Spring 2014

PHYS-2010

Lecture 42

Clicker Question

Room Frequency BA

A helium-filled balloon of volume *V* can carry a total mass *M* (*M* includes the mass of the rubber balloon but not the mass of the Helium inside).

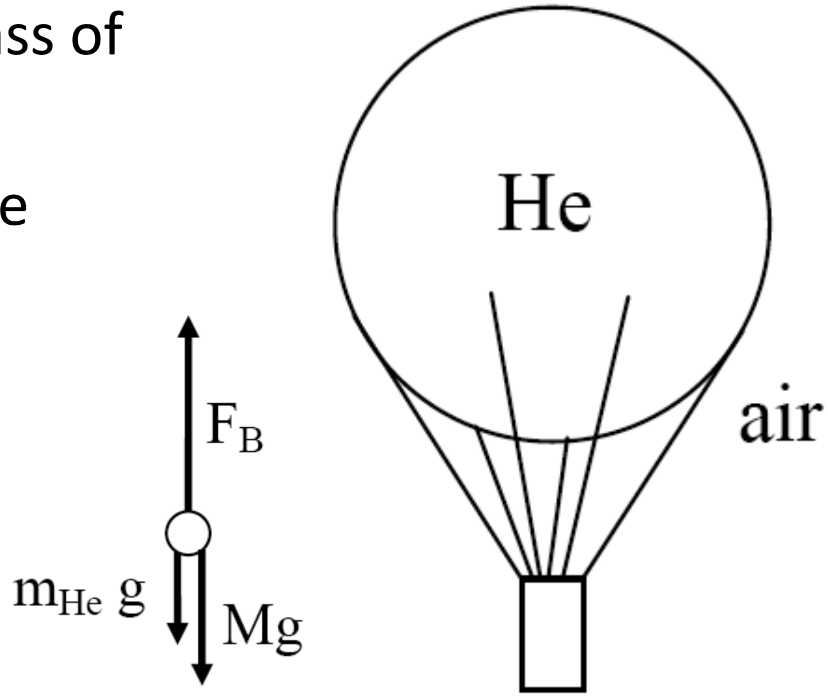
What is the correct expression for the **buoyant** force F_B on the balloon?

A) $\rho^{air} V g$

B) $\rho^{helium} V g - M g$

C) Mg

D) $(\rho^{air} - \rho^{helium}) V g - M g$



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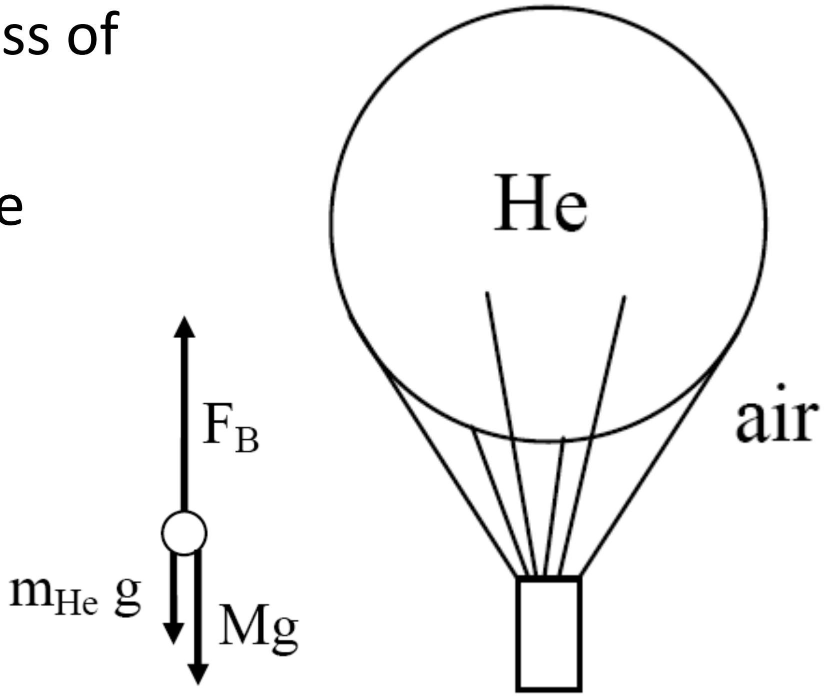


Weight of displaced fluid

Clicker Question

Room Frequency BA

A helium-filled balloon of volume *V* can carry a total mass *M* (*M* includes the mass of the rubber balloon but not the mass of the Helium inside).

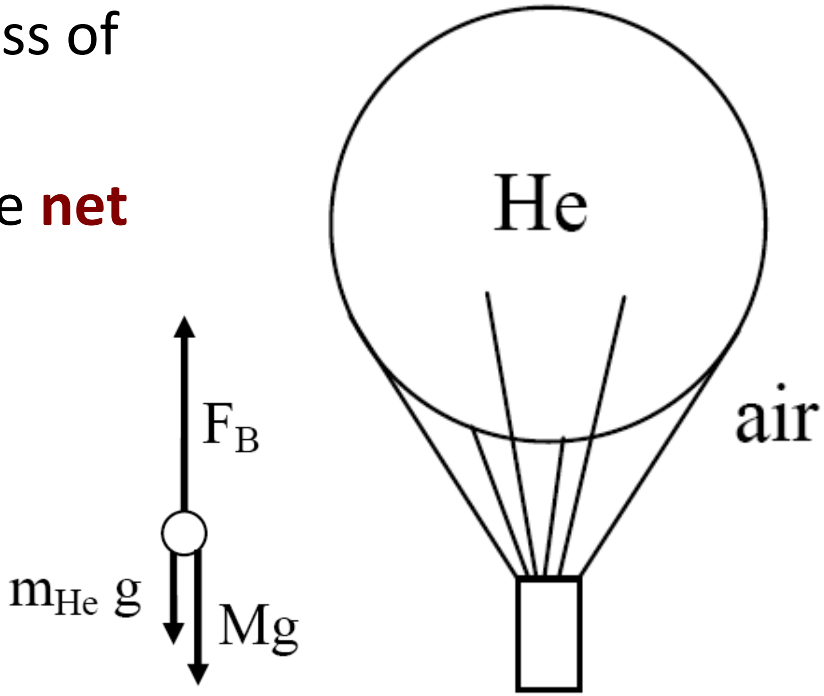
What is the correct expression for the **net** force F_{net} on the balloon?

A) $\rho^{air} V g$

B) $\rho^{helium} V g - M g$

C) Mg

D) $(\rho^{air} - \rho^{helium}) V g - M g$



Helium has weight!

Announcements

- Finish Giancoli **Chapter 10** and start **Chapter 11.**
- Special **Study Session** by Prof. Pollock and Rosemary Wulf, Tuesday, April 29, 5-6 pm in G125.
- **This week** in sections: Review Recitation and Lab makeup (Labs 4-8). Attendance required.
- **Final Exam:**
  - Monday, May 5, 1:30-4:00, in G1B30.
  - Cumulative, but with more focus on last chapters.
  - Practice exam posted on D2L.

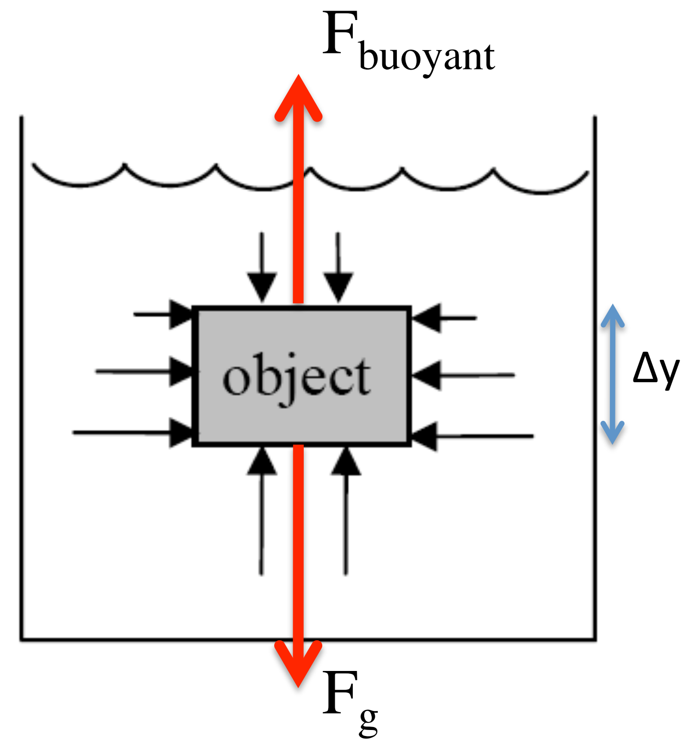
Motion of Submerged Objects: Sinking and Floating

When will an object sink or float?

$$F_{buoy} = m_{fluid}\, g$$

$$F_g = -\, m_{object}\, g$$

$$F_{net} = m_{Fluid}\, g - m_{Object}\, g$$



Object will rise: $F_{buoy} > |F_g|$ $(m_{fluid} > m_{object})$

Object will sink: $F_{buoy} < |F_g|$ $(m_{fluid} < m_{object})$

Object will be in equilibrium: $F_{buoy} = |F_g|$ $(m_{fluid} = m_{object})$

Motion of Submerged Objects: Sinking and Floating

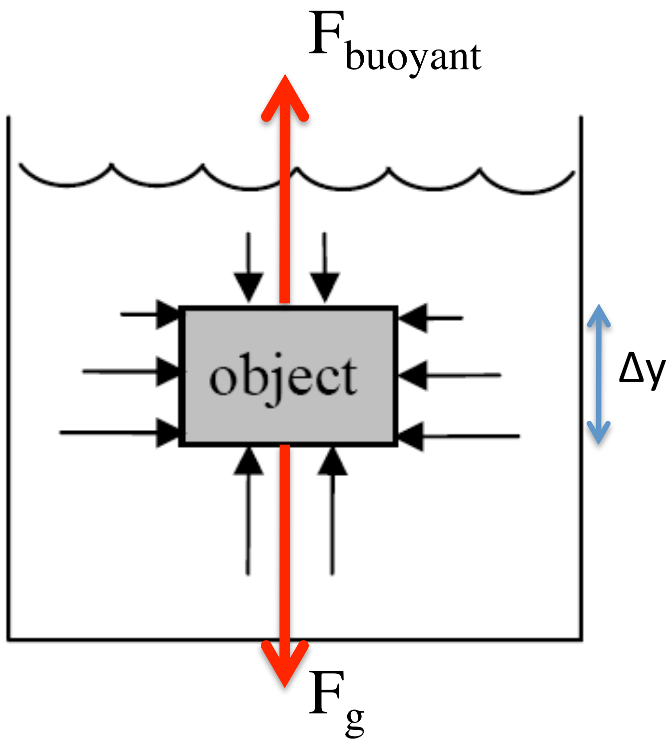
Since F_{buoy} and F_g both depend on the ***same volume V***, we can also write

Object will rise: $\varrho_{fluid} > \varrho_{object}$

Object will sink: $\varrho_{fluid} < \varrho_{object}$

Object will be in equilibrium:

$$\varrho_{fluid} = \varrho_{object}$$



Floating objects

<u>Floating Object:</u> Displaces a mass of water equal to its mass.

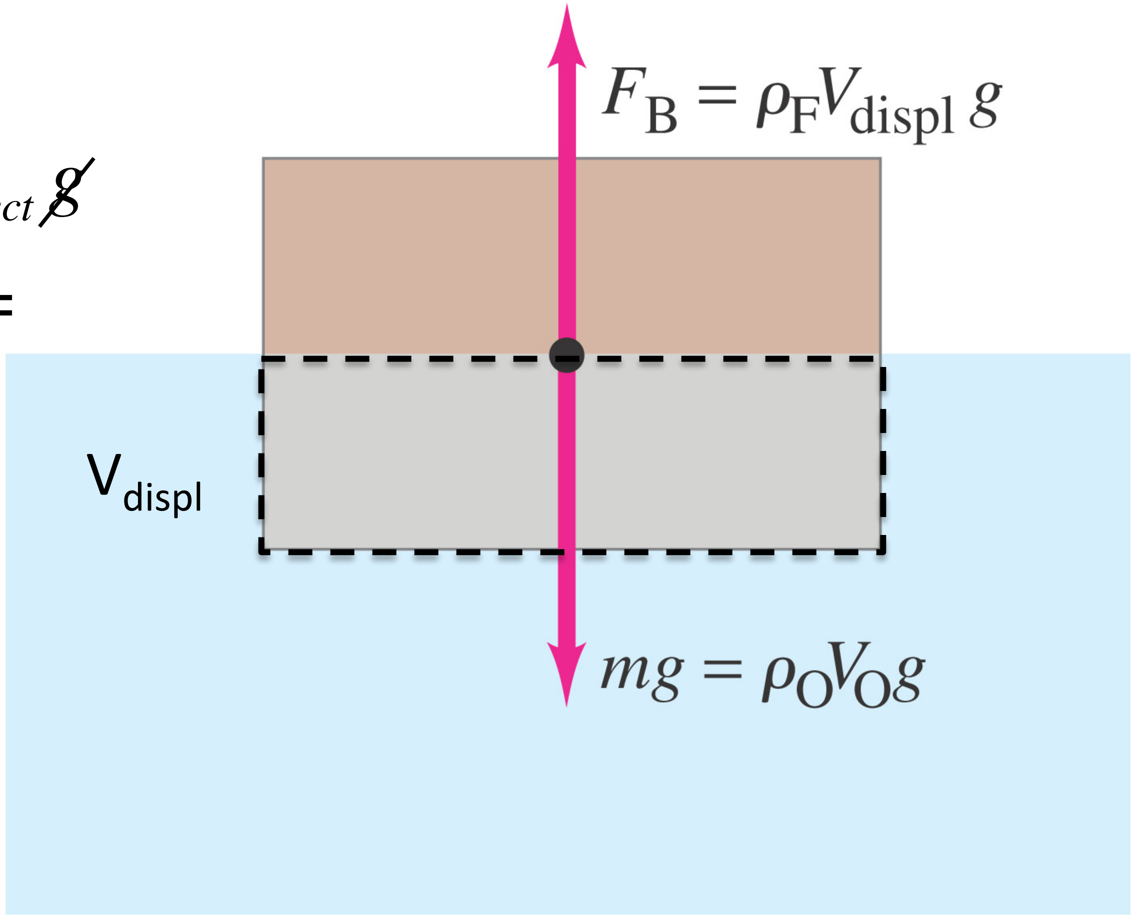
$$F_B = mg$$

$$\rho_{fluid} V_{displaced} \not{g} = \rho_{object} V_{object} \not{g}$$

mass of fluid displaced = mass of the object

or

$$\frac{V_{displaced}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}}$$



Clicker Question

Room Frequency BA

What fraction of a piece of Aluminum will be submerged if it is placed in a tank of Mercury? (ρ_{Al} = 2.7 x 10^3 kg/m^3, ρ_{Hg} = 13.6 x 10^3 kg/m^3)

$$\frac{V_{displaced}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}}$$

A) 20%

B) 40%

C) 60%

D) 80%

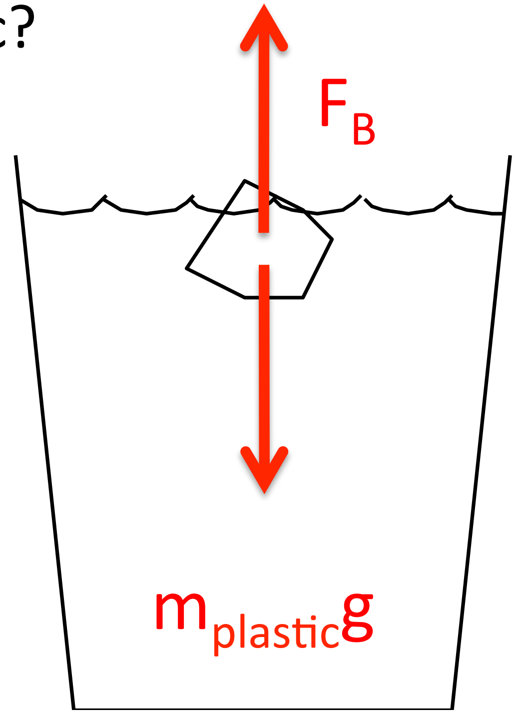
$$V_{displaced} = \left(\frac{\rho_{object}}{\rho_{fluid}}\right) V_{object} = \left(\frac{2.7x10^3}{13.6x10^3}\right) V_{object} = 0.2V_{object}$$

The volume of the Mercury displaced is the volume of the Aluminum that will be submerged.

Clicker Question

Room Frequency BA

A solid piece of plastic of volume V, and density $\rho_{plastic}$ is floating *partially submerged* in a cup of water. (The density of water is ρ_{water}.) What is the buoyant force on the plastic?



A) Zero

B) $\rho_{plastic} V$

C) $\rho_{water} V$

D) $\rho_{water} V g$

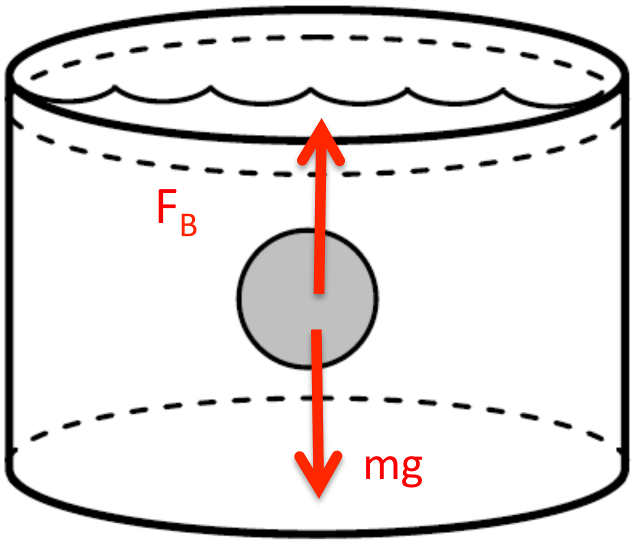
E) $\rho_{plastic} V g$

The plastic is in equilibrium so $F_B = m_{plastic} g = \rho_{plastic} V g$!

Clicker Question

Room Frequency BA

A carefully-made sphere, when placed under water, remains at rest, in equilibrium as shown above. How does the magnitude of the upward buoyant force F_B compare to the gravitational force *mg* on the sphere?



A) $F_B > mg$

B) $F_B = mg$

C) $F_B < mg$

Net force = 0

OSCILLATIONS AND WAVES

Throughout nature things are bound together by forces that allow things to oscillate back and forth.

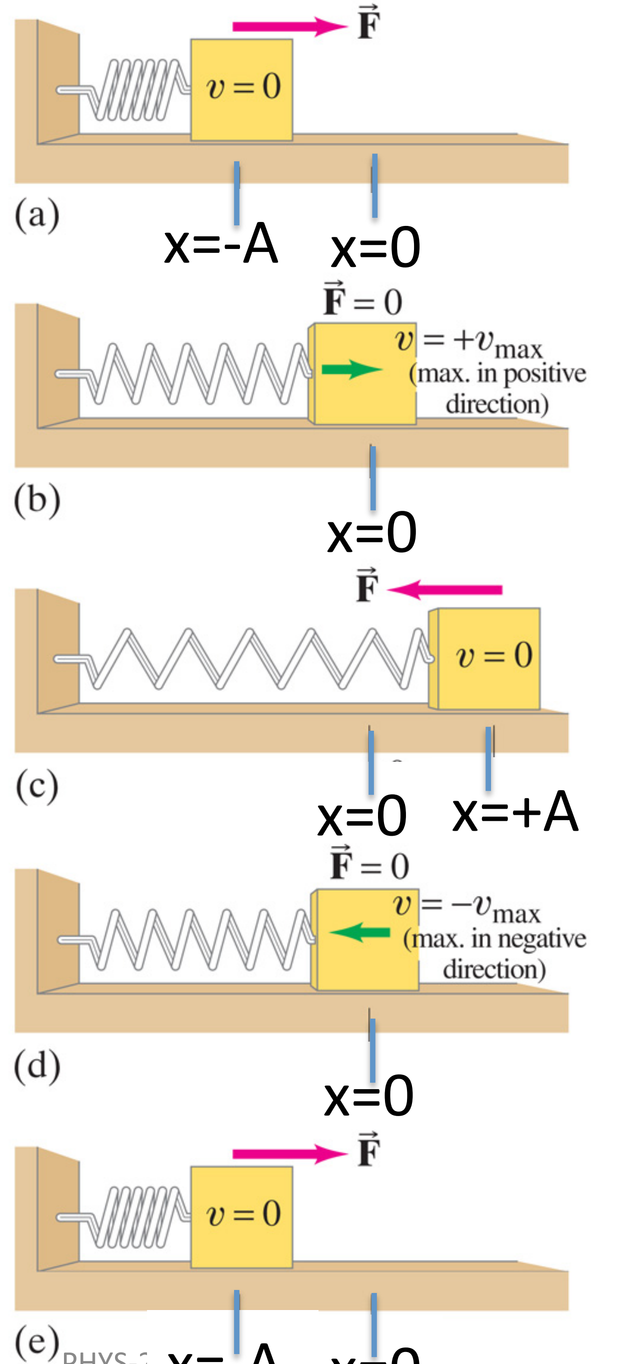
It is important to get a deeper understanding of these phenomena!

We'll focus on the most common and the most simple oscillation: **Simple Harmonic Motion (SHM)**

Requirements for SHM:

1) A restoring force proportional to the displacement from equilibrium.
2) The range of the motion (amplitude) is independent of the frequency.
3) Position, velocity, and acceleration are all sinusoidal (harmonic) in time.

Mass and Spring

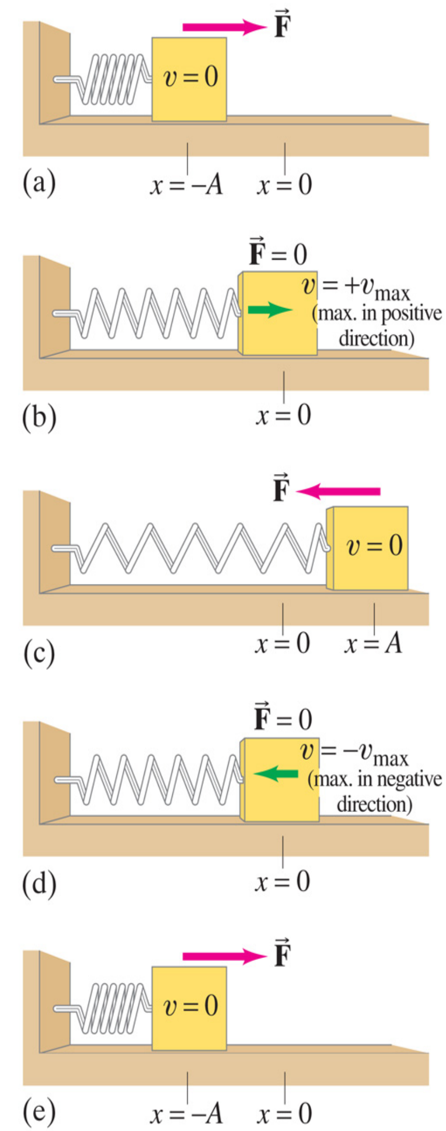


A Simple Harmonic Oscillator: Mass on a Spring

$$F = ma = -kx \qquad \text{(Hooke's Law)}$$

- ***Restoring force*** is proportional to displacement.
- The force is not constant, so acceleration isn't either: *a = -(k/m)x.*
- ***"Amplitude" A*** is the maximum displacement x_{max}, occurs with *v* = 0.
- Position oscillates between *x=A* and *x=-A.*
- Maximum speed v_{max} occurs at *x=0.*
- ***Cycle*** is the full extent of motion as shown.
- Time to complete 1 cycle is called the ***period T***.
- ***Frequency f*** is the # of cycles per second:

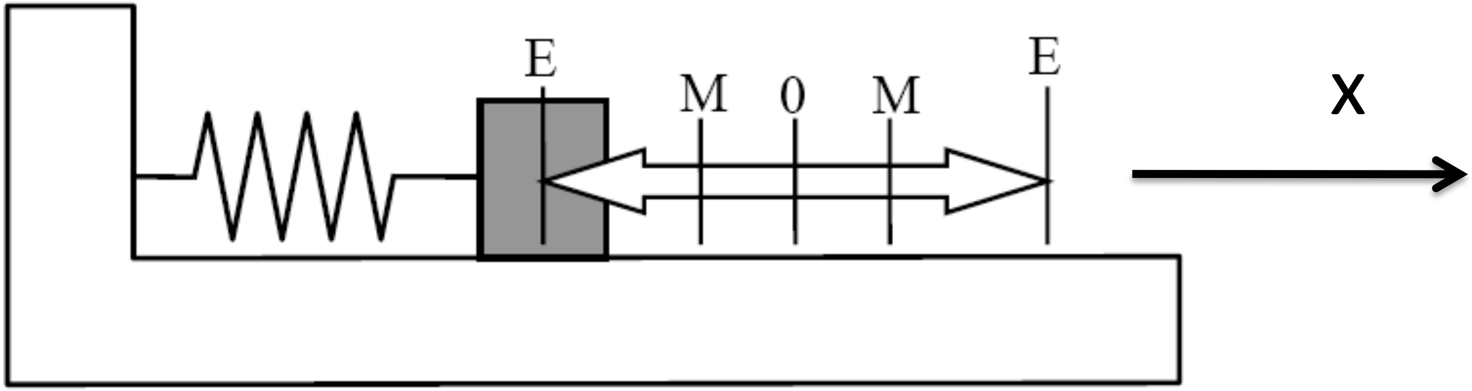
$f = 1/T$ (units Hz)



Clicker Question

Room Frequency BA

A mass on a spring is oscillating back and forth on a frictionless table as shown. Position **0** is the equilibrium position and position **E** is the extreme position (its amplitude).



At which position is the magnitude of the acceleration of the mass maximum?

A) 0 B) M C) E D) *a is constant everywhere*

Net force = - *kx*

Acceleration = (Net Force/mass) = - (*k/m*)*x*

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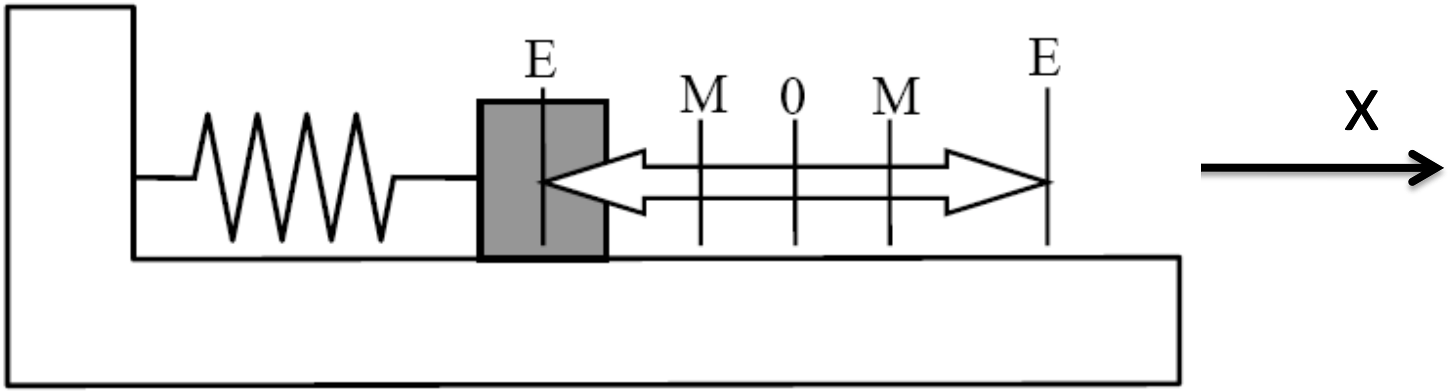


At what position is the total mechanical energy (PE + KE) a maximum?

A) 0 B) M C) E D) energy is constant everywhere.

No friction or dissipative forces! Energy is conserved.

Energy Analysis of Horizontal Spring and Mass

Total Mechanical Energy $$E_{tot} = PE + KE$$

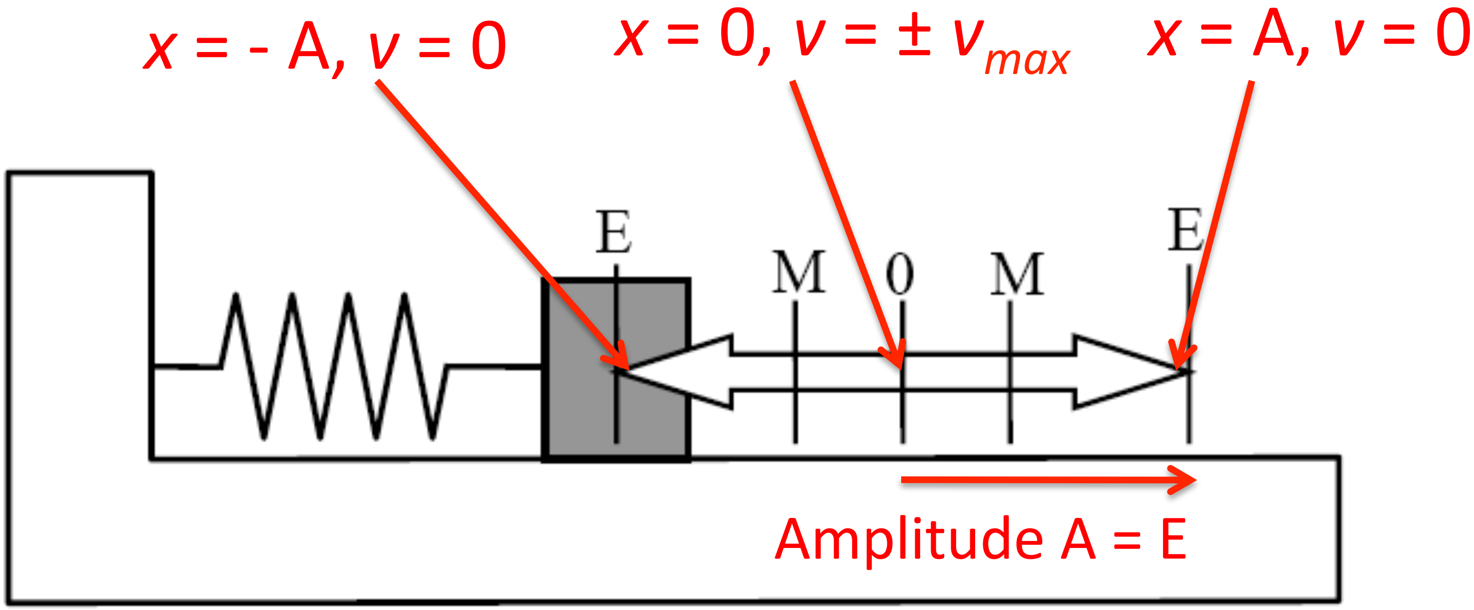
PE for spring with equilibrium at x = 0 is $$PE = \tfrac{1}{2}kx^2$$

As usual, KE = $\tfrac{1}{2}mv^2$

$$E_{tot} = \tfrac{1}{2}kx^2 + \tfrac{1}{2}mv^2$$

Once oscillator is set in motion, total energy is constant, hence we can always determine *x* from *v* or *v* from *x* if we know E_{tot}.

Special Points of Horizontal Spring and Mass Oscillation



$$E_{tot} = \tfrac{1}{2}kx^2 + \tfrac{1}{2}mv^2$$

At turning points $x = \pm A$, $v = 0$, E_{tot} = PE = $\frac{1}{2}kA^2$.

At equilibrium point $x = 0$, $v = \pm v_{max}$, E_{tot} = KE = $\frac{1}{2}mv_{max}^2$.