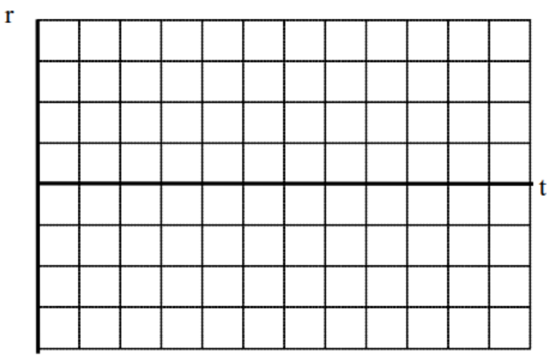
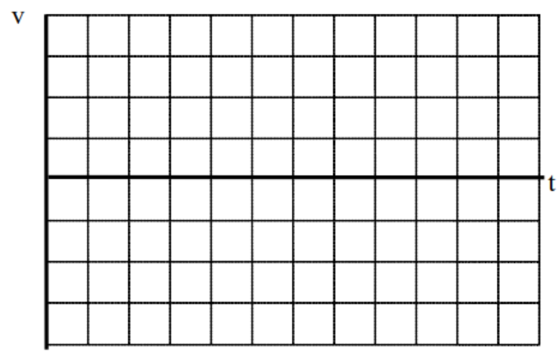
6.3: Activities

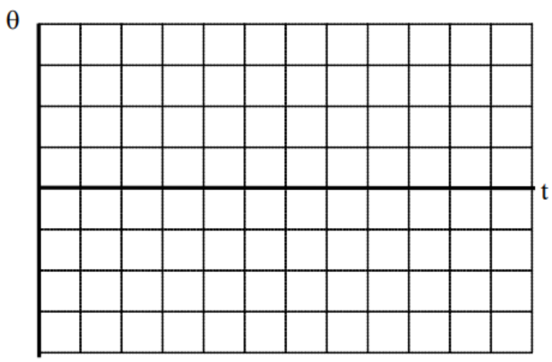
Sketch the indicated motion graphs for one complete cycle of the motions described below. Set the origin of the coordinate system at the equilibrium position of the mass.

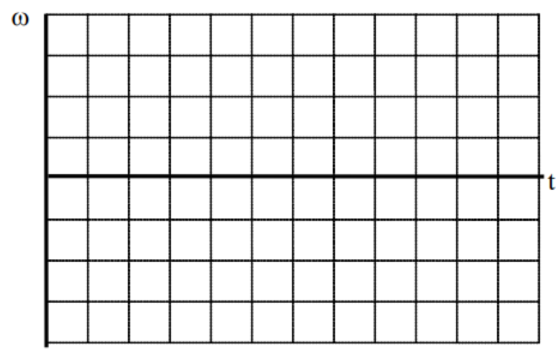
a. A mass is attached to a vertically-oriented spring. The mass is pulled a short distance below its equilibrium position and released. Begin the graph the instant the mass is released. Assume air resistance is so small that it can be ignored.





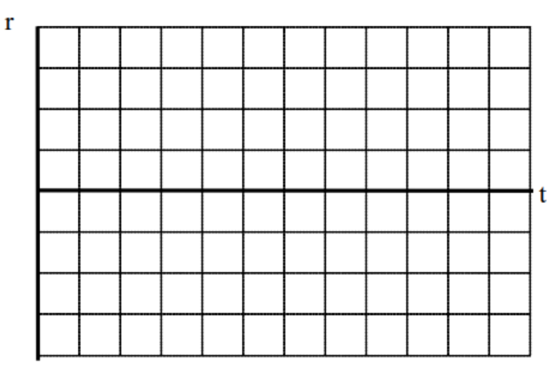
b. A pendulum is displaced from its equilibrium position and released. Begin the graph the instant the pendulum is released. Assume air resistance is so small that it can be ignored.

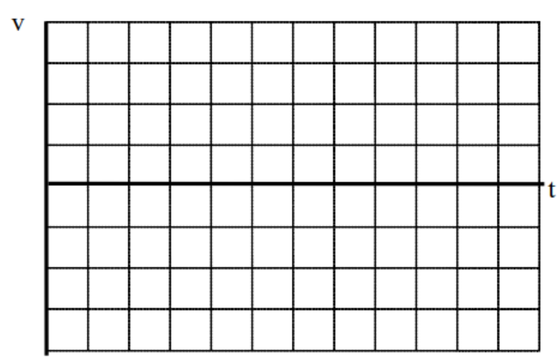




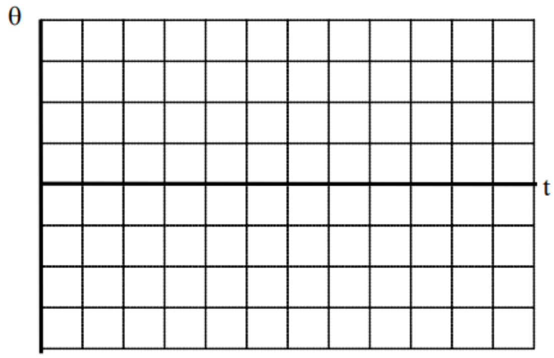
Sketch the indicated motion graphs for one complete cycle of the motions described below. Set the origin of the coordinate system at the equilibrium position of the mass.

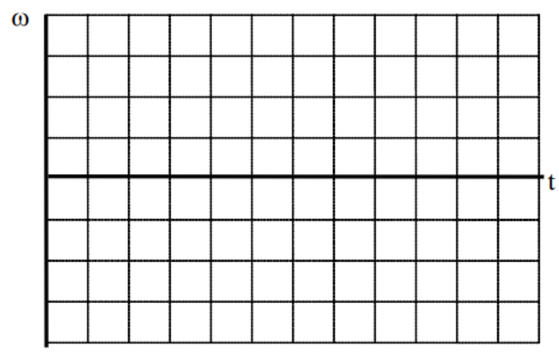
a. A mass is attached to a vertically-oriented spring. The mass is pulled a short distance below its equilibrium position and released. Begin the graph the instant the mass is released. Assume air resistance is so large that it cannot be ignored.



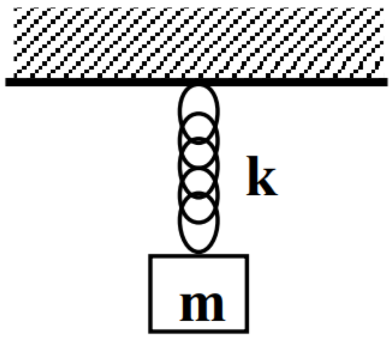


b. A pendulum is displaced from its equilibrium position and released. Begin the graph the instant the pendulum is released. Assume air resistance is so large that it cannot be ignored.





A crate of mass m is attached to a spring of stiffness k. The crates are held in place such that none of the springs are initially stretched. All springs are initially the same length. The crates are released and the springs stretch.



	m	**k**
A	5 kg	20 N/m
B	20 kg	5 N/m
C	10 kg	10 N/m
D	15 kg	20 N/m
E	5 kg	5 N/m
F	15 kg	10 N/m

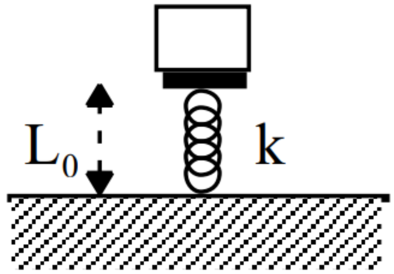
Rank the time required for the crates to return to their initial position.

Largest 1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ Smallest

_____ The ranking cannot be determined based on the information provided.

Explain the reason for your ranking:

Different mass crates are placed on top of springs of uncompressed length L0 and stiffness k. The crates are released and the springs compress to a length L before bringing the crates back up to their original positions.



	k	L_0	L
A	5 N/m	1.0 m	0.5 m
B	10 N/m	1.0 m	0.5 m
C	5 N/m	2.0 m	1.0 m
D	10 N/m	2.0 m	0.5 m
E	15 N/m	1.5 m	1.0 m
F	20 N/m	1.5 m	0.5 m

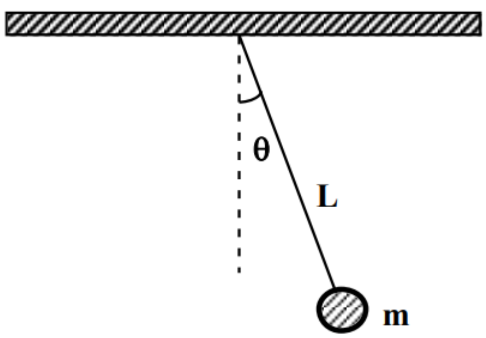
Rank the time required for the crates to return to their initial positions.

Largest 1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ Smallest

_____ The ranking cannot be determined based on the information provided.

Explain the reason for your ranking:

A pendulum of mass m and length L is released from rest from an angle θ from vertical.



	m	L
A	2 kg	1 m
B	1 kg	4 m
C	4 kg	1 m
D	4 kg	2 m
E	2 kg	2 m
F	4 kg	4 m

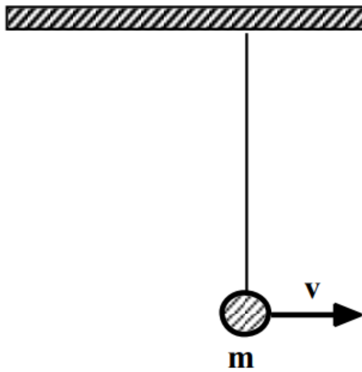
Rank the number of complete cycles of motion each pendulum goes through per minute.

Largest 1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ Smallest

_____ The ranking cannot be determined based on the information provided.

Explain the reason for your ranking:

A 2 m long pendulum of mass m is moving at velocity v as it passes through its equilibrium position.



	m	v
A	2 kg	4 m/s
B	1 kg	4 m/s
C	4 kg	2 m/s
D	8 kg	1 m/s
E	2 kg	2 m/s
F	3 kg	3 m/s

Rank the period of the pendulum.

Largest 1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ Smallest

_____ The ranking cannot be determined based on the information provided.

Explain the reason for your ranking:

A 75 kg bungee jumper is about to step off of a platform high above a raging river and plummet downward. The elastic bungee cord has an effective spring constant of 50 N/m and is initially slack, although it begins to stretch the moment the jumper steps off of the platform.

Free-Body Diagram

Mathematical Analysis

Questions

What is the bungee jumper's maximum velocity?

How far does the bungee jumper fall?

If the river is only 25 m below the platform, how fast is the jumper going when she hits the river?

A 75 kg bungee jumper is about to step off of a platform 65 m above a raging river and plummet downward. She hopes to get just the top of her hair wet. The elastic bungee cord exerts a linear restoring force and is initially slack, although it begins to stretch the moment the jumper steps off of the platform.

Free-Body Diagram

Mathematical Analysis

Questions

What is the period of the jumper’s motion?

What is the maximum force acting on the jumper?

How fast is the jumper moving 2.0 s after leaving the platform?

A 85 kg bungee jumper is about to step off of a platform high above a raging river and plummet downward. The elastic bungee cord has an effective spring constant of 40 N/m and is initially slack, although it begins to stretch the moment the jumper steps off of the platform. The amplitude of the jumper’s motion decreases by approximately 20% after one complete cycle of his motion due to a drag force proportional to his speed.

Free-Body Diagram

Mathematical Analysis

Questions

What is the bungee jumper’s maximum speed on his second cycle downward?

How far does the bungee jumper fall?

The suspension of an automobile sags by 8 cm when the 900 kg frame is placed on it. To check the shock absorbers, the autoworkers drop the car from a small height and note that the amplitude of oscillation decreases by about 80% during each oscillation. Assume the shock absorbers exert a damping force proportional to the car’s speed.

Free-Body Diagram

Mathematical Analysis

Questions

What is the effective spring constant of the suspension?

What is the period of oscillation of the car?

What is the effective damping coefficient of the suspension?

A man steps onto a bathroom scale. The bathroom scale acts as an initially uncompressed, undamped spring of spring constant 40,000 N/m. The scale displays the force exerted by the spring on the man, and reaches a maximum display of 1574 N shortly after the man steps on the scale.

Free-Body Diagram

Mathematical Analysis

Question

What is the man’s mass?

What is the period of oscillation of the scale’s reading?

A man steps onto a bathroom scale. The bathroom scale acts as an initially uncompressed spring of spring constant 40,000 N/m. The scale displays the force exerted by the spring on the man, and reaches a maximum display of 1574 N shortly after the man steps on the scale. After the next oscillation, the maximum display is 1234 N. Assume the internal damping is proportional to the speed of the oscillating man.

Free-Body Diagram

Mathematical Analysis

Question

What is the man’s mass?

What does the scale read 5 s after the man steps on?

A 70 kg skier is zooming down a mountain out of control when he decides to veer off the trail into the Safety-Spring. The Safety-Spring is a 900 N/m spring into which the skier can collide and be brought to rest much more gently than if he hit a tree. The skier *is traveling at 20 m/s when he pulls off onto a horizontal path and collides with and sticks to the spring. Assume friction is so small that it can be ignored.*

Free-Body Diagram

Mathematical Analysis

Question

What is the maximum force that acts on the man?

How long does it take for the Safety-Spring to stop the man's motion?

A 50 kg skier is zooming down a mountain out of control when she decides to veer off the trail into the new and improved Safety-Spring. The new and improved Safety-Spring is a 900 N/m spring into which the skier can collide and be brought to rest much more gently than if she hit a tree. The new and improved part is that a baffle has been built into the Safety-Spring which provides a damping coefficient of 2.2 Ns/m. The skier is traveling at 25 m/s when she pulls off onto a horizontal path and collides with and sticks to the spring. Assume sliding friction is so small that it can be ignored.

Free-Body Diagram

Mathematical Analysis

Question

What is the skier's speed at the end of one complete oscillation?

How long does it take for the Safety-Spring to reduce the skier's maximum speed during oscillation to less than 5 m/s?

A 65 kg physicist digs a hole through the center of the earth and out the other side and jumps in. She knows that the force of gravity acting on a particle ***below*** *the earth's surface is $F_G = G\ M\ m\ r\ /\ R^3$, where G is the universal gravitational constant ($6.7 \times 10^{-11} Nm^2/kg^2$), M is the mass of the earth (6.0×10^{24} kg), m is the mass of the particle, R is the radius of the earth ($6.4 \times 10^6 m$), and r is the distance between the particle and the center of the earth.*

Free-Body Diagram

Mathematical Analysis

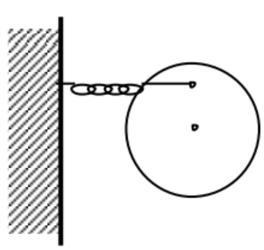
Question

How long does it take the physicist to reach the other side of the earth?

What is the maximum speed of the physicist during her journey?

If the physicist's 75 kg partner jumps into the hole the same time as the physicist, which one reaches the other side of the earth first?

The device at right is the top view of a vibrating dance floor. A 2200 kg, disk-shaped dance floor of radius 15 m is mounted horizontally. At a position 10 m from the rotation axis, a spring of constant 40,000 N/m is attached to the underside of the dance floor. The spring is unstretched in the orientation shown. The disk is rotated by 5° and released. Assume friction in the mount is so small it can be ignored.



Free-Body Diagram

Mathematical Analysis

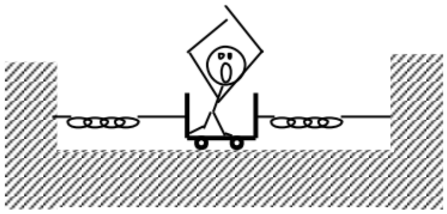
Question

What is the period of oscillation of the dance floor?

What is the maximum speed of someone standing on the outer edge of the dance floor?

What is the maximum acceleration of someone standing on the outer edge of the dance floor?

The SkakerCar at right is designed to test your balance. At present, a woman of mass m is standing in the mass M ShakerCar. Two springs, of constant k_1 and k_2, are attached to the car and are initially unstretched. The car is displaced a distance D to the left and released. Assume friction is so small it can be ignored.



Free-Body Diagram

Mathematical Analysis

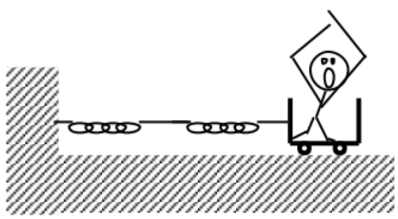
Question

What is the period of oscillation of the ShakerCar without the woman in it?

What is the maximum speed of the occupant during her journey?

What is the maximum acceleration of the occupant during her journey?

The SkakerCar at right is designed to test your balance. At present, a woman of mass m is standing in the mass M ShakerCar. Two springs, both of constant k, are attached to each other and are initially unstretched. The car is displaced a distance D to the left and released. Assume friction is so small it can be ignored.



Free-Body Diagram

Mathematical Analysis

Question

What is the period of oscillation of the ShakerCar without the woman in it?

What is the maximum speed of the occupant during her journey?

What is the maximum acceleration of the occupant during her journey?

Stranded on a desert island with only a meterstick and a nail, a physicist builds a pendulum clock by nailing one end of the meterstick to a tree branch. He then displaces the meterstick by 5° and lets it go. Assume friction in the mount is so small that it can be ignored.

Free-Body Diagram

Mathematical Analysis

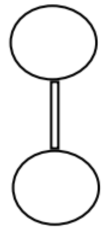
Question

What is the period of the pendulum clock?

What is the maximum speed of the bottom edge of the meterstick?

If the meterstick is cut in half, how will the period change?

Two identical spheres of mass M and radius R are connected as shown by a very thin rod of negligible inertia and length L, forming a dumbbell. In designing a pendulum clock, the designer considered mounting the dumbbell on an axis located a distance D from the CM, and perpendicular to the drawing at right, and displacing the dumbbell by a small angle.



Free-Body Diagram

Mathematical Analysis

Question

What is the period of oscillation of the dumbbell as a function of D?

What is the period of oscillation of the dumbbell if D = 0? Why?

For what value of D is the period a minimum?
