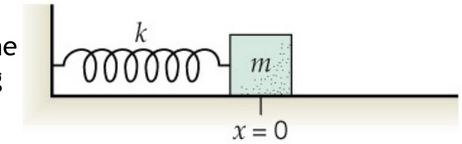
Exam I: Solution

The block shown right has a mass m. It is attached to a spring with a constant k. The spring is at unstretched equilibrium when $x = 0$. Assume a coordinate system in which to the right is the +x direction. The spring is **compressed** to $x = -A$ from its equilibrium position and the system is released from rest. Answer Questions 1–6 using this information.



1. At the instant of release, the force exerted on the block by the spring is
   A) positive. B) negative. C) zero.

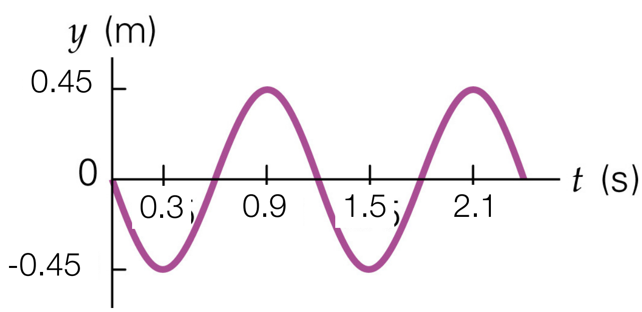
2. In what position(s) will the block be when the magnitude of the force on it is **maximum**?
   A) x = 0. B) x = ±½A. **C) x = ±A.**

3. As the block moves from position **x = -A** to position **x = 0**, what happens to its **velocity** and **acceleration**?
   A) The speed of the block never changes: v = A√[k/m], so the acceleration is zero.
   B) The velocity increases (to the right), while the acceleration remains constant (and non-zero).
   C) The velocity increases (to the right). The acceleration does not remain constant, it also increases (to the right).
   D) The velocity increases (direction is still to the right). The acceleration is not constant, it decreases (smaller magnitude, direction = right).
   E) Velocity decreases (direction = left), but the acceleration increases (magnitude increases, direction = right).

4. Let's talk about the **potential energy** of the system.
   A) The potential energy of the system is zero because it was released from rest.
   B) The potential energy varies. It is maximum at x=+A, zero at x=0, and minimum at x=-A.
   C) The potential energy is not constant, but not minimum at x=-A, either. U = maximum at x=±A, U=0 at x=0.
   D) The potential energy is maximum when the kinetic energy is minimum. This occurs when x = 0, and K = 0.
   E) The potential energy is constant, because the speed of the block is constant: energy is evenly split between kinetic and potential at any location of the oscillation.

5. Here's a *new* trick question about the energy. If you *decrease* the amplitude of the oscillation, releasing the block from rest at **x = —½A**, what happens to the system energy?
   A) The total energy of the oscillation is doubled.
   B) The system energy is decreased by a factor of two.
   C) The potential energy is halved, but the kinetic energy remains the same.
   D) The total energy of the system decreases: half the amplitude, ¼ the energy.
   E) The energy remains constant. Unless you change the mass or the spring itself, the system energy does not change.

6. This particular oscillation has a frequency of 40Hz. To *decrease* the frequency to exactly 20Hz, you should
   A) add mass. Replace the original mass m with a new one having exactly 2m.
   B) remove mass. Using ¼ as much mass will halve the original frequency.
   C) replace the spring with one having a smaller constant k. Half the k, half the frequency.
   D) using a smaller spring constant will decrease the frequency, but ¼ the k means ½ the frequency.
   E) adjust the amplitude of the oscillation. Doubling the amplitude will decrease the frequency by a factor of 2.



On the left is a graph illustrating the vertical oscillation of a 1 kg mass attached to a spring. Assume that up is the positive direction, and down is the negative direction.

7. What is the **amplitude** of this oscillation? Answer with two sig figs.

$$A = 0.45\text{m}$$

8. What is the **frequency**? Answer with two sig figs.

$$f = \frac{1}{T} = \frac{1}{1.2s} = 0.83\text{Hz}$$

9. At what point in time is the **velocity** of the mass exactly **zero**?
   A) t = 0s. B) t = 0.6s. C) t = 1.2s. D) t = 1.8s. **E) t = 2.1s**

10. At t = 0.6s, the mass's position and velocity are the same as at
    A) t = 0s. B) t = 0.3s. C) t = 1.2s. **D) t = 1.8s.** E) t = 2.1s.

11. The position of the mass will be described by the equation:
    1) y = (045m)cos[5.24t]
    2) y = (0.45m)sin[5.24πt]
    3) y = —(0.45m)cos[5.24t]
    4) y = —(0.45m)sin[5.24t]
    5) y = —(0.90m)cos[10.5t]
    6) y = —(0.90m)sin[10.5t]

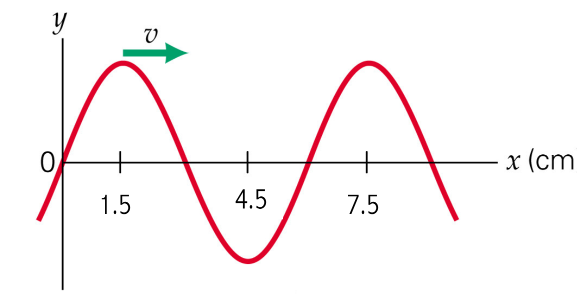
12. The velocity and acceleration of the mass will be described by the equations:
   A) v = −(2.36m)cos[5.24t]
   a = +(12.3m)sin[5.24t]
   B) v = +(9.42m)cos[10.5t]
   a = −(98.7m)sin[10.5t]
   C) v = −(2.36m)cos[5.24t]
   a = −(12.3m)sin[5.24t]

13. An oscillation can be described mathematically by $y = (0.10\text{m})\cos(100t)$. What is the **period** of this oscillation? Answer with two sig figs.

$$100 = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{100} = 0.063\text{s}$$

14. True or false: As a wave propagates through a medium, the molecules of the medium travel along with the wave parallel to the direction of propagation.

15. Compare the direction of *oscillation* to the direction of *propagation* for the wave represented on the right.
   A) Oscillation and propagation are both in the x-direction.
   B) Oscillation and propagation are both in the y-direction.
   C) Oscillation and propagation are both in the z-direction.
   D) Oscillation occurs in the y-direction, propagation occurs in the x-direction.
   E) Oscillation occurs in the x-direction, propagation occurs in the y-direction.



16. The wave described by the graphs is a
   A) transverse wave.
   B) longitudinal wave.
   C) converse wave.
   D) latitudinal wave.

17. What is the **amplitude** in cm of this wave? Two sig figs.

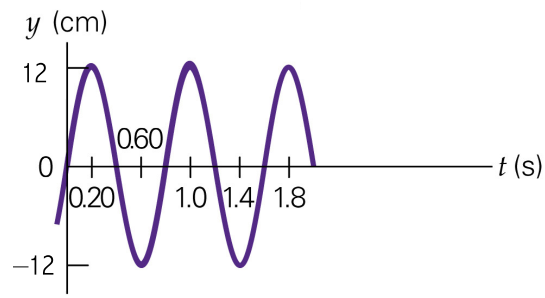
$$A = 12\text{cm}$$

18. What is the **wavelength in cm**? Two sig figs.

$$\lambda = 6.0\text{cm}$$

19. What is the wave **speed in cm/s**? Answer with two sig figs.

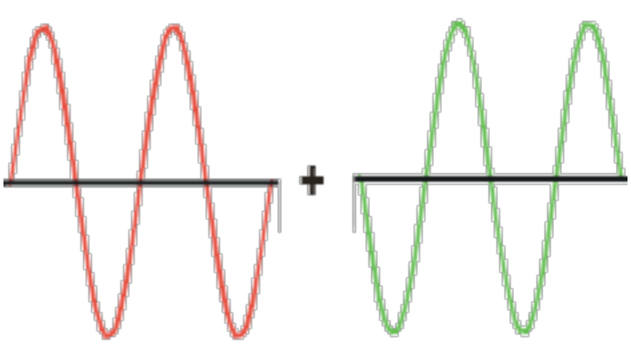
$$v = \frac{\lambda}{T} = \frac{6.0\text{cm}}{0.8\text{s}} = 7.5\,\frac{\text{cm}}{\text{s}}$$



20. A longitudinal wave
   A) occurs when the direction of oscillation is parallel to the direction of travel.
   B) occurs when the direction of oscillation is perpendicular to the direction of travel.
   C) only exists in theory; there are no longitudinal waves actually found naturally.
   D) is identical to a transverse wave. If the medium is solid, the wave is called longitudinal. In a fluid medium, it's called a transverse wave.

21. The crests of a transverse wave are analogous to the
   A) amplitude of a longitudinal wave.
   B) compressions of a longitudinal wave.
   C) wavelengths of a longitudinal wave.
   D) rarefactions of a longitudinal wave.

22. Compare the density of the medium in regions of compression and rarefaction.
   A) Why? Because longitudinal waves only travel through solids, the density remains constant in all regions.
   B) A rarefaction is a region where the density is unchanged. Compressions may have higher or lower density, just not the same density as a rarefaction.
   C) Compressions are denser regions than rarefactions, but both are denser than node regions.
   D) A compression is a region of *reduced* density, a rarefaction has *greater* density.
   E) A compression has greater density than a node. A rarefaction is a region of lower density than a node.



23. The superposition principle is based on the idea that
   A) a wave propagates by superimposing a propagation over an oscillation. The result is that the wave medium moves right along with the energy.
   B) two particles can occupy the same space at the same time. They superimpose to result in a new particle having the combined mass: $m = m_1 + m_2$.
   C) two waves can occupy the same space at the same time. They superimpose to result in a new wave having the combined amplitude: $A = A_1 + A_2$.
   D) two waves cannot occupy the same space at the same time. Neither can two particles. Which must mean that there really isn't any superposition of matter or energy. What a crazy universe we live in!

24. The to waves shown above will interfere
 A) constructively. B) destructively. C) impulsively. D) satirically.

25. If two waves interfere constructively, by how much should you shift the phase of one of the waves to preserve the complete constructive reinforcement when the waves are superimposed?
 A) Any phase shift will create destructive cancellation.
 B) π/2, or ¼ wavelength.
 C) π, or ½ wavelength.
 D) 3π/2, or ¾ wavelength.
 E) 2π, or one whole λ.

A steel guitar string is **75cm** long, with diameter **0.05cm** and mass **12g**. The fundamental frequency is **320 Hz**.

26. What are the **wavelengths** of the first three harmonic resonances?
 A) 2.25m, 1.5 m, and 0.75m
 B) 1.5m, 0.75m, and 0.375m
 C) 1.5m, 0.75m, and 0.50m
 D) 0.75m, 0.375m, and 0.25m
 E) 0.75m, 0.50m, and 0.25m

27. How **fast** (m/s) will a wave having the fundamental frequency propagate along the string? Answer with **three** sig figs.

$$v = \lambda f = (1.5\text{m})(320\text{Hz}) = 480\,\tfrac{\text{m}}{\text{s}}$$

You replace the string with a **thicker** one having the same length, but a **greater** mass density. It is adjusted to the same tension as the last string.

28. True or false: The new string will have a lower fundamental frequency than the previous string.

29. True or false: The fundamental wave will travel more slowly through the thicker string than the thinner string.

30. To increase the fundamental frequency of the string,
 A) increase the tension. B) decrease the tension.

31. Sound waves may have both longitudinal and transverse components when propagating
 A) through a low density medium like air.
 B) through a fluid medium like water.
 C) through a solid medium like steel.
 D) through vacuum.

32. A sound wave has a frequency **f = 18kHz** and an intensity **I =10^{-12}W/m^2**.
 A) This sound is perfectly audible to human ears. It's definitely going to be loud, though.
 B) This sound is probably just barely audible to you. The frequency is almost as high as human ears can hear,and the intensity is at the threshold of hearing. You could just hear it, but it would not be loud or penetrating.
 C) This sound is not audible because the frequency is far above the limit of human sensitivity. This is like the sound that bats emit when they are screaming at insects, using echolocation to find flying food.
 D) The sound in inaudible because the intensity is too low. The frequency is in the range of human sensitivity, but there is simply not enough energy to hear anything.
 E) It's not possible to determine whether this could be heard. You would need to know how fast the sound was traveling (through air or water or whatever) in order to calculate if it was audible or not.

33. True or false: For a sound wave propagating through the atmosphere, cold air is faster than warm air.

34. True or false: For a sound wave propagating through the atmosphere, humid air is faster than dry air.

35. Two sound waves travel through air at **20˚C**. The second wave has **half** the wavelength of the first.
 A) Its speed is half the speed of the original wave. The frequency is the same for both waves.
 B) Its speed is twice the speed of the original wave. Its frequency is twice the original frequency.
 C) Both waves have the same frequency and speed. The frequency is independent of wavelength.
 D) Its frequency is half the frequency of the original wave. The speed is the same for both waves.
 E) Its frequency is twice the frequency of the original wave. Its speed is the same as the original speed.

A **512Hz** tuning fork is struck inside the lab (**22˚C**). Outdoors, the temperature is **19˚C**.

$$v = 331 + 0.6T$$

$$v_{in} = 331 + 0.6(22°\text{C}) = 344\,\tfrac{\text{m}}{\text{s}}$$

$$v_{out} = 331 + 0.6(19°\text{C}) = 342\,\tfrac{\text{m}}{\text{s}}$$

36. True or false: Striking the fork will create a sound wave that travels at 331 m/s, either inside or outside.

37. True or false: Striking the fork outside will create a higher frequency sound (compared to striking it inside).

38. True or false: Striking the fork outside will create a shorter wavelength (compared to striking it inside).

39. Compare the speed of sound through brass to the speed of sound through air.
 A) Air is about the fastest medium through which sound propagates (only vacuum is faster). Sound travels roughly ten times faster through air than through brass.
 B) Brass is a very fast medium compared to air. Sound travels approximately ten times faster through brass than air.
 C) Brass is faster, but no way is it a factor of ten. It's more like a factor of three faster than air.
 D) The speed of sound is constant for all media: v = [331 + 0.6T]m/s. The composition of the medium is simply not relevant. If the air and brass have the same temperature, they have the same speed.
 E) The speed of sound is not constant for all media, but by coincidence brass and air have almost identical speeds.

40. Two solid materials have the same density, but sound does not propagate at the same speed through both media.
   A) **The faster medium would have greater elasticity, and therefore greater Young's modulus.**
   B) The faster medium would have less elasticity, and a correspondingly smaller Young's modulus.
   C) This is not possible. If the densities match, then sound will propagate at the same speed through either.

41. The intensity of a sound is exactly **4 W/m²** at a distance of **12m**. At **3m**, the intensity will be
   A) 0.25 W/m² B) 1 W/m² C) 4 W/m² D) 12 W/m² **E) 64 W/m²**

42. You perceive that sound B is twice as loud as sound A. What is the difference in the intensity of these?
   A) B has half the intensity of A.
   B) B must have ¼ the intensity of A.
   C) Twice the loudness implies twice the intensity.
   D) Twice the loudness means the intensity is four times greater.
   E) **A doubling of the loudness means an order of magnitude, or factor of 10, increase in intensity.**

43. Doubling the absolute intensity of a sound results in an intensity level increase of
   A) 1 dB B) 2 dB **C) 3 dB** D) 5 dB E) 10 dB

44. **True** or false: A typical conversation (where no one is shouting about politics or anything) has an intensity level of about 60dB.

45. A sound has an intensity **I = 10^{-7}W/m²**. How many **decibels** is this? Answer with two sig figs.

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{10^{-7}}{10^{-12}}\right) = 10\log\left(10^{5}\right) = 10(5) = 50$$