- B) Period
- C) Wavelength
- D) Frequency

**Solution:** C. One wavelength is the distance between identical points on successive cycles of a wave. Two consecutive crests are therefore separated by one wavelength.

197. **Wave speed depends primarily on:**

- A) Frequency
- B) Wavelength
- C) The medium
- D) Amplitude

**Solution:** C. Wave speed is set mainly by the properties of the material the wave travels through. Changing the medium changes the speed.

198. **Points of zero amplitude on a standing wave are called:**

- A) Nodes
- B) Antinodes
- C) Crests
- D) Troughs

**Solution:** A. In a standing wave, nodes are points that never move. Their amplitude stays zero at all times.

199. **As frequency increases, if speed is constant, wavelength:**

- A) Increases
- B) Decreases
- C) Stays same
- D) Becomes zero

**Solution:** B. If wave speed stays constant, increasing frequency must decrease wavelength to keep  $v = f\lambda$  true. So the wavelength becomes shorter.

200. **Pitch of a sound is determined by its:**

- A) Amplitude
- B) Speed
- C) Frequency
- D) Phase

**Solution:** C. Pitch depends on how rapidly the source vibrates. A higher frequency corresponds to a higher pitch.

201. **Loudness of a sound is determined by its:**

- A) Amplitude
- B) Speed
- C) Frequency
- D) Wavelength

**Solution:** A. Loudness is related to the energy carried by the sound wave. Greater amplitude means a louder sound.

202. **Constructive interference occurs when waves meet:**

- A) In phase
- B) Out of phase
- C) Perpendicularly
- D) Randomly

**Solution:** A. Constructive interference happens when two waves line up in phase. Their displacements add together, making a larger amplitude.

203. **The period of a simple pendulum depends on:**

- A) Mass
- B) Length
- C) Amplitude
- D) Speed

**Solution:** B. For a simple pendulum, the period depends mainly on its length and gravity. It does not depend on the pendulum's mass for small oscillations.

204. **Energy in a wave is related to its:**

- A) Wavelength
- B) Period
- C) Amplitude
- D) Speed

**Solution:** C. A wave with larger amplitude carries more energy. In fact, the energy is proportional to the square of the amplitude.

205. **A wave bouncing off a fixed end is:**

- A) Reflected upright
- B) Reflected inverted
- C) Absorbed
- D) Refracted

**Solution:** B. Reflection from a fixed end flips the wave upside down. So the reflected wave is inverted.

206. **The fundamental frequency of a string has how many antinodes?**

- A) 1
- B) 2
- C) 3
- D) 0

**Solution:** A. The fundamental mode is the simplest standing-wave pattern on the string. It has one antinode, often called one loop.

207. **A wave oscillates with a frequency of 5 Hz. What is its period?**

- A) 0.2 s
- B) 0.5 s
- C) 2 s
- D) 5 s

**Solution:** A. Period and frequency are reciprocals, so  $T = 1/f$ . With  $f = 5$  Hz, the period is 0.2 s.

208. **If period is 0.01 s, what is the frequency?**

- A) 10 Hz
- B) 100 Hz
- C) 1000 Hz
- D) 0.1 Hz

**Solution:** B. Frequency is the reciprocal of the period. Since  $T = 0.01$  s, the frequency is 100 Hz.

209. **A string vibrates with fundamental frequency 100 Hz. 2nd harmonic?**

- A) 50 Hz
- B) 100 Hz
- C) 200 Hz
- D) 300 Hz

**Solution:** C. Harmonic frequencies are whole-number multiples of the fundamental. The second harmonic is therefore  $2 \times 100 = 200$  Hz.

210. **Distance between a node and the next antinode is:**

- A)  $\lambda$
- B)  $\lambda/2$
- C)  $\lambda/4$
- D)  $2\lambda$

**Solution:** C. In a standing wave, the spacing from a node to the nearest antinode is one-quarter of a wavelength. So the distance is  $\lambda/4$ .

211. **Echo returns in 2 s. If speed is 340 m/s, distance to wall?**

- A) 170 m
- B) 340 m
- C) 680 m
- D) 68 m

**Solution:** B. The 2 s is the round-trip time for the echo, so the sound travels to the wall and back in that interval. The total distance is  $340 \times 2 = 680$  m, so the wall is 340 m away.

212. **Pendulum length is quadrupled. The period becomes:**

- A) Double
- B) Half
- C) Quadruple
- D) Same

**Solution:** A. A pendulum's period is proportional to the square root of its length. Quadrupling the length multiplies the period by  $\sqrt{4} = 2$ , so it doubles.

213. **Wave with  $\lambda = 2$  m passes every 0.5 s. Speed?**

- A) 1 m/s
- B) 2 m/s
- C) 4 m/s
- D) 0.25 m/s

**Solution:** C. Wave speed can be found from  $v = \lambda/T$ . Dividing 2 m by 0.5 s gives 4 m/s.

214. **Frequency of a wave on a string depends on tension. If tension quadruples, speed:**

- A) Doubles
- B) Halves
- C) Quadruples
- D) Stays same

**Solution:** A. For waves on a string, speed varies as the square root of the tension. If the tension becomes four times larger, the speed doubles.

215. **A 2 m string vibrates in 2 loops (2nd harmonic). Wavelength?**

- A) 1 m
- B) 2 m
- C) 4 m
- D) 0.5 m

**Solution:** B. In the second harmonic, the string contains two loops, which together make one full wavelength. Since the string is 2 m long, the wavelength is 2 m.

216. **Amplitude of a wave is 5 cm. Total vertical distance from crest to trough?**

- A) 5 cm
- B) 10 cm
- C) 2.5 cm
- D) 0 cm

**Solution:** B. Amplitude is measured from the equilibrium line to a crest or trough. The full vertical distance from crest to trough is therefore twice the amplitude.

217. **If 10 waves pass in 5 seconds, frequency is:**

- A) 0.5 Hz
- B) 2 Hz
- C) 5 Hz

D) 10 Hz

**Solution:** B. Frequency is the number of waves passing per second. If 10 waves pass in 5 s, the frequency is 2 Hz.

218. **Speed of sound is highest in:**

- A) Vacuum
- B) Air
- C) Water
- D) Steel

**Solution:** D. Sound travels fastest in media where particles are tightly connected and can pass along vibrations quickly. Among the choices, steel is the fastest.

219. **Which property distinguishes a note played on a piano vs a guitar (same pitch)?**

- A) Frequency
- B) Wavelength
- C) Timbre/Quality
- D) Speed

**Solution:** C. If two instruments play the same pitch, they still sound different because of their harmonic content. That sound quality is called timbre.

220. **To tune a guitar string to a higher pitch, you should:**

- A) Loosen the string
- B) Tighten the string
- C) Use a thicker string
- D) Make it longer

**Solution:** B. Tightening the string increases its tension, which raises the wave speed on the string. That leads to a higher vibration frequency and therefore a higher pitch.

221. **Ultrasound used in medical imaging has a frequency:**

- A) Below 20 Hz
- B) Between 20 Hz and 20 kHz
- C) Above 20,000 Hz
- D) Zero

**Solution:** C. Human hearing extends up to about 20,000 Hz. Ultrasound refers to sound with frequencies above that range.

222. When an ambulance passes you, the pitch of the siren drops. This is called:

- A) Doppler Effect
- B) Resonance
- C) Interference
- D) Diffraction

**Solution:** A. The observed frequency changes when a source moves relative to you. That change in pitch is called the Doppler effect.

223. A string has mass 0.02 kg and length 4 m. What is the linear mass density (mass per unit length)?

- A) 0.005 kg/m
- B) 0.008 kg/m
- C) 0.05 kg/m
- D) 0.08 kg/m

**Solution:** A. Linear mass density is mass divided by length. So  $\mu = 0.02/4 = 0.005$  kg/m.

224. A 5 m string with mass 0.015 kg is under tension of 120 N. What is the wave speed on this string? ( $v = \sqrt{T/\mu}$ )

- A) 100 m/s
- B) 141 m/s
- C) 200 m/s
- D) 245 m/s

**Solution:** C. First compute the linear density:  $\mu = 0.015/5 = 0.003$  kg/m. Then use  $v = \sqrt{T/\mu} = \sqrt{120/0.003} = 200$  m/s.

225. A guitar string has linear mass density 0.004 kg/m and is under tension 80 N. A wave on this string has frequency 200 Hz. What is the wavelength? ( $v = \sqrt{T/\mu}$ )

- A) 0.35 m
- B) 0.71 m
- C) 1.41 m
- D) 2.24 m

**Solution:** B. First find the wave speed using  $v = \sqrt{T/\mu}$ , which gives about 141.4 m/s. Then use  $\lambda = v/f$  to get  $141.4/200 \approx 0.71$  m.

226. A wave pulse travels a distance of 100 m in 5 seconds. What is the wave speed?

- A) 20 m/s
- B) 100 m/s
- C) 500 m/s
- D) 0.05 m/s

**Solution:** A. Speed is distance divided by time. A pulse that goes 100 m in 5 s therefore has speed 20 m/s.

227. A wave has speed 30 m/s and wavelength 6 m. What is its frequency?

- A) 0.2 Hz
- B) 5 Hz
- C) 24 Hz
- D) 180 Hz

**Solution:** B. Rearranging the wave equation gives  $f = v/\lambda$ . Dividing 30 m/s by 6 m gives 5 Hz.

228. A string of length 3 m is fixed at both ends and vibrates in its 3rd harmonic. What is the wavelength?

- A) 1 m
- B) 2 m
- C) 3 m
- D) 6 m

**Solution:** B. In the third harmonic, the string length contains three half-wavelengths. So  $L = 3\lambda/2$ , and with  $L = 3$  m this gives  $\lambda = 2$  m.

229. A wave on a string has linear mass density  $\mu = 0.01$  kg/m and tension  $T = 40$  N. What is the wave speed?

- A) 20 m/s
- B) 40 m/s
- C) 63 m/s
- D) 200 m/s

**Solution:** C. Use the string wave-speed formula  $v = \sqrt{T/\mu}$ . Substituting 40 N and 0.01 kg/m gives about 63.2 m/s.

230. A pendulum has a period of 4 s. If its length is reduced to one-fourth of its original value, the new period is:

- A) 1 s
- B) 2 s
- C) 4 s
- D) 8 s

**Solution:** B. A pendulum's period scales with the square root of its length. Reducing the length to one-fourth cuts the period by a factor of 2, so the new period is 2 s.