Phys 2050 HOMEWORK

Chapter 15- Oscillatory motion:

Hand in on Thursday: # 4, 6

Prepare the following problems. We will solve some of them IN CLASS: #5, 19

Scroll down to see the list of problems for Chapt15

Chapter 13:

Hand in on Thursday: # 4, 10, 14

Prepare the following problems. We will solve some of them IN CLASS: #1, 13, 18, 27, 29

Scroll down to see the list of problems for Chapt13

Chapter 12: short week due to Thanksgiving break.

NO Hand in work on Thursday

Prepare the following problems. We will solve some of them IN CLASS: #1, 8, 10

Scroll down to see the list of problems for Chapt12

Chapter 11 homework

Hand in on Thursday: # 4, 12, 26

Prepare also the following problems we will solve some of them IN CLASS: #1, 7, 11, 23

Scroll down to see the list of problems for Chapt11

Chapter 10 homework

Hand in on Thursday: # 13, 44

Prepare also the following problems we will solve some of them IN CLASS: # 9, 25, 40, 41

Scroll down to see the list of problems for Chapt10

Chapter 9 homework
Hand in on Thursday: # 18,32,37

Prepare also the following problems we will solve some of them IN CLASS: # 14,28,33,41,55

Scroll down to see the list of problems for Chapt 9

---

Chapter 8 homework

Hand in on Thursday: # 10,22

Prepare also the following problems we will solve some of them IN CLASS: # 5, 24, 23

We will go over Chapt 7 homework pbs on Monday and start Chapt 8. Scroll down to see the list of problems for Chapt 8

---

Chapter 7 homework

Hand in on Thursday: # 28, 32,42

Prepare also the following problems we will solve some of them IN CLASS: # 1,11,15,17, 31,33, 49.

---

Chapter 6 homework

Hand in on Thursday: # 4,16

Prepare also the following problems we will solve IN CLASS: # 17, 18

---

Chapter 5 homework

Hand in on Thursday: # 24,25,30

Prepare also the following problems we will solve IN CLASS: # 1,16,33,39,43 Scroll to the next page to see the list of problems for Chapt 5

---

Chapter 4 homework

Hand in on Thursday: # 10,13, 16,30
Prepare also the following problems we will solve IN CLASS: \(3, 7, 15, 19, 31, 32\)

Scroll to the next page to see the list of problems for Chapt 4

---

**Chapter 3 homework**

**Hand in on Thursday: \# 22, 32, 36**

Prepare also the following problems we will solve IN CLASS: \# 2, 7, 27, 28, 31.

---

**Chapter 2 homework**

**Hand in on Thursday: \# 10, 12, 22, 40**

In class we will work through some of the following problems: \#1, 8, 9, 14, 25, 42

Scroll down to the next pages to see the problems.

---

**Chapter 1 Homework**

Problems: \# 1, 9, 10, 18, 24, 27, 32, 34

This is the only homework that will not be picked/graded because it is the start of the semester.
not, give an example of a real vibration that keeps constant amplitude forever if the system is isolated.

7. The mechanical energy of an undamped block–spring system is constant as kinetic energy transforms to elastic potential energy and vice versa. For comparison, explain what happens to the energy of a damped oscillator in terms of the mechanical, potential, and kinetic energies.

8. Is it possible to have damped oscillations when a system is at resonance? Explain.

9. Will damped oscillations occur for any values of $b$ and $k$? Explain.

10. If a pendulum clock keeps perfect time at the base of a mountain, will it also keep perfect time when it is moved to the top of the mountain? Explain.

11. You are looking at a small, leafy tree. You do not notice any breeze, and most of the leaves on the tree are motionless. One leaf, however, is fluttering back and forth wildly. After a while, that leaf stops moving and you notice a different leaf moving much more than all the others. Explain what could cause the large motion of one particular leaf.

### Problems

**Section 15.1 Motion of an Object Attached to a Spring**

Problems 16, 17, 18, 22, and 65 in Chapter 7 can also be assigned with this section.

1. A 0.60-kg block attached to a spring with force constant 130 N/m is free to move on a frictionless, horizontal surface as in Active Figure 15.1. The block is released from rest when the spring is stretched 0.13 m. At the instant the block is released, find (a) the force on the block and (b) its acceleration.

2. When a 4.25-kg object is placed on top of a vertical spring, the spring compresses a distance of 2.62 cm. What is the force constant of the spring?

**Section 15.2 Analysis Model: Particle in Simple Harmonic Motion**

3. A vertical spring stretches 3.9 cm when a 10-g object is hung from it. The object is replaced with a block of mass 25 g that oscillates up and down in simple harmonic motion. Calculate the period of motion.

4. In an engine, a piston oscillates with simple harmonic motion so that its position varies according to the expression $x = 5.00 \cos \left( \frac{2t + \pi}{6} \right)$ where $x$ is in centimeters and $t$ is in seconds. At $t = 0$, find (a) the position of the particle, (b) its velocity, and (c) its acceleration. Find (d) the period and (e) the amplitude of the motion.

5. The position of a particle is given by the expression $x = 4.00 \cos (3.00\pi t + \pi)$, where $x$ is in meters and $t$ is in seconds. Determine (a) the frequency and (b) period of the motion, (c) the amplitude of the motion, (d) the phase constant, and (e) the position of the particle at $t = 0.250$ s.

6. A piston in a gasoline engine is in simple harmonic motion. The engine is running at the rate of 3 600 rev/min. Taking the extremes of its position relative to its center point as $\pm 5.00$ cm, find the magnitudes of the (a) maximum velocity and (b) maximum acceleration of the piston.

7. A 1.00-kg object is attached to a horizontal spring. The spring is initially stretched by 0.100 m, and the object is released from rest there. It proceeds to move without friction. The next time the speed of the object is zero is 0.500 s later. What is the maximum speed of the object?

8. A simple harmonic oscillator takes 12.0 s to undergo five complete vibrations. Find (a) the period of its motion, (b) the frequency in hertz, and (c) the angular frequency in radians per second.
9. A 7.00-kg object is hung from the bottom end of a vertical spring fastened to an overhead beam. The object is set into vertical oscillations having a period of 2.60 s. Find the force constant of the spring.

10. **Q.C** (a) A hanging spring stretches by 35.0 cm when an object of mass 450 g is hung on it at rest. The object is pulled down an additional 18.0 cm and released from rest to oscillate without friction. What is its position at a moment 84.4 s later? (b) Find the distance traveled by the vibrating object in part (a). (c) **What If?** Another hanging spring stretches by 35.5 cm when an object of mass 440 g is hung on it at rest. We define this new position as \( x = 0 \). This object is also pulled down an additional 18.0 cm and released from rest to oscillate without friction. Find its position 84.4 s later. (d) Find the distance traveled by the object in part (c). (e) Why are the answers to parts (a) and (c) so different when the initial data in parts (a) and (c) are so similar and the answers to parts (b) and (d) are relatively close? Does this circumstance reveal a fundamental difficulty in calculating the future?

11. **Review.** A particle moves along the \( x \) axis. It is initially at the position \( 0.270 \) m, moving with velocity \( 0.140 \) m/s and acceleration \(-0.320 \) m/s\(^2\). Suppose it moves as a particle under constant acceleration for 4.50 s. Find (a) its position and (b) its velocity at the end of this time interval. Next, assume it moves as a particle in simple harmonic motion for 4.50 s and \( x = 0 \) is its equilibrium position. Find (c) its position and (d) its velocity at the end of this time interval.

12. **Q.C** A ball dropped from a height of 4.00 m makes an elastic collision with the ground. Assuming no mechanical energy is lost due to air resistance, (a) show that the ensuing motion is periodic and (b) determine the period of the motion. (c) Is the motion simple harmonic? Explain.

13. A particle moving along the \( x \) axis in simple harmonic motion starts from its equilibrium position, the origin, at \( t = 0 \) and moves to the right. The amplitude of its motion is 2.00 cm, and the frequency is 1.50 Hz. (a) Find an expression for the position of the particle as a function of time. Determine (b) the maximum speed of the particle and (c) the earliest time \( (t > 0) \) at which the particle has this speed. Find (d) the maximum positive acceleration of the particle and (e) the earliest time \( (t > 0) \) at which the particle has this acceleration. (f) Find the total distance traveled by the particle between \( t = 0 \) and \( t = 1.00 \) s.

14. A 1.00-kg glider attached to a spring with a force constant of 25.0 N/m oscillates on a frictionless, horizontal air track. At \( t = 0 \), the glider is released from rest at \( x = -3.00 \) cm (that is, the spring is compressed by 3.00 cm). Find (a) the period of the glider’s motion, (b) the maximum values of its speed and acceleration, and (c) the position, velocity, and acceleration as functions of time.

15. A 0.500-kg object attached to a spring with a force constant of 8.00 N/m vibrates in simple harmonic motion with an amplitude of 10.0 cm. Calculate the maximum value of its (a) speed and (b) acceleration, (c) the speed and (d) the acceleration when the object is 6.00 cm from the equilibrium position, and (e) the time interval required for the object to move from \( x = 0 \) to \( x = 8.00 \) cm.

16. **Q.C** You attach an object to the bottom end of a hanging vertical spring. It hangs at rest after extending the spring 18.3 cm. You then set the object vibrating. (a) Do you have enough information to find its period? (b) Explain your answer and state whatever you can about its period.

### Section 15.3 Energy of the Simple Harmonic Oscillator

17. **M** To test the resiliency of its bumper during low-speed collisions, a 1 000-kg automobile is driven into a brick wall. The car’s bumper behaves like a spring with a force constant \( 5.00 \times 10^5 \) N/m and compresses 3.16 cm as the car is brought to rest. What was the speed of the car before impact, assuming no mechanical energy is transformed or transferred away during impact with the wall?

18. A 200-g block is attached to a horizontal spring and executes simple harmonic motion with a period of 0.250 s. The total energy of the system is 2.00 J. Find (a) the force constant of the spring and (b) the amplitude of the motion.

19. A 50.0-g object connected to a spring with a force constant of 35.0 N/m oscillates with an amplitude of 4.00 cm on a frictionless, horizontal surface. Find (a) the total energy of the system and (b) the speed of the object when its position is 1.00 cm. Find (c) the kinetic energy and (d) the potential energy when its position is 3.00 cm.

20. A 2.00-kg object is attached to a spring and placed on a frictionless, horizontal surface. A horizontal force of 20.0 N is required to hold the object at rest when it is pulled 0.200 m from its equilibrium position (the origin of the \( x \) axis). The object is now released from rest from this stretched position, and it subsequently undergoes simple harmonic oscillations. Find (a) the force constant of the spring, (b) the frequency of the oscillations, and (c) the maximum speed of the object. (d) Where does this maximum speed occur? (e) Find the maximum acceleration of the object. (f) Where does the maximum acceleration occur? (g) Find the total energy of the oscillating system. Find (h) the speed and (i) the acceleration of the object when its position is equal to one-third the maximum value.

21. **Q.C** A simple harmonic oscillator of amplitude \( A \) has a total energy \( E \). Determine (a) the kinetic energy and (b) the potential energy when the position is one-third the amplitude. (c) For what values of the position does the kinetic energy equal one-half the potential energy? (d) Are there any values of the position where the kinetic energy is greater than the maximum potential energy? Explain.

22. **G.E** **Review.** A 65.0-kg bungee jumper steps off a bridge with a light bungee cord tied to her body and to the bridge. The unstretched length of the cord is 11.0 m. The jumper reaches the bottom of her motion 36.0 m below the bridge before bouncing back. We wish to find the time interval between her leaving the bridge and her arriving at the bottom of her motion. Her overall motion can be separated into an 11.0-m free fall and a 25.0-m section of simple harmonic oscillation. (a) For the free-fall part, what is the appropriate analysis model to describe her motion? (b) For what time interval is she in free fall? (c) For the simple harmonic oscillation part of the plunge, is the system of the bungee jumper, the spring, and the Earth isolated or non-
isolated? (d) From your response in part (c) find the spring constant of the bungee cord. (e) What is the location of the equilibrium point where the spring force balances the gravitational force exerted on the jumper? (f) What is the angular frequency of the oscillation? (g) What time interval is required for the cord to stretch by 25.0 m? (h) What is the total time interval for the entire 36.0-m drop?

23. **Review.** A 0.250-kg block resting on a frictionless, horizontal surface is attached to a spring whose force constant is 83.8 N/m as in Figure P15.23. A horizontal force \( F \) causes the spring to stretch a distance of 5.46 cm from its equilibrium position. (a) Find the magnitude of \( F \). (b) What is the total energy stored in the system when the spring is stretched? (c) Find the magnitude of the acceleration of the block just after the applied force is removed. (d) Find the speed of the block when it first reaches the equilibrium position. (e) If the surface is not frictionless but the block still reaches the equilibrium position, would your answer to part (d) be larger or smaller? (f) What other information would you need to know to find the actual answer to part (d) in this case? (g) What is the largest value of the coefficient of friction that would allow the block to reach the equilibrium position?

24. A 326-g object is attached to a spring and executes simple harmonic motion. (b) If the object is in simple harmonic motion with a frequency of 0.250 s. If the total energy of the system is 5.83 J, find (a) the maximum speed of the object, (b) the force constant of the spring, and (c) the amplitude of the motion.

### Section 15.4 Comparing Simple Harmonic Motion with Uniform Circular Motion

25. **Review.** While driving behind a car traveling at 3.00 m/s, you notice that one of the car’s tires has a small hemispherical bump on its rim as shown in Figure P15.25. (a) Explain why the bump, from your viewpoint behind the car, executes simple harmonic motion. (b) If the radii of the car’s tires are 0.300 m, what is the bump’s period of oscillation?

### Section 15.5 The Pendulum

Problem 62 in Chapter 1 can also be assigned with this section.

26. A “seconds pendulum” is one that moves through its equilibrium position once each second. (The period of the pendulum is precisely 2 s.) The length of a seconds pendulum is 0.992 ft at Tokyo, Japan, and 0.994 ft at Cambridge, England. What is the ratio of the free-fall accelerations at these two locations?

27. A simple pendulum makes 120 complete oscillations in 3.00 min at a location where \( g = 9.80 \) m/s\(^2\). Find (a) the period of the pendulum and (b) its length.

28. A particle of mass \( m \) slides without friction inside a hemispherical bowl of radius \( R \). Show that if the particle starts from rest with a small displacement from equilibrium, it moves in simple harmonic motion with an angular frequency equal to that of a simple pendulum of length \( R \). That is, \( \omega = \sqrt{g/R} \).

29. A physical pendulum in the form of a planar object moves in simple harmonic motion with a frequency of 0.450 Hz. The pendulum has a mass of 2.20 kg, and the pivot is located 0.350 m from the center of mass. Determine the moment of inertia of the pendulum about the pivot point.

30. A physical pendulum in the form of a planar object moves in simple harmonic motion with a frequency \( f \). The pendulum has a mass \( m \), and the pivot is located a distance \( d \) from the center of mass. Determine the moment of inertia of the pendulum about the pivot point.

31. A pendulum has a mass of 0.250 kg and a length of 1.00 m. It is displaced through an angle of 15.0° and then released. Using the analysis model of a particle in simple harmonic motion, what are (a) the maximum speed of the bob, (b) its maximum angular acceleration, and (c) the maximum restoring force on the bob? (d) **What If?** Solve parts (a) through (c) again by using analysis models introduced in earlier chapters. (e) Compare the answers.

32. Consider the physical pendulum of Figure 15.17. (a) Represent its moment of inertia about an axis passing through its center of mass and parallel to the axis passing through its pivot point as \( I_{CM} \). Show that its period is

\[
T = 2\pi \sqrt{\frac{I_{CM} + md^2}{mgd}}
\]

where \( d \) is the distance between the pivot point and the center of mass. (b) Show that the period has a minimum value when \( d \) satisfies \( md^2 = I_{CM} \).

33. **Review.** A simple pendulum is 5.00 m long. What is the period of small oscillations for this pendulum if it is located in an elevator (a) accelerating upward at 5.00 m/s\(^2\)? (b) Accelerating downward at 5.00 m/s\(^2\)? (c) What is the period of this pendulum if it is placed in a truck that is accelerating horizontally at 5.00 m/s\(^2\)?

34. A very light rigid rod of length 0.500 m extends straight out from one end of a meterstick. The combination is suspended from a pivot at the upper end of the rod as shown in Figure P15.34. The combination is then pulled out by a small angle and released. (a) Determine the period of oscillation of the system. (b) By what percentage does the period differ from the period of a simple pendulum 1.00 m long?

35. A watch balance wheel (Fig. P15.35) has a period of oscillation of 0.250 s. The wheel is constructed so that its mass of 20.0 g is concentrated around a rim of radius 0.500 cm. What
36. A small object is attached to the end of a string to form a simple pendulum. The period of its harmonic motion is measured for small angular displacements and three lengths. For lengths of 1.00 m, 0.750 m, and 0.500 m, total time intervals for 50 oscillations of 99.8 s, 86.6 s, and 71.1 s are measured with a stopwatch. (a) Determine the period of motion for each length. (b) Determine the mean value of the period obtained from these three independent measurements and compare it with the accepted value. (c) Plot $T^2$ versus $L$ and obtain a value for $g$ from the slope of your best-fit straight-line graph. (d) Compare the value found in part (c) with that obtained in part (b).

Section 15.6 Damped Oscillations

37. A pendulum with a length of 1.00 m is released from an initial angle of 15.0°. After 1 000 s, its amplitude has been reduced by friction to 5.50°. What is the value of $b/2m$?

38. Show that the time rate of change of mechanical energy for a damped, undriven oscillator is given by $dE/dt = -2b\omega$ and hence is always negative. To do so, differentiate the expression for the mechanical energy of an oscillator, $E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$, and use Equation 15.31.

39. A 10.6-kg object oscillates at the end of a vertical spring that has a spring constant of 2.05 x 10^4 N/m. The effect of air resistance is represented by the damping coefficient $b = 3.00$ N·s/m. (a) Calculate the frequency of the damped oscillation. (b) By what percentage does the amplitude of the oscillation decrease in each cycle? (c) Find the time interval that elapses while the energy of the system drops to 50.0% of its initial value.

40. Show that Equation 15.32 is a solution of Equation 15.31 provided that $b^2 < 4mk$.

Section 15.7 Forced Oscillations

41. As you enter a fine restaurant, you realize that you have accidentally brought a small electronic timer from home. The timer is operating. The arm of your chair presses the timer into a side pocket of your suit coat, not realizing that instead of your cell phone. In frustration, you drop the timer into a side pocket of your suit coat, not realizing that the timer is operating. The arm of your chair presses the light cloth of your coat against your body at one spot. Fabric with a length $L$ hangs freely below that spot, with the timer at the bottom. At one point during your dinner, the timer goes off and a buzzer and a vibrator turn on and off with a frequency of 1.50 Hz. It makes the hanging part of your coat swing back and forth with remarkably large amplitude, drawing everyone’s attention. Find the value of $L$.

42. A baby bounces up and down in her crib. Her mass is 12.5 kg, and the crib mattress can be modeled as a light spring with force constant 700 N/m. (a) The baby soon learns to bounce with maximum amplitude and minimum effort by bending her knees at what frequency? (b) If she were to use the mattress as a trampoline—losing contact with it for part of each cycle—what minimum amplitude of oscillation does she require?

43. A 2.00-kg object attached to a spring moves without friction ($b = 0$) and is driven by an external force given by the expression $F = 3.00 \sin(2\pi t)$, where $F$ is in newtons and $t$ is in seconds. The force constant of the spring is 20.0 N/m. Find (a) the resonance angular frequency of the system, (b) the angular frequency of the driven system, and (c) the amplitude of the motion.

44. A block weighing 40.0 N is suspended from a spring that has a force constant of 200 N/m. The system is undamped ($b = 0$) and is subjected to a harmonic driving force of frequency 10.0 Hz, resulting in a forced-motion amplitude of 2.00 cm. Determine the maximum value of the driving force.

45. M Damping is negligible for a 0.150-kg object hanging from a light, 6.30-N/m spring. A sinusoidal force with an amplitude of 1.70 N drives the system. At what frequency will the force make the object vibrate with an amplitude of 0.440 m?

46. Considering an undamped, forced oscillator ($b = 0$), show that Equation 15.35 is a solution of Equation 15.34, with an amplitude given by Equation 15.36.

Additional Problems

47. The mass of the deuterium molecule (D₂) is twice that of the hydrogen molecule (H₂). If the vibrational frequency of H₂ is 1.30 x 10^14 Hz, what is the vibrational frequency of D₂? Assume the “spring constant” of attracting forces is the same for the two molecules.

48. Review. This problem extends the reasoning of Problem 59 in Chapter 9. Two gliders are set in motion on an air track. Glider 1 has mass $m_1 = 0.420$ kg and moves to the right with speed 0.740 m/s. It will have a rear-end collision with glider 2, of mass $m_2 = 0.360$ kg, which initially moves to the right with speed 0.120 m/s. A light spring of force constant 45.0 N/m is attached to the back end of glider 2 as shown in Figure P9.59. When glider 1 touches the spring, superglue instantly and permanently makes it stick to its end of the spring. (a) Find the common speed the two gliders have when the spring is at maximum compression. (b) Find the maximum spring compression distance. The motion after the gliders become attached consists of a combination of (1) the constant-velocity motion of the center of mass of the two-glider system found in part (a) and (2) simple harmonic motion of the gliders relative to the center of mass. (c) Find the energy of the center-of-mass motion. (d) Find the energy of the oscillation.

49. An object of mass $m$ moves in simple harmonic motion with amplitude 12.0 cm on a light spring. Its maximum acceleration is 108 cm/s². Regard $m$ as a variable. (a) Find the period $T$ of the object. (b) Find its frequency $f$. (c) Find the maximum speed $v_{\text{max}}$ of the object. (d) Find the total energy $E$ of the object–spring system. (e) Find the force constant $k$ of the spring. (f) Describe the pattern of dependence of each of the quantities $T, f, v_{\text{max}}, E,$ and $k$ on $m$.

50. Review. A rock rests on a concrete sidewalk. An earthquake strikes, making the ground move vertically in simple harmonic motion with a constant frequency of 2.40 Hz and with gradually increasing amplitude. (a) With what amplitude does the ground vibrate when the rock begins to lose contact with the sidewalk? Another rock is sitting on the concrete bottom of a swimming pool full of