KEY TERMS

air resistance a frictional force that slows the motion of objects as they travel through the air; when solving basic physics problems, air resistance is assumed to be zero

amplitude the maximum displacement from the equilibrium position of an object oscillating around the equilibrium position

analytical method the method of determining the magnitude and direction of a resultant vector using the Pythagorean theorem and trigonometric identities

component (of a 2-dimensional vector) a piece of a vector that points in either the vertical or the horizontal direction; every 2-d vector can be expressed as a sum of two vertical and horizontal vector components

deformation displacement from equilibrium, or change in shape due to the application of force

equilibrium position where an object would naturally rest in the absence of force

frequency number of events per unit of time

graphical method drawing vectors on a graph to add them using the head-to-tail method

head (of a vector) the end point of a vector; the location of the vector's arrow; also referred to as the tip

head-to-tail method a method of adding vectors in which the tail of each vector is placed at the head of the previous vector

Hooke's law proportional relationship between the force **F** on a material and the deformation ΔL it causes, $\mathbf{F} = \mathbf{k}\Delta L$

kinetic friction a force that opposes the motion of two systems that are in contact and moving relative to one another

maximum height (of a projectile) the highest altitude, or maximum displacement in the vertical position reached in the path of a projectile

oscillate moving back and forth regularly between two points

period time it takes to complete one oscillation

periodic motion motion that repeats itself at regular time intervals

projectile an object that travels through the air and experiences only acceleration due to gravity

projectile motion the motion of an object that is subject only to the acceleration of gravity

range the maximum horizontal distance that a projectile travels

restoring force force acting in opposition to the force caused by a deformation

resultant the sum of the a collection of vectors

resultant vector the vector sum of two or more vectors

simple harmonic motion the oscillatory motion in a system where the net force can be described by Hooke's law

simple pendulum an object with a small mass suspended from a light wire or string

static friction a force that opposes the motion of two systems that are in contact and are not moving relative to one another

tail the starting point of a vector; the point opposite to the head or tip of the arrow

trajectory the path of a projectile through the air

vector addition adding together two or more vectors

SECTION SUMMARY

5.1 Vector Addition and Subtraction: Graphical Methods

- The graphical method of adding vectors $\mathbf{A}$ and $\mathbf{B}$ involves drawing vectors on a graph and adding them by using the head-to-tail method. The resultant vector $\mathbf{R}$ is defined such that $\mathbf{A} + \mathbf{B} = \mathbf{R}$. The magnitude and direction of $\mathbf{R}$ are then determined with a ruler and protractor.
- The graphical method of subtracting vectors **A** and **B** involves adding the opposite of vector **B**, which is defined as $-\mathbf{B}$. In this case, $\mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B}) = \mathbf{R}$. Next, use the head-to-tail method as for vector addition to obtain the resultant vector $\mathbf{R}$.
- Addition of vectors is independent of the order in which they are added; $\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$.
- The head-to-tail method of adding vectors involves drawing the first vector on a graph and then placing the tail of each subsequent vector at the head of the previous vector. The resultant vector is then drawn from the tail of the first vector to the head of the final vector.
- Variables in physics problems, such as force or velocity, can be represented with vectors by making the length of the vector proportional to the magnitude of the force or velocity.
- Problems involving displacement, force, or velocity may be solved graphically by measuring the resultant vector's magnitude with a ruler and measuring the direction with a protractor.

5.2 Vector Addition and Subtraction: Analytical Methods

- The analytical method of vector addition and subtraction uses the Pythagorean theorem and trigonometric identities to determine the magnitude

and direction of a resultant vector.

- The steps to add vectors A and B using the analytical method are as follows:

1. Determine the coordinate system for the vectors. Then, determine the horizontal and vertical components of each vector using the equations

$$A_x = A\cos\theta$$
$$B_x = B\cos\theta$$

and

$$A_y = A\sin\theta$$
$$B_y = B\sin\theta.$$

2. Add the horizontal and vertical components of each vector to determine the components R_x and R_y of the resultant vector, R.

$$R_x = A_x + B_x$$

and

$$R_y = A_y + B_y.$$

3. Use the Pythagorean theorem to determine the magnitude, R, of the resultant vector R.

$$R = \sqrt{R_x^2 + R_y^2}$$

4. Use a trigonometric identity to determine the direction, θ, of R.

$$\theta = \tan^{-1}(R_y/R_x)$$

5.3 Projectile Motion

- Projectile motion is the motion of an object through the air that is subject only to the acceleration of gravity.
- Projectile motion in the horizontal and vertical directions are independent of one another.
- The maximum height of an projectile is the highest altitude, or maximum displacement in the vertical position reached in the path of a projectile.
- The range is the maximum horizontal distance traveled by a projectile.
- To solve projectile problems: choose a coordinate system; analyze the motion in the vertical and horizontal direction separately; then, recombine the horizontal and vertical components using vector addition equations.

5.4 Inclined Planes

- Friction is a contact force between systems that opposes the motion or attempted motion between them. Simple friction is proportional to the normal force **N** pushing the systems together. A normal force is always perpendicular to the contact surface between systems. Friction depends on both of the materials involved.
- μ_s is the coefficient of static friction, which depends on both of the materials.
- μ_k is the coefficient of kinetic friction, which also depends on both materials.
- When objects rest on an inclined plane that makes an angle θ with the horizontal surface, the weight of the object can be broken into components that act perpendicular ($\mathbf{w}_\perp$) and parallel ($\mathbf{w}_{||}$) to the surface of the plane.

5.5 Simple Harmonic Motion

- An oscillation is a back and forth motion of an object between two points of deformation.
- An oscillation may create a wave, which is a disturbance that propagates from where it was created.
- The simplest type of oscillations are related to systems that can be described by Hooke's law.
- Periodic motion is a repetitious oscillation.
- The time for one oscillation is the period T.
- The number of oscillations per unit time is the frequency
- A mass m suspended by a wire of length L is a simple pendulum and undergoes simple harmonic motion for amplitudes less than about 15 degrees.

KEY EQUATIONS

5.2 Vector Addition and Subtraction: Analytical Methods

resultant magnitude	$R = \sqrt{R_x^2 + R_y^2}$
resultant direction	$\theta = \tan^{-1}(R_y/R_x)$
x-component of a vector A (when an angle is given relative to the horizontal)	$A_x = A\cos\theta$
y-component of a vector A (when an angle is given relative to the horizontal)	$A_y = A\sin\theta$
addition of vectors	$\mathbf{A_x} + \mathbf{A_y} = \mathbf{A}$

5.3 Projectile Motion

angle of displacement	$\theta = \tan^{-1}(\mathbf{y}/\mathbf{x})$

velocity	$\mathbf{v} = \sqrt{\mathbf{v}_x^2 + \mathbf{v}_y^2}$
angle of velocity	$\theta_v = \tan^{-1}(\mathbf{v}_y/\mathbf{v}_x)$
maximum height	$h = \frac{\mathbf{v}_{0y}^2}{2\mathbf{g}}$
range	$R = \frac{\mathbf{v}_0^2 \sin 2\theta_0}{\mathbf{g}}$

5.4 Inclined Planes

force of static friction	$\mathbf{f}_s \leq \mu_s \mathbf{N}$
force of kinetic friction	$\mathbf{f}_k = \mu_k \mathbf{N}$
perpendicular component of weight on an inclined plane	$\mathbf{w}_\perp = \mathbf{w}\cos(\theta) = m\mathbf{g}\cos(\theta)$
parallel component of weight on an inclined plane	$\mathbf{w}_{\|\|} = \mathbf{w}\sin(\theta) = m\mathbf{g}\sin(\theta)$

5.5 Simple Harmonic Motion

Hooke's law	$\mathbf{F} = -\mathbf{kx}$
period in simple harmonic motion	$T = 2\pi\sqrt{\frac{m}{\mathbf{k}}}$
frequency in simple harmonic motion	$f = \frac{1}{2\pi}\sqrt{\frac{\mathbf{k}}{m}}$
period of a simple pendulum	$T = 2\pi\sqrt{\frac{L}{\mathbf{g}}}$

CHAPTER REVIEW

Concept Items

5.1 Vector Addition and Subtraction: Graphical Methods

1. There is a vector $\vec{A}$, with magnitude 5 units pointing towards west and vector $\vec{B}$, with magnitude 3 units, pointing towards south. Using vector addition, calculate the magnitude of the resultant vector.
   a. 4.0
   b. 5.8
   c. 6.3
   d. 8.0

2. If you draw two vectors using the head-to-tail method, how can you then draw the resultant vector?
   a. By joining the head of the first vector to the head of the last
   b. By joining the head of the first vector with the tail of the last
   c. By joining the tail of the first vector to the head of the last
   d. By joining the tail of the first vector with the tail of the last

3. What is the global angle of 20° south of west?
   a. 110°
   b. 160°
   c. 200°
   d. 290°

5.2 Vector Addition and Subtraction: Analytical Methods

4. What is the angle between the x and y components of a vector?
   a. 0°
   b. 45°
   c. 90°
   d. 180°

5. Two vectors are equal in magnitude and opposite in direction. What is the magnitude of their resultant vector?
   a. The magnitude of the resultant vector will be zero.
   b. The magnitude of resultant vector will be twice the magnitude of the original vector.
   c. The magnitude of resultant vector will be same as magnitude of the original vector.
   d. The magnitude of resultant vector will be half the magnitude of the original vector.

6. How can we express the x and y-components of a vector in terms of its magnitude, A, and direction, global angle θ?
   a. $A_x = A\cos\theta\, A_y = A\sin\theta$
   b. $A_x = A\cos\theta\, A_y = A\cos\theta$
   c. $A_x = A\sin\theta\, A_y = A\cos\theta$

d. $A_x = A \sin\theta A_y = A \sin\theta$

7. True or False—Every 2-D vector can be expressed as the product of its x and y-components.
   a. True
   b. False

5.3 Projectile Motion

8. Horizontal and vertical motions of a projectile are independent of each other. What is meant by this?
   a. Any object in projectile motion falls at the same rate as an object in freefall, regardless of its horizontal velocity.
   b. All objects in projectile motion fall at different rates, regardless of their initial horizontal velocities.
   c. Any object in projectile motion falls at the same rate as its initial vertical velocity, regardless of its initial horizontal velocity.
   d. All objects in projectile motion fall at different rates and the rate of fall of the object is independent of the initial velocity.

9. Using the conventional choice for positive and negative axes described in the text, what is the y-component of the acceleration of an object experiencing projectile motion?
   a. $-9.8\ \text{m/s}$
   b. $-9.8\ \text{m/s}^2$
   c. $9.8\ \text{m/s}$
   d. $9.8\ \text{m/s}^2$

5.4 Inclined Planes

10. True or False—Kinetic friction is less than the limiting static friction because once an object is moving, there are fewer points of contact, and the friction is reduced. For this reason, more force is needed to start moving an object than to keep it in motion.
    a. True
    b. False

11. When there is no motion between objects, what is the relationship between the magnitude of the static friction f_s and the normal force N?
    a. $f_s \leq N$
    b. $f_s \leq \mu_s N$
    c. $f_s \geq N$
    d. $f_s \geq \mu_s N$

12. What equation gives the magnitude of kinetic friction?
    a. $f_k = \mu_s N$
    b. $f_k = \mu_k N$
    c. $f_k \leq \mu_s N$
    d. $f_k \leq \mu_k N$

5.5 Simple Harmonic Motion

13. Why is there a negative sign in the equation for Hooke's law?
    a. The negative sign indicates that displacement decreases with increasing force.
    b. The negative sign indicates that the direction of the applied force is opposite to that of displacement.
    c. The negative sign indicates that the direction of the restoring force is opposite to that of displacement.
    d. The negative sign indicates that the force constant must be negative.

14. With reference to simple harmonic motion, what is the equilibrium position?
    a. The position where velocity is the minimum
    b. The position where the displacement is maximum
    c. The position where the restoring force is the maximum
    d. The position where the object rests in the absence of force

15. What is Hooke's law?
    a. Restoring force is directly proportional to the displacement from the mean position and acts in the the opposite direction of the displacement.
    b. Restoring force is directly proportional to the displacement from the mean position and acts in the same direction as the displacement.
    c. Restoring force is directly proportional to the square of the displacement from the mean position and acts in the opposite direction of the displacement.
    d. Restoring force is directly proportional to the square of the displacement from the mean position and acts in the same direction as the displacement.

Critical Thinking Items

5.1 Vector Addition and Subtraction: Graphical Methods

16. True or False—A person is following a set of directions. He has to walk 2 km east and then 1 km north. He takes a wrong turn and walks in the opposite direction for the second leg of the trip. The magnitude of his total displacement will be the same as it would have been had he followed directions correctly.
    a. True
    b. False

5.2 Vector Addition and Subtraction: Analytical Methods

17. What is the magnitude of a vector whose x-component is 2 units and whose angle is 60°?
a. 1.0 units
b. 2.0 units
c. 2.3 units
d. 4.0 units

18. Vectors $\vec{A}$ and $\vec{B}$ are equal in magnitude and opposite in direction. Does $\vec{A} - \vec{B}$ have the same direction as vector $\vec{A}$ or $\vec{B}$?
a. $\vec{A}$
b. $\vec{B}$

5.3 Projectile Motion

19. Two identical items, object 1 and object 2, are dropped from the top of a 50.0 m building. Object 1 is dropped with an initial velocity of 0 m/s, while object 2 is thrown straight downward with an initial velocity of 13.0 m/s. What is the difference in time, in seconds rounded to the nearest tenth, between when the two objects hit the ground?
a. Object 1 will hit the ground 3.2 s after object 2.
b. Object 1 will hit the ground 2.1 s after object 2.
c. Object 1 will hit the ground at the same time as object 2.
d. Object 1 will hit the ground 1.1 s after object 2.

20. An object is launched into the air. If the y-component of its acceleration is 9.8 m/s^2, which direction is defined as positive?
a. Vertically upward in the coordinate system
b. Vertically downward in the coordinate system
c. Horizontally to the right side of the coordinate system
d. Horizontally to the left side of the coordinate system

5.4 Inclined Planes

21. A box weighing 500 N is at rest on the floor. A person pushes against it and it starts moving when 100 N force is applied to it. What can be said about the coefficient of kinetic friction between the box and the floor?
a. $\mu_k = 0$
b. $\mu_k = 0.2$
c. $\mu_k < 0.2$
d. $\mu_k > 0.2$

22. The component of the weight parallel to an inclined plane of an object resting on an incline that makes an angle of 70.0° with the horizontal is 100.0 N. What is the object's mass?
a. 10.9 kg
b. 29.8 kg
c. 106 kg
d. 292 kg

5.5 Simple Harmonic Motion

23. Two springs are attached to two hooks. Spring A has a greater force constant than spring B. Equal weights are suspended from both. Which of the following statements is true?
a. Spring A will have more extension than spring B.
b. Spring B will have more extension than spring A.
c. Both springs will have equal extension.
d. Both springs are equally stiff.

24. Two simple harmonic oscillators are constructed by attaching similar objects to two different springs. The force constant of the spring on the left is 5 N/m and that of the spring on the right is 4 N/m. If the same force is applied to both, which of the following statements is true?
a. The spring on the left will oscillate faster than spring on the right.
b. The spring on the right will oscillate faster than the spring on the left.
c. Both the springs will oscillate at the same rate.
d. The rate of oscillation is independent of the force constant.

Problems

5.1 Vector Addition and Subtraction: Graphical Methods

25. A person attempts to cross a river in a straight line by navigating a boat at 15 m/s. If the river flows at 5.0 m/s from his left to right, what would be the magnitude of the boat's resultant velocity? In what direction would the boat go, relative to the straight line across it?
a. The resultant velocity of the boat will be 10.0 m/s. The boat will go toward his right at an angle of 26.6° to a line drawn across the river.
b. The resultant velocity of the boat will be 10.0 m/s. The boat will go toward his left at an angle of 26.6° to a line drawn across the river.
c. The resultant velocity of the boat will be 15.8 m/s. The boat will go toward his right at an angle of

18.4° to a line drawn across the river.

d. The resultant velocity of the boat will be $15.8\ \text{m/s}$. The boat will go toward his left at an angle of 18.4° to a line drawn across the river.

26. A river flows in a direction from south west to north east at a velocity of $7.1\ \text{m/s}$. A boat captain wants to cross this river to reach a point on the opposite shore due east of the boat's current position. The boat moves at $13\ \text{m/s}$. Which direction should it head towards if the resultant velocity is $19.74\ \text{m/s}$?

a. It should head in a direction 22.6° east of south.
b. It should head in a direction 22.6° south of east.
c. It should head in a direction 45.0° east of south.
d. It should head in a direction 45.0° south of east.

5.2 Vector Addition and Subtraction: Analytical Methods

27. A person walks 10.0 m north and then 2.00 m east. Solving analytically, what is the resultant displacement of the person?

a. $\vec{R} = 10.2$ m, $\theta = 78.7°$ east of north
b. $\vec{R} = 10.2$ m, $\theta = 78.7°$ north of east
c. $\vec{R} = 12.0$ m, $\theta = 78.7°$ east of north
d. $\vec{R} = 12.0$ m, $\theta = 78.7°$ north of east

28. A person walks 12.0° north of west for $55.0\ \text{m}$ and 63.0° south of west for $25.0\ \text{m}$. What is the magnitude of his displacement? Solve analytically.

a. $10.84\ \text{m}$
b. $65.1\ \text{m}$
c. $66.04\ \text{m}$
d. $80.00\ \text{m}$

5.3 Projectile Motion

29. A water balloon cannon is fired at $30\ \text{m/s}$ at an angle of 50° above the horizontal. How far away will it fall?

a. $2.35\ \text{m}$
b. $3.01\ \text{m}$
c. $70.35\ \text{m}$
d. $90.44\ \text{m}$

30. A person wants to fire a water balloon cannon such that it hits a target 100 m away. If the cannon can only be launched at 45° above the horizontal, what should be the initial speed at which it is launched?

a. 31.3 m/s
b. 37.2 m/s
c. 980.0 m/s
d. 1,385.9 m/s

5.4 Inclined Planes

31. A coin is sliding down an inclined plane at constant velocity. If the angle of the plane is 10° to the horizontal, what is the coefficient of kinetic friction?

a. $\mu_k = 0$
b. $\mu_k = 0.18$
c. $\mu_k = 5.88$
d. $\mu_k = \infty$

32. A skier with a mass of 55 kg is skiing down a snowy slope that has an incline of 30°. Find the coefficient of kinetic friction for the skier if friction is known to be 25 N .

a. $\mu k = 0$
b. $\mu k = 0.05$
c. $\mu k = 0.09$
d. $\mu k = \infty$

5.5 Simple Harmonic Motion

33. What is the time period of a $6\ \text{cm}$ long pendulum on earth?

a. $0.08\ \text{s}$
b. $0.49\ \text{s}$
c. $4.9\ \text{s}$
d. $80\ \text{s}$

34. A simple harmonic oscillator has time period $4\ \text{s}$. If the mass of the system is $2\ \text{kg}$, what is the force constant of the spring used?

a. $0.125\ \text{N/m}$
b. $0.202\ \text{N/m}$
c. $0.81\ \text{N/m}$
d. $4.93\ \text{N/m}$

Performance Task

5.5 Simple Harmonic Motion

35. Construct a seconds pendulum (pendulum with time period 2 seconds).

TEST PREP

Multiple Choice

5.1 Vector Addition and Subtraction: Graphical Methods

36. True or False—We can use Pythagorean theorem to calculate the length of the resultant vector obtained from the addition of two vectors which are at right angles to each other.
a. True
b. False

37. True or False—The direction of the resultant vector depends on both the magnitude and direction of added vectors.
a. True
b. False

38. A plane flies north at 200 m/s with a headwind blowing from the north at 70 m/s. What is the resultant velocity of the plane?
a. 130 m/s north
b. 130 m/s south
c. 270 m/s north
d. 270 m/s south

39. Two hikers take different routes to reach the same spot. The first one goes 255 m southeast, then turns and goes 82 m at 14° south of east. The second hiker goes 200 m south. How far and in which direction must the second hiker travel now, in order to reach the first hiker's location destination?
a. 200 m east
b. 200 m south
c. 260 m east
d. 260 m south

5.2 Vector Addition and Subtraction: Analytical Methods

40. When will the x-component of a vector with angle θ be greater than its y-component?
a. $0^\circ < \theta < 45^\circ$
b. $\theta = 45^\circ$
c. $45^\circ < \theta < 60^\circ$
d. $60^\circ < \theta < 90^\circ$

41. The resultant vector of the addition of vectors $\vec{a}$ and $\vec{b}$ is $\vec{r}$. The magnitudes of $\vec{a}$, $\vec{b}$, and $\vec{r}$ are A, B, and R, respectively. Which of the following is true?
a. $R_x + R_y = 0$
b. $A_x + A_y = \vec{A}$
c. $A_x + B_y = B_x + A_y$
d. $A_x + B_x = R_x$

42. What is the dimensionality of vectors used in the study of atmospheric sciences?
a. One-dimensional
b. Two-dimensional
c. Three-dimensional

5.3 Projectile Motion

43. After a projectile is launched in the air, in which direction does it experience constant, non-zero acceleration, ignoring air resistance?
a. The x direction
b. The y direction
c. Both the x and y directions
d. Neither direction

44. Which is true when the height of a projectile is at its maximum?
a. $v_y = 0$
b. $v_y = \text{maximum}$
c. $v_x = \text{maximum}$

45. A ball is thrown in the air at an angle of 40°. If the maximum height it reaches is 10 m, what must be its initial speed?
a. 17.46 m/s
b. 21.78 m/s
c. 304.92 m/s
d. 474.37 m/s

46. A large rock is ejected from a volcano with a speed of 30 m/s and at an angle 60° above the horizontal. The rock strikes the side of the volcano at an altitude of 10.0 m lower than its starting point. Calculate the horizontal displacement of the rock.
a. 84.90 m
b. 96.59 m
c. 169.80 m
d. 193.20 m

5.4 Inclined Planes

47. For objects of identical masses but made of different materials, which of the following experiences the most static friction?
a. Shoes on ice
b. Metal on wood
c. Teflon on steel

48. If an object sits on an inclined plane and no other object makes contact with the object, what is typically equal in magnitude to the component of the weight perpendicular to the plane?

a. The normal force
b. The total weight
c. The parallel force of weight

49. A 5 kg box is at rest on the floor. The coefficient of static friction between the box and the floor is 0.4. A horizontal force of 50 N is applied to the box. Will it move?
a. No, because the applied force is less than the maximum limiting static friction.
b. No, because the applied force is more than the maximum limiting static friction.
c. Yes, because the applied force is less than the maximum limiting static friction.
d. Yes, because the applied force is more than the maximum limiting static friction.

50. A skier with a mass of 67 kg is skiing down a snowy slope with an incline of 37°. Find the friction if the coefficient of kinetic friction is 0.07.
a. 27.66 N
b. 34.70 N
c. 36.71 N
d. 45.96 N

5.5 Simple Harmonic Motion

51. A change in which of the following is an example of deformation?
a. Velocity
b. Length
c. Mass
d. Weight

52. The units of amplitude are the same as those for which of the following measurements?
a. Speed
b. Displacement
c. Acceleration
d. Force

53. Up to approximately what angle is simple harmonic motion a good model for a pendulum?
a. 15°
b. 45°
c. 75°
d. 90°

54. How would simple harmonic motion be different in the absence of friction?
a. Oscillation will not happen in the absence of friction.
b. Oscillation will continue forever in the absence of friction.
c. Oscillation will have changing amplitude in the absence of friction.
d. Oscillation will cease after a certain amount of time in the absence of friction.

55. What mass needs to be attached to a spring with a force constant of $7\ \text{N/m}$ in order to make a simple harmonic oscillator oscillate with a time period of 3 s?
a. $0.03\ \text{kg}$
b. $1.60\ \text{kg}$
c. $30.7\ \text{kg}$
d. $63.0\ \text{kg}$

Short Answer

5.1 Vector Addition and Subtraction: Graphical Methods

56. Find $\vec{A} - \vec{B}$ for the following vectors:
$\vec{A} = (122\,\text{cm}, \angle 145^\circ)\ \vec{B} = (110\,\text{cm}, \angle 270^\circ)$
a. 108 cm, $\theta = 119.0^\circ$
b. 108 cm, $\theta = 125.0^\circ$
c. 206 cm, $\theta = 119.0^\circ$
d. 206 cm, $\theta = 125.0^\circ$

57. Find $\vec{A} + \vec{B}$ for the following vectors:
$\vec{A} = (122\,\text{cm}, \angle 145^\circ)\ \vec{B} = (110\,\text{cm}, \angle 270^\circ)$
a. 108 cm, $\theta = 119.1^\circ$
b. 108 cm, $\theta = 201.8^\circ$
c. 232 cm, $\theta = 119.1^\circ$
d. 232 cm, $\theta = 201.8^\circ$

58. Consider six vectors of 2 cm each, joined from head to tail making a hexagon. What would be the magnitude of the addition of these vectors?
a. Zero
b. Six
c. Eight
d. Twelve

59. Two people pull on ropes tied to a trolley, each applying 44 N of force. The angle the ropes form with each other is 39.5°. What is the magnitude of the net force exerted on the trolley?
a. 0.0 N
b. 79.6 N
c. 82.8 N
d. 88.0 N

5.2 Vector Addition and Subtraction: Analytical Methods

60. True or False—A vector can form the shape of a right angle triangle with its x and y components.
a. True

b. False

61. True or False—All vectors have positive x and y components.
a. True
b. False

62. Consider $\vec{A} - \vec{B} = \vec{R}$. What is R_x in terms of A_x and B_x?
a. $R_x = \frac{A_x}{B_x}$
b. $R_x = \frac{B_x}{A_x}$
c. $R_x = A_x + B_x$
d. $R_x = A_x - B_x$

63. Consider $\vec{A} - \vec{B} = \vec{R}$. What is R_y in terms of A_y and B_y?
a. $R_y = \frac{A_y}{B_y}$
b. $R_y = \frac{B_y}{A_y}$
c. $R_y = A_y + B_y$
d. $R_y = A_y - B_y$

64. When a three dimensional vector is used in the study of atmospheric sciences, what is z?
a. Altitude
b. Heat
c. Temperature
d. Wind speed

65. Which method is not an application of vector calculus?
a. To find the rate of change in atmospheric temperature
b. To study changes in wind speed and direction
c. To predict changes in atmospheric pressure
d. To measure changes in average rainfall

5.3 Projectile Motion

66. How can you express the velocity, $\vec{v}$, of a projectile in terms of its initial velocity, $\vec{v_0}$, acceleration, $\vec{a}$, and time, t?
a. $\vec{v} = \vec{a}\,t$
b. $\vec{v} = \vec{v_0} + \vec{a}\,t$
c. $\vec{v} + \vec{v_0} = \vec{a}\,t$
d. $\vec{v_0} + \vec{v} + \vec{a}\,t$

67. In the equation for the maximum height of a projectile, what does v_{0y} stand for? $h = \frac{{v_{0y}}^2}{2g}$
a. Initial velocity in the x direction
b. Initial velocity in the y direction
c. Final velocity in the x direction
d. Final velocity in the y direction

68. True or False—Range is defined as the maximum vertical distance travelled by a projectile.
a. True
b. False

69. For what angle of a projectile is its range equal to zero?
a. 0° or 30°
b. 0° or 45°
c. 90° or 0°
d. 90° or 45°

5.4 Inclined Planes

70. What are the units of the coefficient of friction?
a. N
b. m/s
c. m/s^2
d. unitless

71. Two surfaces in contact are moving slowly past each other. As the relative speed between the two surfaces in contact increases, what happens to the magnitude of their coefficient of kinetic friction?
a. It increases with the increase in the relative motion.
b. It decreases with the increase in the relative motion.
c. It remains constant and is independent of the relative motion.

72. When will an object slide down an inclined plane at constant velocity?
a. When the magnitude of the component of the weight along the slope is equal to the magnitude of the frictional force.
b. When the magnitude of the component of the weight along the slope is greater than the magnitude of the frictional force.
c. When the magnitude of the component of the weight perpendicular to the slope is less than the magnitude of the frictional force.
d. When the magnitude of the component of the weight perpendicular to the slope is equal to the magnitude of the frictional force.

73. A box is sitting on an inclined plane. At what angle of incline is the perpendicular component of the box's weight at its maximum?
a. 0°
b. 30°
c. 60°
d. 90°

5.5 Simple Harmonic Motion

74. What is the term used for changes in shape due to the application of force?
a. Amplitude

b. Deformation
c. Displacement
d. Restoring force

75. What is the restoring force?
a. The normal force on the surface of an object
b. The weight of a mass attached to an object
c. Force which is applied to deform an object from its original shape
d. Force which brings an object back to its equilibrium position

76. For a given oscillator, what are the factors that affect its period and frequency?
a. Mass only
b. Force constant only
c. Applied force and mass
d. Mass and force constant

77. For an object in simple harmonic motion, when does the maximum speed occur?
a. At the extreme positions
b. At the equilibrium position
c. At the moment when the applied force is removed
d. Midway between the extreme and equilibrium positions

78. What is the equilibrium position of a pendulum?
a. When the tension in the string is zero
b. When the pendulum is hanging straight down
c. When the tension in the string is maximum
d. When the weight of the mass attached is minimum

79. If a pendulum is displaced by an angle θ, what is the net restoring force it experiences?
a. $mg\sin\theta$
b. $mg\cos\theta$
c. $-mg\sin\theta$
d. $-mg\cos\theta$

a. True
b. False

Extended Response

5.1 Vector Addition and Subtraction: Graphical Methods

80. True or False—For vectors the order of addition is important.
a. True
b. False

81. Consider five vectors *a*, *b*, *c*, *d*, and *e*. Is it true or false that their addition always results in a vector with a greater magnitude than if only two of the vectors were added?
a. True
b. False

5.2 Vector Addition and Subtraction: Analytical Methods

82. For what angle of a vector is it possible that its magnitude will be equal to its y-component?
a. $\theta = 0^\circ$
b. $\theta = 45^\circ$
c. $\theta = 60^\circ$
d. $\theta = 90^\circ$

83. True or False—If only the angles of two vectors are known, we can find the angle of their resultant addition vector.
a. True
b. False

84. True or false—We can find the magnitude and direction of the resultant vector if we know the angles of two vectors and the magnitude of one.

5.3 Projectile Motion

85. Ignoring drag, what is the x-component of the acceleration of a projectile? Why?
a. The x-component of the acceleration of a projectile is 0 because acceleration of a projectile is due to gravity, which acts in the y direction.
b. The x component of the acceleration of a projectile is g because acceleration of a projectile is due to gravity, which acts in the x direction.
c. The x-component of the acceleration of a projectile is 0 because acceleration of a projectile is due to gravity, which acts in the x direction.
d. The x-component of the acceleration of a projectile is g because acceleration of a projectile is due to gravity, which acts in the y direction.

86. What is the optimum angle at which a projectile should be launched in order to cover the maximum distance?
a. 0°
b. 45°
c. 60°
d. 90°

5.4 Inclined Planes

87. True or False—Friction varies from surface to surface because different substances have different degrees of roughness or smoothness.
a. True
b. False

88. As the angle of the incline gets larger, what happens to

the magnitudes of the perpendicular and parallel components of gravitational force?

a. Both the perpendicular and the parallel component will decrease.
b. The perpendicular component will decrease and the parallel component will increase.
c. The perpendicular component will increase and the parallel component will decrease.
d. Both the perpendicular and the parallel component will increase.

5.5 Simple Harmonic Motion

89. What physical characteristic of a system is its force constant related to?

a. The force constant k is related to the stiffness of a system: The larger the force constant, the stiffer the system.
b. The force constant k is related to the stiffness of a system: The larger the force constant, the looser the system.
c. The force constant k is related to the friction in the system: The larger the force constant, the greater the friction in the system.
d. The force constant k is related to the friction in the system: The larger the force constant, the lower the friction in the system.

90. How or why does a pendulum oscillate?

a. A pendulum oscillates due to applied force.
b. A pendulum oscillates due to the elastic nature of the string.
c. A pendulum oscillates due to restoring force arising from gravity.
d. A pendulum oscillates due to restoring force arising from tension in the string.

91. If a pendulum from earth is taken to the moon, will its frequency increase or decrease? Why?

a. It will increase because g on the Moon is less than g on Earth.
b. It will decrease because g on the Moon is less than g on Earth.
c. It will increase because g on the Moon is greater than g on Earth.
d. It will decrease because g on the Moon is greater than g on Earth.