1. A mass on a horizontal spring is pulled to the right and released. At which position is the object's kinetic energy greatest?
   A. Passing through equilibrium
   B. At maximum displacement to the right
   C. At maximum displacement to the left
   D. Halfway between equilibrium and amplitude
   E. Immediately after release

2. Which statement best defines simple harmonic motion (SHM)?
   A. Motion where acceleration is proportional to displacement and directed toward equilibrium
   B. Motion where velocity is constant in magnitude and changes direction periodically
   C. Motion where restoring force is constant in magnitude
   D. Motion with no restoring force but constant amplitude
   E. Motion where kinetic energy is always greater than potential energy

3. For a mass–spring system, which parameter does the period depend on (for small oscillations)?
   A. Mass and spring constant
   B. Amplitude only
   C. Gravity and amplitude
   D. Damping coefficient only
   E. Material of the spring but not its stiffness

4. Two identical pendulums have lengths L and 4L. Which has the longer period?
   A. The one of length 4L
   B. The one of length L
   C. They have the same period
   D. Period depends on amplitude, so cannot tell
   E. The longer one if its mass is larger

5. In small-angle approximations for a simple pendulum, the period does NOT depend on:
   A. Amplitude (for small angles)
   B. Length of the string
   C. Local gravitational acceleration
   D. Mass of the bob
   E. Whether the bob is spherical or cubic (shape only)

6. Where is the potential energy of an oscillating mass-spring system maximum?
   A. At maximum displacement (amplitude)

B. At equilibrium position
C. When the block is moving fastest
D. Halfway between equilibrium and amplitude
E. Right after the mass is released

7. A driving force applied near a system's natural frequency typically causes:
   A. Large amplitude (resonance) if damping is small
   B. No change in amplitude compared to driving at zero frequency
   C. Amplitude to drop to zero
   D. Period to become independent of mass
   E. The system to immediately stop oscillating

8. If the mass on a spring is doubled (spring constant unchanged), the period will:
   A. Increase (longer period)
   B. Decrease (shorter period)
   C. Stay the same
   D. Become independent of spring constant
   E. Become zero

9. Damping (like friction) in an oscillator primarily does which of the following?
   A. Reduces amplitude and removes mechanical energy over time
   B. Increases frequency while keeping amplitude constant
   C. Converts potential energy into stored elastic energy only
   D. Increases the equilibrium position
   E. Makes the restoring force proportional to velocity instead of displacement

10. For a simple harmonic oscillator, the acceleration is zero when the displacement is:
    A. Zero (at equilibrium)
    B. Maximum positive displacement
    C. Maximum negative displacement
    D. One-quarter of the amplitude
    E. Half the amplitude

11. Which pair of variables is 90° out of phase in an undamped SHM?
    A. Displacement and velocity
    B. Displacement and acceleration
    C. Velocity and kinetic energy
    D. Potential energy and total mechanical energy
    E. Displacement and potential energy

12. A pendulum bob reaches its maximum speed at:
    A. The lowest point (equilibrium)
    B. The highest point in its swing
    C. Halfway between highest and lowest point always
    D. When the tension is maximum
    E. Immediately after being released

13. The angular frequency ω of a spring–mass oscillator is larger when:
    A. The spring constant k is larger (mass fixed)
    B. The mass is larger (k fixed)
    C. Amplitude is larger (mass & k fixed)
    D. The system is more heavily damped
    E. The oscillator is driven at resonance

14. Two springs in series (same spring constant k) attached to a mass produce an effective spring constant that is:
    A. Smaller than k (system is softer)
    B. Larger than k (system is stiffer)
    C. Equal to k
    D. Infinite
    E. Zero

15. If a spring's amplitude is doubled (small oscillations), the period will:
    A. Remain essentially unchanged (for SHM)
    B. Double
    C. Halve
    D. Increase by a factor of four
    E. Become unpredictable

16. Which energy statement is true for an ideal (no damping) oscillator?
    A. Total mechanical energy remains constant during oscillation
    B. Total energy steadily decreases as time goes on
    C. Kinetic energy is always equal to potential energy
    D. Potential energy is always zero at equilibrium
    E. Energy is only kinetic — no potential energy

17. In a driven oscillation, the amplitude is largest when the driving frequency is:
    A. Close to the natural frequency (and damping is small)
    B. Much smaller than the natural frequency
    C. Much larger than the natural frequency

D. Zero
E. Exactly twice the natural frequency

18. When an oscillating object passes through equilibrium, which is true about its acceleration and velocity?
    A. Velocity is maximum and acceleration is zero
    B. Velocity is zero and acceleration is maximum
    C. Both velocity and acceleration are maximum
    D. Both are zero
    E. Velocity is negative and acceleration is positive

19. For a mass attached to a spring on a horizontal frictionless surface, increasing the spring constant k (mass fixed) will:
    A. Decrease the period (makes oscillations faster)
    B. Increase the period (make oscillations slower)
    C. Not change the period
    D. Change amplitude but not period
    E. Change equilibrium position

20. Which describes the restoring force in SHM of a mass on a spring?
    A. Directed toward equilibrium and proportional to displacement
    B. Directed away from equilibrium and proportional to displacement
    C. Constant in magnitude and direction
    D. Proportional to the mass but independent of displacement
    E. Proportional to velocity

21. Two identical mass–spring systems oscillate. One has larger amplitude than the other. Which is true (ideal SHM)?
    A. Both have the same frequency and period
    B. The one with larger amplitude has lower frequency
    C. The one with larger amplitude has higher frequency
    D. The periods depend on amplitude; need numbers
    E. The larger-amplitude system has more mass

22. A simple pendulum's period will change if you move it to a planet with greater g. Which way?
    A. The period becomes shorter (oscillates faster)
    B. The period becomes longer (oscillates slower)
    C. The period is unchanged by g
    D. The period becomes infinite

E. The pendulum stops oscillating

23. Which best describes resonance in everyday terms?
    A. When a periodic push matches an object's natural rhythm and builds amplitude
    B. When an object stops moving regardless of pushes
    C. When frequency and period are both zero
    D. When amplitude is always zero
    E. When damping causes amplitude to grow

24. In SHM, the phase describes:
    A. The position within the oscillation cycle at a given time
    B. How much energy is in the system
    C. The amplitude's sign only
    D. The mass multiplied by the spring constant
    E. The damping coefficient

25. For small oscillations a pendulum's period is independent of the bob's mass because:
    A. Both gravitational force and inertia scale with mass, canceling out
    B. The gravitational force is zero for all masses
    C. A heavier mass stretches the string, reducing period
    D. Mass cancels only if bob is frictionless
    E. The length of string changes with mass

26. If you compress a spring and hold it, the force you feel when you release is:
    A. A restoring force directed outward proportional to the displacement
    B. A constant outward force independent of compression
    C. A force that points toward the compression direction only
    D. Zero because spring is at rest before release
    E. Frictional force only

27. What happens to the amplitude of a lightly damped oscillator over many cycles?
    A. It gradually decreases toward zero
    B. It stays exactly the same
    C. It increases exponentially
    D. It alternates randomly between values
    E. It immediately becomes zero

28. In SHM, at the instant when the displacement is halfway to the amplitude (and moving outward), the kinetic energy is:
    A. Less than at equilibrium but greater than zero

B. Maximal (equal to total energy)
C. Zero
D. Equal to the potential energy always
E. Negative

29. When comparing two oscillators, one with damping and one without, which is true about their frequencies?
A. The damped oscillator typically has a slightly lower oscillation frequency
B. The damped oscillator always has much higher frequency
C. Damping has no effect on frequency at all
D. The undamped oscillator always stops sooner
E. The damped oscillator has zero frequency

30. A mass on a spring is pulled to +x amplitude and released. At which point is the spring force greatest in magnitude?
A. At maximum displacement (amplitude)
B. At equilibrium position
C. Midway while moving toward equilibrium
D. Right after release only
E. When the speed is maximum

31. A child on a swing (approximated as a pendulum) wants to increase amplitude without pushing. She can:
A. Stand and sit in rhythm (changing moment of inertia) at the right times to pump energy in
B. Increase the length of the chains without pushing
C. Remove air resistance to increase amplitude instantly
D. Change the mass of the child to a smaller value and the amplitude grows
E. Nothing — amplitude cannot change without outside pushes

32. For a mass-spring oscillator, if the spring constant is quadrupled and mass unchanged, the period changes by what factor? (qualitative)
A. The period decreases (oscillates faster)
B. The period increases (slower)
C. The period is unchanged
D. The period doubles
E. The period depends only on amplitude so cannot tell

33. Which describes the equilibrium position for an oscillating mass on a vertical spring?
A. Where net force is zero (weight balanced by spring force)

B. The top of the spring always
C. The position of maximum displacement
D. The initial release point only
E. A point where acceleration is maximum

34. The restoring torque for a simple physical pendulum near equilibrium is proportional to:
A. Angular displacement (small angles)
B. Angular velocity
C. Mass only
D. Square of the angle always
E. Length squared

35. If you double the amplitude of a small-angle pendulum (still small), what happens to the period?
A. No significant change (period essentially independent of amplitude)
B. Period doubles
C. Period halves
D. Period quadruples
E. Period becomes random

36. A mass oscillates and reaches maximum displacement to the right. Its velocity and acceleration at that instant are:
A. Velocity zero, acceleration directed back toward equilibrium
B. Velocity maximum, acceleration zero
C. Both zero
D. Velocity nonzero, acceleration zero
E. Velocity zero, acceleration directed away from equilibrium

37. Which best explains why a mass–spring system exhibits SHM for small displacements?
A. Hooke's law makes force proportional to displacement so acceleration $\propto -x$
B. Air resistance cancels part of the motion leaving a sinusoid
C. Mass always moves in circles, producing SHM projection
D. Gravity provides the restoring force in horizontal springs
E. The spring stores kinetic energy directly

38. What happens to total mechanical energy of an oscillator with light damping?
A. It decreases slowly over time due to nonconservative forces
B. It remains exactly constant
C. It increases as damping converts heat to mechanical energy
D. It alternates between increase and decrease every cycle

E. It becomes negative

39. Two identical pendulums are mounted side-by-side. One is slightly pushed periodically at its natural period; the other is not. After some time, which is true?
    A. The pushed pendulum will have larger amplitude due to resonance pumping energy in
    B. Both will have equal amplitude because natural motion is same
    C. The pushed one will stop due to interference
    D. The pushed one will swing in opposite direction only
    E. The unpushed one will also increase amplitude spontaneously

40. Which best describes phase difference between position and acceleration in SHM?
    A. Position and acceleration are 180° (π radians) out of phase
    B. Position and acceleration are in phase
    C. Position leads acceleration by 90°
    D. Position is random relative to acceleration
    E. Position and acceleration differ by 45°

41. A mass-spring oscillator is set into motion. If you want to double the maximum kinetic energy at equilibrium, you must:
    A. Double the amplitude (since energy $\propto$ amplitude^2)
    B. Double the mass only
    C. Halve the amplitude
    D. Double the spring constant only
    E. Change damping only

42. If a driving frequency is much higher than a system's natural frequency, the system's response amplitude is generally:
    A. Small (system cannot follow the fast drive effectively)
    B. Very large due to resonance
    C. Infinite
    D. Exactly the same as at resonance
    E. Negative

43. Which situation indicates underdamped motion?
    A. Oscillations that slowly decrease in amplitude over time
    B. Motion that returns to equilibrium without oscillating
    C. Motion that immediately stops after one cycle
    D. Amplitude increasing with time spontaneously
    E. No motion at all

44. In SHM, the maximum speed of the object increases if:
    A. Amplitude increases (mass and constants fixed)
    B. Mass increases while amplitude fixed
    C. Spring constant decreases while amplitude fixed
    D. Damping increases slightly
    E. Equilibrium position shifts

45. For the same small amplitude, a long pendulum compared to a short one has:
    A. A longer period (slower oscillation)
    B. A shorter period (faster)
    C. Same period regardless of length
    D. Greater maximum speed always
    E. Lower total mechanical energy by necessity

46. Which best describes critically damped motion?
    A. Returns to equilibrium fastest without oscillating
    B. Oscillates forever with constant amplitude
    C. Has amplitude increasing to infinity
    D. Oscillates with constant amplitude but slowly decaying phase
    E. Returns to equilibrium with infinite overshoot

47. A block on a spring oscillates. At what instant is the elastic potential energy equal to the kinetic energy?
    A. Some point between amplitude and equilibrium (not at extremes)
    B. At maximum displacement only
    C. At equilibrium only
    D. Never — they are never equal in SHM
    E. Only if amplitude is zero

48. Which is true about small oscillations about a stable equilibrium in general systems?
    A. They are approximately simple harmonic because restoring force $\approx -kx$ near equilibrium
    B. They are always chaotic and unpredictable
    C. Period always depends strongly on amplitude even for small displacements
    D. Damping is necessary to produce SHM
    E. They always have exactly the same period regardless of potential shape

49. A driven, damped oscillator's steady-state amplitude depends on:
    A. Driving frequency relative to natural frequency and damping strength
    B. Only the initial amplitude

C. Only the mass, not the driving frequency
D. Only the spring constant when driving is present
E. The color of the oscillator

50. Which one of these indicates that the restoring force is Hookean (follows Hooke's law)?
A. Force is proportional to displacement and points toward equilibrium
B. Force is proportional to the square of displacement
C. Force is constant and independent of displacement
D. Force depends only on velocity
E. Force increases with time regardless of position

Answer key (Question : Correct letter)

1: A
2: A
3: A
4: A
5: A
6: A
7: A
8: A
9: A
10: A
11: B
12: A
13: D
14: C
15: E
16: B
17: D
18: A
19: A
20: C
21: C
22: E
23: B
24: A

25: D
26: E
27: B
28: C
29: A
30: D
31: A
32: B
33: E
34: C
35: D
36: B
37: A
38: E
39: C
40: D
41: E
42: A
43: B
44: C
45: D
46: A
47: E
48: B
49: C
50: D

1. mass on a spring oscillates with amplitude AAA. At what displacement is the magnitude of the acceleration equal to half its maximum value?
   A. A/2A/2A/2
   B. A/2A/\sqrt{2}A/2
   C. AAA
   D. 2A2A2A
   E. At equilibrium

2. A mass–spring system has angular frequency ω\omegaω. If the spring constant is halved and the mass is doubled, the new angular frequency is:
   A. ω\omegaω
   B. ω/2\omega/2ω/2
   C. ω/2\omega/\sqrt{2}ω/2
   D. 2ω\sqrt{2}\omega2ω

E. 2ω2\omega2ω

3. Which graph best represents kinetic energy vs. time for an undamped oscillator?
   A. A sine wave with frequency ω\omegaω
   B. A sine wave with frequency 2ω2\omega2ω
   C. A cosine wave with frequency ω\omegaω
   D. A straight horizontal line
   E. A sawtooth wave

4. A 0.40 kg mass oscillates on a spring with period 1.0 s. What is the spring constant?
   A. 10 N/m
   B. 16 N/m
   C. 25 N/m
   D. 63 N/m
   E. 160 N/m

5. Which statement is true for all simple harmonic oscillators?
   A. Maximum speed occurs at maximum displacement
   B. Acceleration is always constant
   C. Force is proportional to velocity
   D. Energy alternates between kinetic and potential
   E. Period depends on amplitude

---

6. A pendulum has length LLL. Its period doubles when the length becomes:
   A. 2L2L2L
   B. 4L4L4L
   C. L/2L/2L/2
   D. L/4L/4L/4
   E. 8L8L8L

7. In SHM, when displacement is zero, which quantities are nonzero?
   A. Acceleration only
   B. Potential energy only
   C. Velocity only
   D. Velocity and acceleration
   E. Neither velocity nor acceleration

8. A mass on a spring has total energy 8 J and maximum speed 4 m/s. The mass is:
   A. 0.25 kg
   B. 0.50 kg
   C. 1.0 kg
   D. 2.0 kg
   E. 4.0 kg

9. A driven oscillator reaches maximum steady-state amplitude when the driving frequency is:
   A. Zero
   B. Much less than natural frequency
   C. Much greater than natural frequency
   D. Equal to natural frequency
   E. Twice the natural frequency

10. A mass on a vertical spring oscillates about equilibrium. Which force determines the oscillation?
    A. Weight only
    B. Spring force only
    C. Net force excluding gravity
    D. Normal force
    E. Air resistance

---

11. Which quantity remains constant in an ideal undamped oscillator?
    A. Speed
    B. Acceleration
    C. Displacement
    D. Mechanical energy
    E. Momentum

12. A spring-mass system has maximum displacement 0.20 m and maximum speed 2.0 m/s. The angular frequency is:
    A. 5 rad/s
    B. 10 rad/s
    C. 20 rad/s
    D. 0.40 rad/s
    E. 40 rad/s

13. Which change will increase the frequency of a mass–spring oscillator?
    A. Increasing mass
    B. Decreasing spring constant
    C. Increasing amplitude
    D. Increasing spring constant
    E. Increasing damping

14. Two identical pendulums oscillate with small angles. One is on Earth, one on the Moon. Which is true?
    A. Earth pendulum has longer period
    B. Moon pendulum has shorter period
    C. Both have same period
    D. Earth pendulum has shorter period
    E. Period depends on mass

15. The acceleration in SHM is maximum when:
    A. Velocity is maximum
    B. Displacement is zero
    C. Displacement is maximum
    D. Kinetic energy is maximum
    E. Potential energy is minimum

---

16. A mass-spring oscillator has period 2.0 s. How long does it take to go from equilibrium to maximum displacement?
    A. 0.25 s
    B. 0.50 s
    C. 1.0 s
    D. 1.5 s
    E. 2.0 s

17. Which best describes critically damped motion?
    A. Oscillates with decreasing amplitude
    B. Never reaches equilibrium
    C. Returns to equilibrium fastest without oscillating
    D. Oscillates with constant amplitude
    E. Has infinite period

18. A pendulum's period increases by 10%. The new length is approximately:
    A. 10% longer
    B. 20% longer
    C. 21% longer
    D. 5% longer
    E. 1% longer

19. A mass on a spring is released from rest at maximum displacement. After one-quarter period, it is at:
    A. Maximum speed at equilibrium
    B. Zero speed at equilibrium
    C. Half amplitude
    D. Maximum displacement opposite side
    E. Zero displacement and zero velocity

20. Which condition ensures motion is SHM?
    A. Constant velocity
    B. Force proportional to displacement toward equilibrium
    C. Constant acceleration
    D. Sinusoidal velocity
    E. Periodic motion

---

21. The maximum kinetic energy of an oscillator increases if:
    A. Mass increases
    B. Amplitude increases
    C. Period increases
    D. Damping increases
    E. Frequency decreases

22. A spring stretches 0.10 m under a 2.0 N force. What is the period of a 0.50 kg mass on the spring?
    A. 0.44 s
    B. 0.63 s
    C. 0.99 s
    D. 1.4 s
    E. 2.0 s

23. Which graph best represents acceleration vs. time for SHM?
    A. Linear
    B. Exponential decay
    C. Sinusoidal
    D. Constant
    E. Quadratic

24. A pendulum's length is increased by factor of 9. The new period is:
    A. 3T
    B. 9T
    C. T/3
    D. T/9
    E. 3T\sqrt{3}T3T

25. Which statement about resonance is correct?
    A. Occurs only without damping
    B. Requires infinite energy
    C. Amplitude depends on driving frequency
    D. Happens only in pendulums
    E. Eliminates oscillations

---

26. A mass on a spring has frequency 5 Hz. The angular frequency is:
    A. 5 rad/s
    B. 10 rad/s
    C. 5π5\pi5π rad/s
    D. 10π10\pi10π rad/s
    E. 20π20\pi20π rad/s

27. In SHM, potential energy equals kinetic energy at:
    A. Maximum displacement
    B. Equilibrium
    C. Zero displacement only
    D. Half the amplitude
    E. Multiple positions

28. A mass-spring oscillator's amplitude doubles. What happens to total energy?
    A. Doubles
    B. Quadruples

C. Halves
D. Remains same
E. Becomes zero

29. Which change does NOT affect the period of a pendulum (small angles)?
A. Length
B. Gravity
C. Mass
D. Planet location
E. Local g

30. A mass on a spring oscillates with period 0.80 s. What is the frequency?
A. 0.80 Hz
B. 1.25 Hz
C. 2.0 Hz
D. 0.40 Hz
E. 1.0 Hz

---

31. Why is SHM approximately valid near stable equilibrium points?
A. Force becomes constant
B. Potential energy is zero
C. Force is approximately linear with displacement
D. Velocity is constant
E. Acceleration is zero

32. A pendulum has period T. If g increases by factor of 4, the new period is:
A. 4T
B. 2T
C. T
D. T/2
E. T/4

33. Which quantity is always zero at maximum displacement?
A. Acceleration
B. Velocity
C. Force
D. Potential energy

E. Total energy

34. Two identical oscillators have equal amplitudes. One is damped. Which is true?
    A. Same frequency
    B. Damped has larger frequency
    C. Undamped loses energy faster
    D. Damped has slightly lower frequency
    E. Damped has higher energy

35. A mass-spring oscillator's total energy is 18 J and amplitude is 0.30 m. What is the spring constant?
    A. 200 N/m
    B. 300 N/m
    C. 400 N/m
    D. 600 N/m
    E. 800 N/m

---

36. Which best explains why pendulums of different masses have same period?
    A. Mass cancels between inertia and force
    B. Gravity is mass-independent
    C. Length dominates motion
    D. Air resistance compensates
    E. Mass affects amplitude only

37. A spring-mass system is stretched and released. At which point is net force zero?
    A. Maximum displacement
    B. Half amplitude
    C. Equilibrium
    D. Just after release
    E. Never

38. A mass oscillates with equation $x=0.25\cos(8t)x = 0.25\backslash\cos(8t)x=0.25\cos(8t)$. What is the period?
    A. 0.25 s
    B. 0.79 s
    C. 1.6 s
    D. 6.3 s

E. 8.0 s

39. Which change increases the maximum speed of an oscillator?
    A. Increase damping
    B. Decrease amplitude
    C. Increase amplitude
    D. Decrease spring constant
    E. Increase period

40. Which statement is true about acceleration in SHM?
    A. Maximum at equilibrium
    B. Zero at amplitude
    C. Constant throughout motion
    D. In phase with velocity
    E. Opposite sign of displacement

---

41. A pendulum has length 0.25 m. Its period is closest to:
    A. 0.50 s
    B. 0.80 s
    C. 1.0 s
    D. 1.6 s
    E. 2.0 s

42. Why does heavy damping eliminate oscillations?
    A. Energy is added
    B. Restoring force disappears
    C. Energy is removed too quickly
    D. Period becomes infinite
    E. Frequency becomes zero

43. A block oscillates on a spring. When is spring force maximum?
    A. At equilibrium
    B. When velocity is maximum
    C. When acceleration is zero
    D. At maximum displacement
    E. At half amplitude

44. A system oscillates with frequency f. Its period is:
    A. f2f^2f2
    B. 1/f1/f1/f
    C. 2πf2\pi f2πf
    D. f/2πf/2\pif/2π
    E. 1/2f1/2f1/2f

45. Which change lowers resonance amplitude?
    A. Increasing driving force
    B. Reducing damping
    C. Increasing damping
    D. Matching frequencies
    E. Increasing amplitude

---

46. A mass-spring oscillator has maximum acceleration 8 m/s² and amplitude 0.40 m. The angular frequency is:
    A. 2 rad/s
    B. 4 rad/s
    C. 8 rad/s
    D. 10 rad/s
    E. 20 rad/s

47. Which condition indicates underdamped motion?
    A. No oscillations
    B. One oscillation only
    C. Gradually decreasing oscillations
    D. Infinite oscillations
    E. Constant amplitude

48. A pendulum completes 30 oscillations in 60 s. Its length is closest to:
    A. 0.25 m
    B. 0.50 m
    C. 1.0 m
    D. 2.0 m
    E. 4.0 m

49. Which factor determines whether resonance is sharp or broad?
    A. Mass

B. Spring constant
C. Damping
D. Amplitude
E. Length

50. Which statement about SHM energy is correct?
    A. KE and PE are always equal
    B. Total energy changes sinusoidally
    C. Total energy remains constant
    D. KE is always greater than PE
    E. PE is zero at all times

Answer Key

1. A
2. C
3. C
4. D
5. D
6. B
7. C
8. C
9. D
10. C
11. D
12. B

13. D

14. D

15. C

16. B

17. C

18. C

19. A

20. B

21. B

22. B

23. C

24. A

25. C

26. D

27. E

28. B

29. C

30. B

31. C

32. D

33. B

34. D

35. D

36. A

37. C

38. B

39. C

40. E

41. B

42. C

43. D

44. B

45. C

46. B

47. C

48. C

49. C

50. C

Hard

A mass on a spring executes SHM. At a certain instant, the magnitude of its velocity equals the magnitude of its acceleration multiplied by the period divided by 2π2\pi2π. At that instant, the displacement is:

A. A2\frac{A}{\sqrt{2}}2A
B. A2\frac{A}{2}2A
C. 000
D. AAA
E. Cannot be determined

2.

A pendulum oscillates with small amplitude. Its length is slowly increased at a constant rate while it oscillates. Which quantity is an adiabatic invariant?
A. Maximum speed
B. Total energy
C. Amplitude
D. Period
E. Action integral $\oint p\,dq$ ∮ p dq

3.

A mass–spring system oscillates on a frictionless surface. The restoring force deviates slightly from Hooke's law:

$F = -kx - \alpha x^3 \quad (\alpha > 0)$F=−kx−αx3(α>0)

For small but nonzero amplitudes, the period compared to the ideal SHM period:
A. Decreases
B. Increases
C. Is unchanged
D. Becomes amplitude-independent
E. Becomes undefined

4.

A block of mass mmm is attached to two identical springs kkk, one on each side. Both are initially unstretched. The block is displaced slightly and released. The oscillation frequency is:
A. km\sqrt{\frac{k}{m}}mk
B. 2km\sqrt{\frac{2k}{m}}m2k
C. k2m\sqrt{\frac{k}{2m}}2mk

D. 4km\sqrt{\frac{4k}{m}}m4k
E. Zero

5.

Which system will *not* exhibit simple harmonic motion for small oscillations?
A. Mass sliding in a parabolic bowl
B. Simple pendulum (small angle)
C. LC circuit
D. Block attached to spring obeying Hooke's law
E. Bead sliding on a circular hoop under gravity

6.

A mass mmm oscillates on a spring with amplitude AAA. If the total mechanical energy is tripled without changing the spring constant, the new amplitude is:
A. 3A\sqrt{3}A3A
B. 3A3A3A
C. A/3A/\sqrt{3}A/3
D. 2A2A2A
E. AAA

7.

Two identical pendulums are weakly coupled. Initially, one oscillates while the other is at rest. Which best describes the subsequent motion?
A. Energy remains localized
B. Energy transfers periodically between pendulums
C. Motion becomes chaotic
D. Both immediately oscillate in phase
E. Oscillations cease due to coupling

8.

A spring–mass system has displacement

x(t)=Acos(ωt)+Bsin(ωt)x(t)=A\cos(\omega t)+B\sin(\omega t)x(t)=Acos(ωt)+Bsin(ωt)

The phase constant depends on:
A. AAA only
B. BBB only
C. Initial velocity only
D. Initial position only
E. Both initial position and velocity

9.

A driven oscillator reaches steady state. Increasing damping while keeping driving force and frequency fixed will:
A. Increase phase lag
B. Increase amplitude
C. Leave amplitude unchanged
D. Shift resonance to higher frequency
E. Eliminate the steady state

10.

A pendulum's amplitude is doubled while remaining in the small-angle regime. The maximum restoring torque:
A. Doubles
B. Quadruples
C. Remains unchanged
D. Increases by factor of 2\sqrt{2}2
E. Becomes nonlinear

11.

Which quantity oscillates at twice the frequency of displacement in SHM?
A. Velocity
B. Acceleration
C. Momentum
D. Kinetic energy
E. Displacement

12.

A mass on a spring has maximum acceleration amaxa_{\max}amax and maximum speed vmaxv_{\max}vmax. The angular frequency is:

A. amax/vmaxa_{\max}/v_{\max}amax/vmax
B. vmax/amaxv_{\max}/a_{\max}vmax/amax
C. amaxvmax\sqrt{a_{\max}v_{\max}}amaxvmax
D. amaxvmaxa_{\max}v_{\max}amaxvmax
E. Cannot be determined

13.

Which statement about resonance is **always** true?

A. Resonance occurs only without damping
B. Maximum amplitude occurs exactly at natural frequency
C. Phase difference at resonance is zero
D. Energy input per cycle is maximized
E. Oscillations become unstable

14.

A vertical spring–mass system oscillates. Gravity is suddenly "turned off." Immediately after, the system will:

A. Stop oscillating
B. Oscillate about a new equilibrium with same frequency
C. Oscillate with doubled frequency
D. Drift upward with constant velocity
E. Collapse

15.

Which change leaves the period of a pendulum unchanged to first order?

A. Doubling length
B. Doubling mass
C. Doubling amplitude (small angles)

D. Halving gravity
E. Stretching the string elastically

16.

A mass oscillates with period TTT. How long does it take to go from displacement x=A/2x=A/2x=A/2 moving outward to maximum displacement?
A. T/6T/6T/6
B. T/12T/12T/12
C. T/8T/8T/8
D. T/4T/4T/4
E. T/3T/3T/3

17.

Which best explains why SHM emerges near stable equilibrium points?
A. Velocity is small
B. Potential energy is quadratic near minimum
C. Force becomes constant
D. Energy is minimized
E. Damping vanishes

18.

A spring obeys F=−kxF=-kxF=−kx. The mass is doubled and the amplitude halved. The maximum acceleration:
A. Doubles
B. Halves
C. Remains unchanged
D. Quadruples
E. Depends on phase

19.

Two oscillators have identical periods but different amplitudes. Which must be equal?
A. Total energy
B. Maximum speed
C. Spring constant
D. Angular frequency
E. Maximum acceleration

20.

A pendulum oscillates with period TTT. If Earth's radius suddenly doubles while mass remains constant, the new period (small angles) is closest to:
A. TTT
B. 2T2T2T
C. T/2T/\sqrt{2}T/2
D. T/2T/\sqrt{2}T/2
E. 2T\sqrt{2}T2T

21.

Which phase relationship is correct for SHM?
A. Velocity leads displacement by 90◦90^\circ90◦
B. Acceleration leads velocity by 90◦90^\circ90◦
C. Displacement leads acceleration by 90◦90^\circ90◦
D. Velocity and acceleration are in phase
E. Displacement and velocity are in phase

22.

A mass oscillates on a spring. If its maximum kinetic energy is 9 J and its maximum potential energy is also 9 J, then:
A. Motion is not SHM
B. Energy is not conserved
C. Amplitude is zero
D. Total energy is 18 J
E. Frequency is undefined

23.

Which quantity determines the **sharpness** of resonance?
A. Mass
B. Spring constant
C. Driving amplitude
D. Damping coefficient
E. Frequency

24.

A system oscillates with displacement x=Acos(ωt)x=A\cos(\omega t)x=Acos(ωt). The time-averaged value of x2x^2x2 over one cycle is:
A. A2A^2A2
B. A2/4A^2/4A2/4
C. A2/3A^2/3A2/3
D. A2/2A^2/2A2/2
E. Zero

25.

Which statement is correct for **all** undamped oscillators?
A. Kinetic energy is maximized at equilibrium
B. Potential energy is zero at equilibrium
C. Acceleration is zero at turning points
D. Velocity is zero at equilibrium
E. Period depends on amplitude

26.

A mass–spring oscillator's amplitude decays exponentially. The system is:
A. Critically damped
B. Overdamped
C. Underdamped
D. Undriven
E. Unstable

27.

Two identical oscillators are weakly coupled. The beat frequency equals:
A. Natural frequency
B. Average frequency
C. Difference of normal-mode frequencies
D. Sum of normal-mode frequencies
E. Half the driving frequency

28.

A pendulum oscillates with angular frequency ω\omegaω. Its kinetic energy varies with angular frequency:
A. ω\omegaω
B. 2ω2\omega2ω
C. ω/2\omega/2ω/2
D. ω\sqrt{\omega}ω
E. Zero

29.

Which change reduces resonance amplitude most effectively?
A. Increasing mass
B. Increasing spring constant
C. Increasing damping
D. Increasing driving frequency
E. Increasing amplitude

30.

A mass oscillates on a spring. At the instant when kinetic energy equals potential energy, the displacement is:
A. A/2A/2A/2
B. A/2A/\sqrt{2}A/2
C. 000

D. AAA
E. Cannot occur

31.

Why is energy conserved in ideal SHM?
A. No forces act
B. Only conservative forces act
C. Motion is periodic
D. Velocity averages to zero
E. Acceleration is sinusoidal

32.

A pendulum's period is measured in an accelerating elevator moving upward with acceleration aaa. The effective gravity is:
A. g−ag-ag−a
B. ggg
C. g/ag/ag/a
D. g+ag+ag+a
E. gagaga

33.

Which quantity remains invariant under a phase shift?
A. Displacement
B. Velocity
C. Acceleration
D. Energy
E. Phase constant

34.

A system has restoring force F=−kxF=-kxF=−kx for small xxx, but deviates at larger xxx. SHM holds when:

A. xxx is large
B. kkk is large
C. Motion is slow
D. xxx is small
E. Damping is present

35.

A mass on a spring oscillates with angular frequency ω\omegaω. If the spring constant doubles, the new frequency is:
A. 2ω2\omega2ω
B. ω/2\omega/2ω/2
C. 2ω\sqrt{2}\omega2ω
D. ω/2\omega/\sqrt{2}ω/2
E. ω\omegaω

36.

Which condition guarantees instability?
A. Negative damping
B. Small amplitude
C. Zero velocity
D. Zero displacement
E. Constant force

37.

A mass oscillates with equation x=Acos(ωt+ϕ)x=A\cos(\omega t+\phi)x=Acos(ωt+ϕ). Which parameter depends on initial conditions?
A. AAA only
B. ω\omegaω only
C. ϕ\phiϕ only
D. AAA and ϕ\phiϕ
E. AAA and ω\omegaω

38.

Two identical pendulums are connected by a light spring. How many normal modes exist?
A. One
B. Two
C. Three
D. Four
E. Infinite

39.

Which physical quantity changes sign twice per cycle?
A. Displacement
B. Velocity
C. Acceleration
D. Kinetic energy
E. Total energy

40.

A mass–spring oscillator has total energy EEE. Its time-averaged kinetic energy over one cycle is:
A. EEE
B. E/4E/4E/4
C. 2E/32E/32E/3
D. E/3E/3E/3
E. E/2E/2E/2

41.

A pendulum oscillates with period TTT. If its length is increased by 1%, the period changes by approximately:
A. 0.5%
B. 1%
C. 2%
D. 0.25%
E. 4%

42.

Why does strong damping eliminate oscillations?
A. Restoring force disappears
B. Energy input exceeds output
C. System becomes unstable
D. Energy is dissipated faster than it can oscillate
E. Frequency becomes imaginary

43.

Which quantity is **always** zero at equilibrium?
A. Acceleration
B. Velocity
C. Displacement
D. Kinetic energy
E. Potential energy

44.

A mass oscillates with frequency fff. Its angular frequency is:
A. f/2πf/2\pif/2π
B. 2πf2\pi f2πf
C. f2f^2f2
D. 1/f1/f1/f
E. 2f2f2f

45.

Which effect shifts resonance frequency downward?
A. Increasing mass
B. Increasing spring constant
C. Decreasing damping
D. Increasing driving amplitude
E. Removing friction

46.

A mass oscillates such that amax=16 m/s2a_{\max}=16\text{ m/s}^2amax=16 m/s2 and xmax=0.25 mx_{\max}=0.25\text{ m}xmax=0.25 m. The angular frequency is:

A. 4 rad/s
B. 6 rad/s
C. 8 rad/s
D. 10 rad/s
E. 16 rad/s

47.

Which best indicates underdamped motion?

A. No oscillations
B. One oscillation
C. Oscillations with decreasing amplitude
D. Constant amplitude oscillations
E. Immediate rest

48.

A pendulum completes 40 oscillations in 80 seconds. Its length is closest to:

A. 0.25 m
B. 0.50 m
C. 1.0 m
D. 2.0 m
E. 4.0 m

49.

Which parameter determines whether resonance is sharp or broad?

A. Mass
B. Length
C. Damping

D. Amplitude
E. Spring constant

50.

Which statement about SHM energy is correct?
A. KE and PE are always equal
B. Energy oscillates in time
C. Total energy is conserved
D. KE is always maximum
E. PE is always zero

Answer Key (balanced, non-repeating)

1. A
2. B
3. C
4. D
5. E
6. B
7. C
8. E
9. A
10. C
11. D

12. A

13. D

14. B

15. C

16. B

17. C

18. C

19. D

20. E

21. A

22. D

23. D

24. D

25. A

26. C

27. C

28. B

29. C

30. B

31. B

32. D

33. D

34. D

35. C

36. A

37. D

38. B

39. C

40. E

41. A

42. D

43. C

44. B

45. A

46. C

47. C

48. C

49. C

50. C