Periodic motion

Earth around the sun
Elastic ball bouncing up an down
Quartz in your watch, computer clock, iPod clock, etc.
Heart beat, and many more

In taking your pulse, you count 70.0 heartbeats in 1 min.

What is the period of your heart's oscillations? 0.86 s

What is their frequency? 1.17 Hz

Simple Harmonic Motion

What do all *harmonic* oscillations have in common?

- A position of equilibrium
- A restoring force, which must be *linear*

  ($F = -kx$; F = mg is only linear for small angles: $\sin\theta = \theta = s/L$

  In this limit we have: $F = -ks$ with $k = mg/L$)
- Inertia
- The resistive forces are reasonably small

Simple Harmonic Motion

the restoring force on the mass is *linear*, that is,

exactly proportional to the displacement of

the mass from rest position

Hook's Law : $F = -kx$

large k <=> rapid oscillations <=> large frequency
large mass <=> low frequency

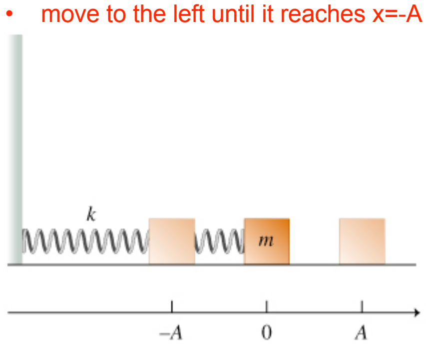
Demo cart on springs&plots
Video 1
DC: springs

good vibes

- m, k, A, no friction
- Pull block to the right until x=A

After the block is released from x=A, it will

- remain at rest.
- move to the left until it reaches equilibrium and stop there.
- move to the left until it reaches x=-A and stop there.
- move to the left until it reaches x=-A and then begin to move to the right.

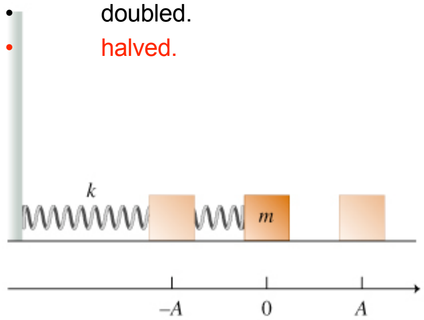


good vibes

- The time it takes the block to complete one cycle is called the period. Usually, the period is denoted T and is measured in seconds.
- The frequency, denoted f, is the number of cycles that are completed per unit of time: $f=1/T$. In SI units, f is measured in inverse seconds, or hertz (Hz).

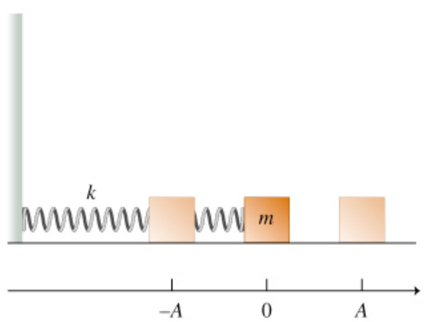
If the period is doubled, the frequency is

- unchanged.
- doubled.
- halved.



good vibes

- An oscillating object takes 0.10 s to complete one cycle; that is, its period is 0.10 s. What is its frequency f?
- Express your answer in hertz.
- $f = 1/T = 10$ Hz



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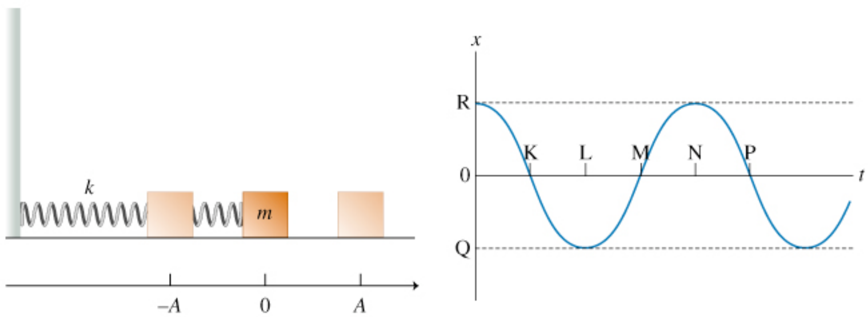
- Note in the (x,t) graph that the vertical axis represents the x coordinate of the oscillating object, and the horizontal axis represents time.

Which points on the x axis are located a distance A from the equilibrium position?

- R only
- Q only
- both R and Q

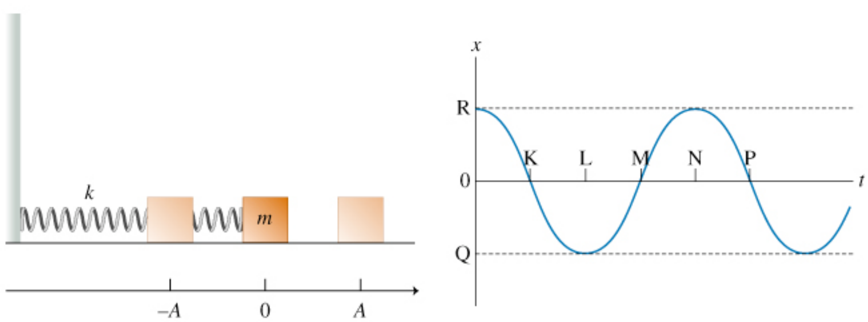


good vibes

- Suppose that the period is T.

Which of the following points on the t axis are separated by the time interval T?

- K and L
- K and M
- K and P
- L and N
- M and P



good vibes

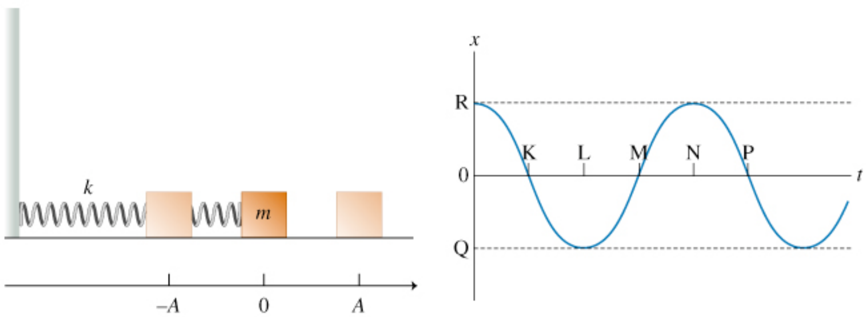
- Now assume that the t coordinate of point K is 0.0050 s.

What is the period T , in seconds?

- T = 0.02 s

How much time t does the block take to travel from the point of maximum displacement to the opposite point of maximum displacement?

- t = 0.01 s



good vibes

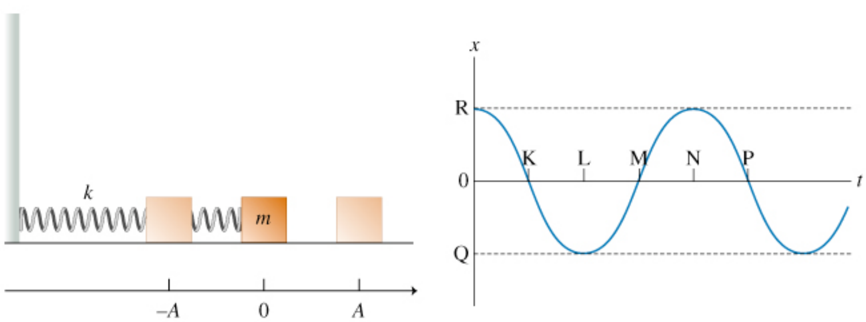
- Now assume that the x coordinate of point R is 0.12 m.

What distance d does the object cover during one period of oscillation?

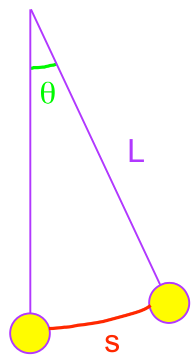
- d = 0.48 m

What distance d does the object cover between the moments labeled K and N on the graph?

- d = 0.36 m



pendulum



DC demo
videos 2,3

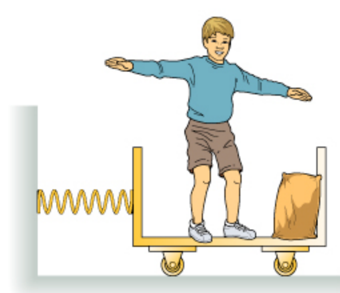
The shaker cart

- You stand inside a small cart attached to a heavy-duty spring, the spring is compressed and released, and you shake back and forth, attempting to maintain your balance. Note that there is also a sandbag in the cart with you.
- At the instant you pass through the equilibrium position of the spring, you drop the sandbag out of the cart onto the ground.

What effect does jettisoning the sandbag at the equilibrium position have on the amplitude of your oscillation?

- It increases the amplitude.
- It decreases the amplitude.
- It has no effect on the amplitude.

Hint: At equilibrium, both the cart and the bag are moving at their maximum speed. By dropping the bag at this point, energy (specifically the kinetic energy of the bag) is lost from the spring-cart system. Thus, both the elastic potential energy at maximum displacement and the kinetic energy at equilibrium must decrease.



The shaker cart

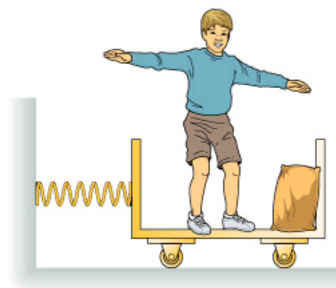
- Instead of dropping the sandbag as you pass through equilibrium, you decide to drop the sandbag when the cart is at its maximum distance from equilibrium.

What effect does jettisoning the sandbag at the cart's maximum distance from equilibrium have on the amplitude of your oscillation?

- It increases the amplitude.
- It decreases the amplitude.
- It has no effect on the amplitude.

Hint: Dropping the bag at maximum distance from equilibrium, both the cart and the bag are at rest.

By dropping the bag at this point, no energy is lost from the spring-cart system. Therefore, both the elastic potential energy at maximum displacement and the kinetic energy at equilibrium must remain constant.

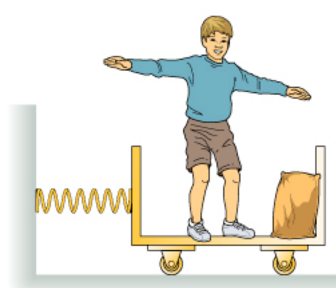


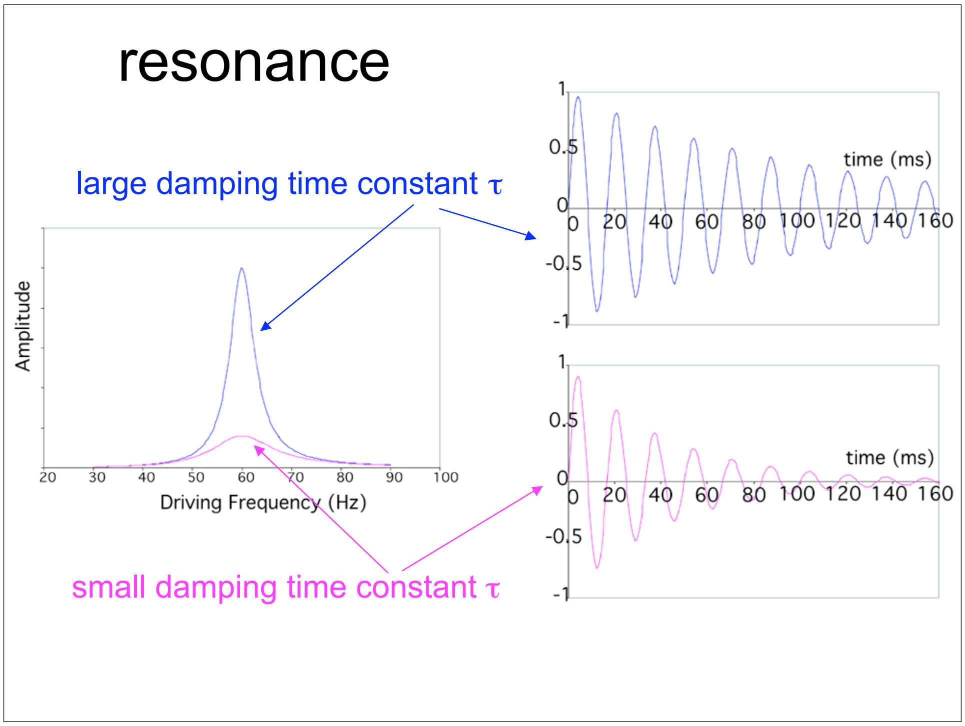
The shaker cart

What effect does jettisoning the sandbag at the cart's maximum distance from equilibrium have on the maximum speed of the cart?

- It increases the maximum speed.
- It decreases the maximum speed.
- It has no effect on the maximum speed.

Hint: Dropping the bag at maximum distance from equilibrium, both the cart and the bag are at rest. By dropping the bag at this point, no energy is lost from the spring-cart system. Therefore, both the elastic potential energy at maximum displacement and the kinetic energy at equilibrium must remain constant.




resonance
large damping time constant τ
small damping time constant τ
Amplitude
Driving Frequency (Hz)
20 30 40 50 60 70 80 90 100
time (ms)
1
0.5
0
-0.5
-1
0 20 40 60 80 100 120 140 160
time (ms)
1
0.5
0
-0.5
-1
0 20 40 60 80 100 120 140 160