4.5 – Energy Diagrams

AP Physics 1

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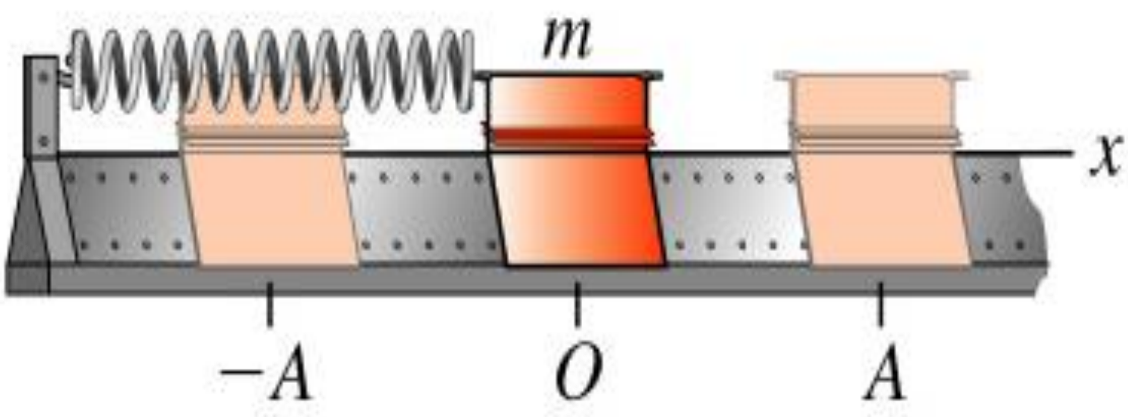
Potential Energy Diagrams

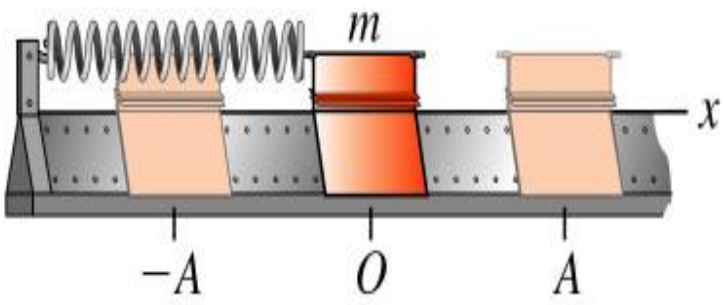
In situations where a particle moves in one-dimension only under the influence of a single ***conservative*** force it is very useful to study the graph of the potential energy as a ***function*** of position: $\boldsymbol{U}(x)$.

Potential Energy Diagrams

Example: Let us consider a glider on an air track (frictionless) attached to a spring. The motion is due to the compressed spring being released.



Potential Energy Diagrams



- The spring exerts a force described by Hooke's Law: F = -kx
- Initially, x = -A
- We consider the motion past the equilibrium point to a distance +A, where the glider stops.
- -A and +A are our boundaries.

Potential Energy Diagrams

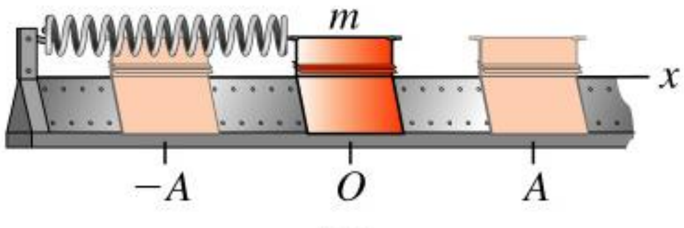
At any point on a graph of ***U***(x) – that is, potential energy U vs position x – the ***force*** can be calculated as the negative of the ***slope of the potential energy*** function:

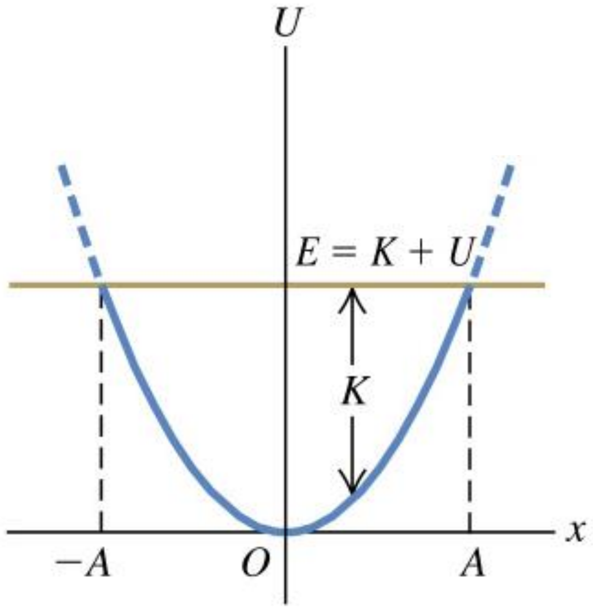
$$\text{F} = -slope = -\frac{\Delta y}{\Delta x} = -\frac{\Delta U}{\Delta x}$$

Potential Energy Diagrams

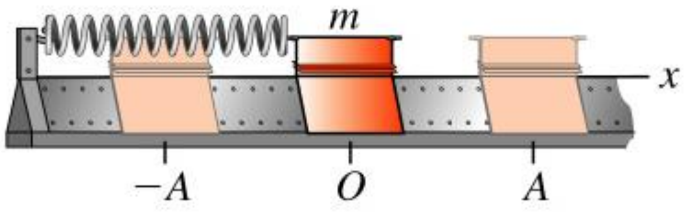
Let us now consider the potential energy, U, versus position, x, of our glider on an air track…

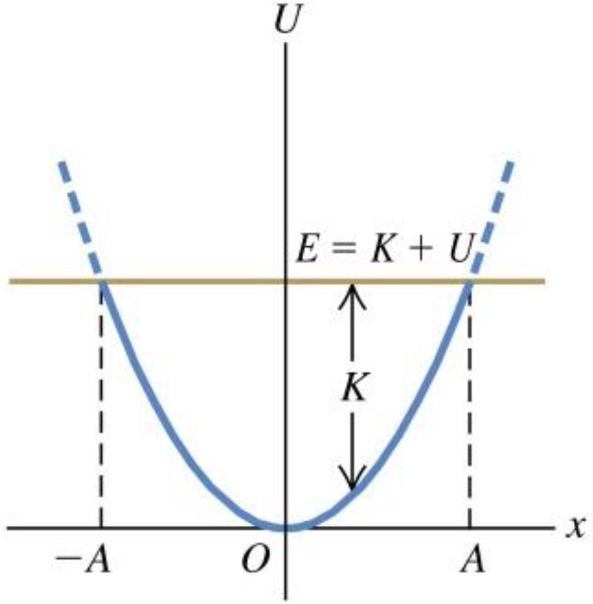
Potential Energy Diagrams





Potential Energy Diagrams

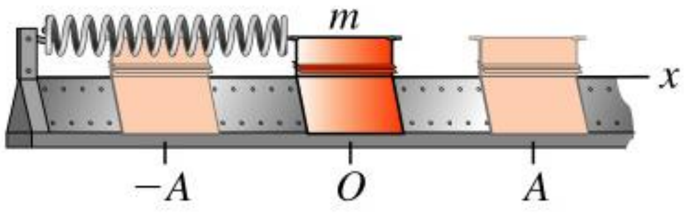


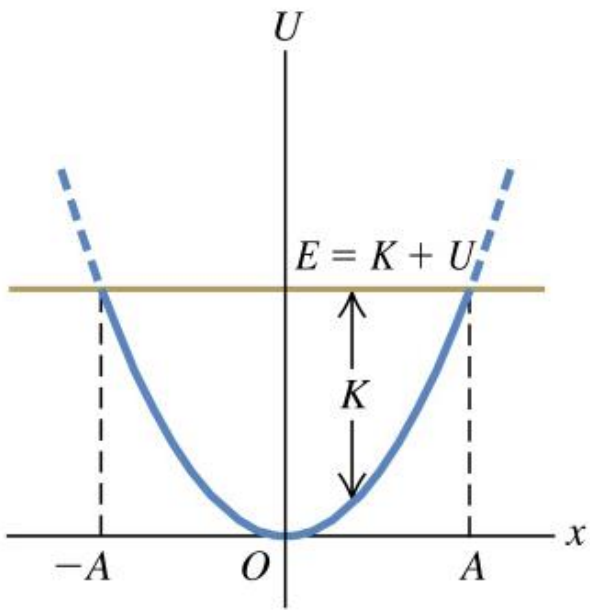


We note:

- The limits of motion are the points where U(x) intersects the horizontal line representing the total mechanical energy, E.
- The system started off with maximum potential energy at –A.
- The system has zero potential energy at point O (all kinetic).
- The glider comes to a rest at A, where the kinetic energy is zero and all energy has returned to the spring in the form of potential energy.
- The point where the force is zero, O, is the equilibrium point.

Potential Energy Diagrams

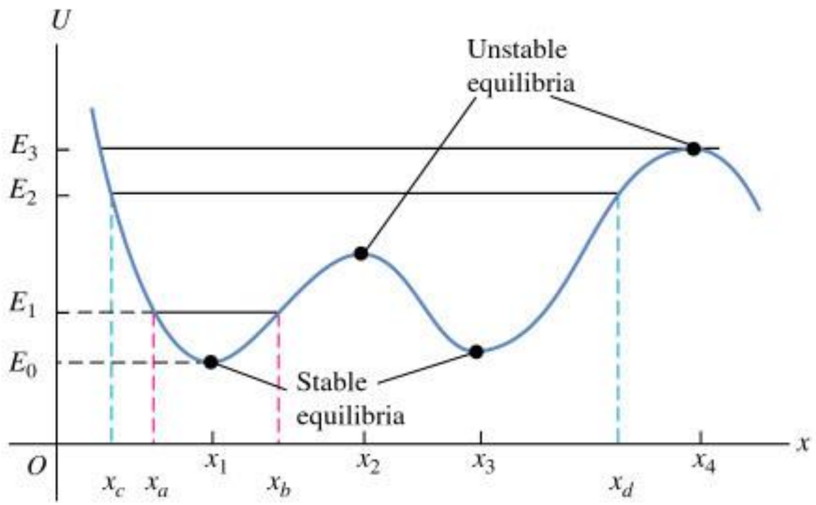




The potential energy graph can be used to determine the <u>speed at any point</u> since

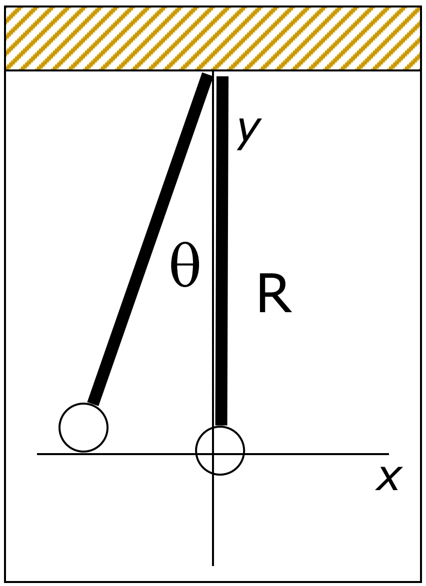
E = ***K*** + ***U*** is constant

Potential Energy Diagrams



- Points on the graph that are local minima correspond to "***stable equilibria***" since the force on particle tends to push it back toward the equilibrium point.
- Points on the graph that are local maxima correspond to "***unstable equilibria***" since force on particle tends to push it back toward the equilibrium point.

Potential Energy Diagrams – The Pendulum

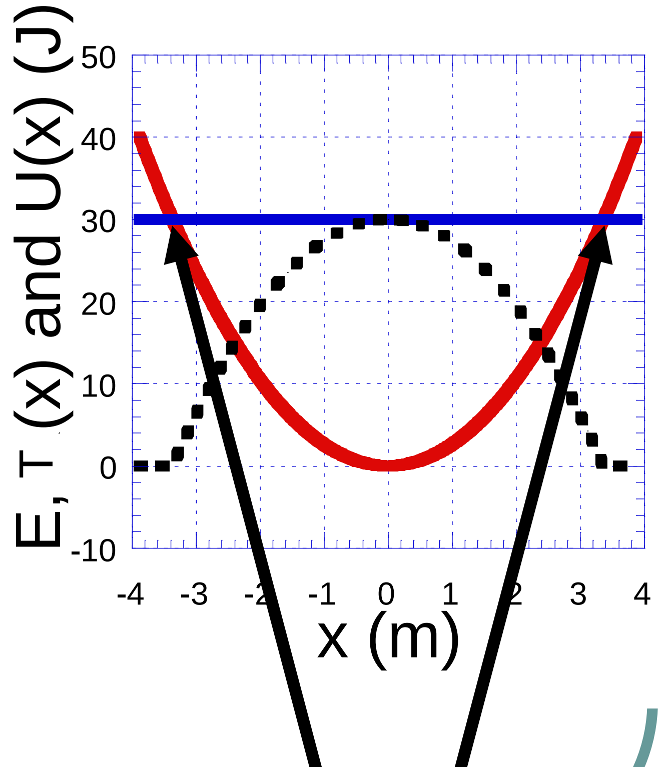


A Pendulum

$$U = mgy$$

$$E = K + U =$$

$$= \frac{1}{2} m v^2 + m g y$$



What is the motion?

T can never be negative

Turning Points

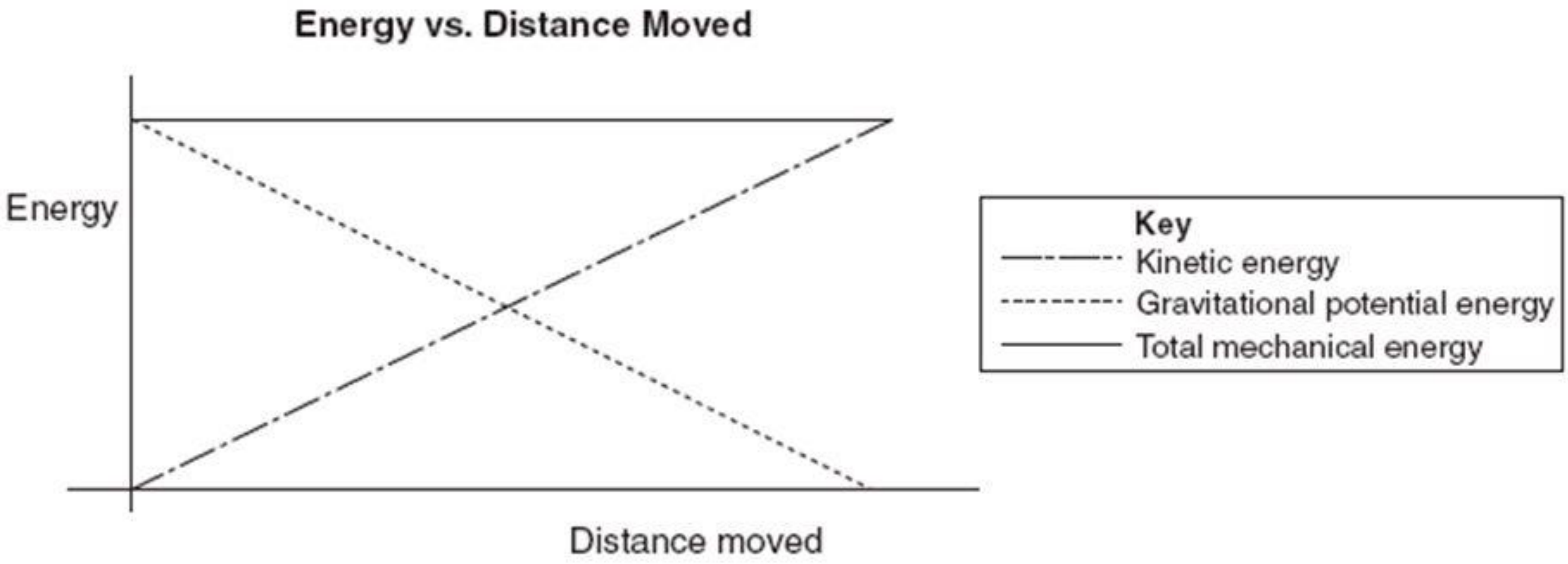
Motion is bounded

Thought Question…

What would an energy vs. position graph look like for an object in free-fall?

Energy graph of a free falling object

The graph shows as a ball is dropped, how its energy is transformed.

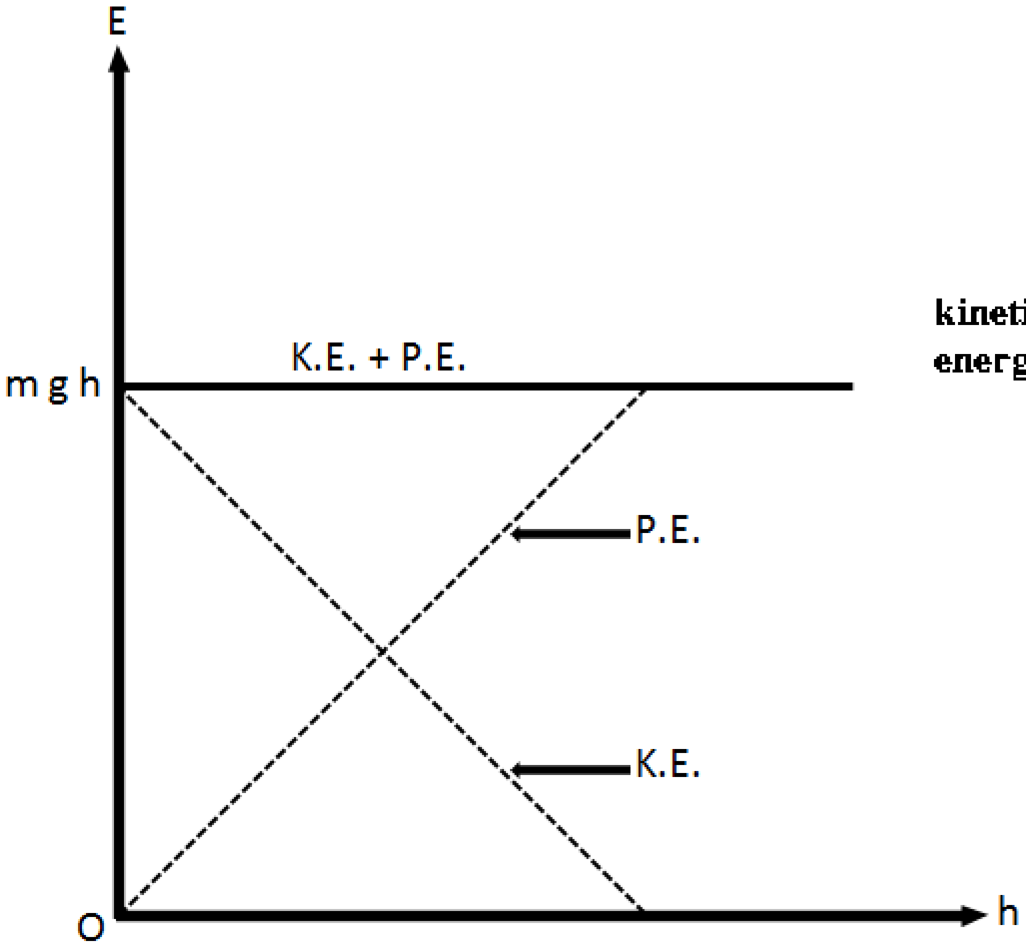


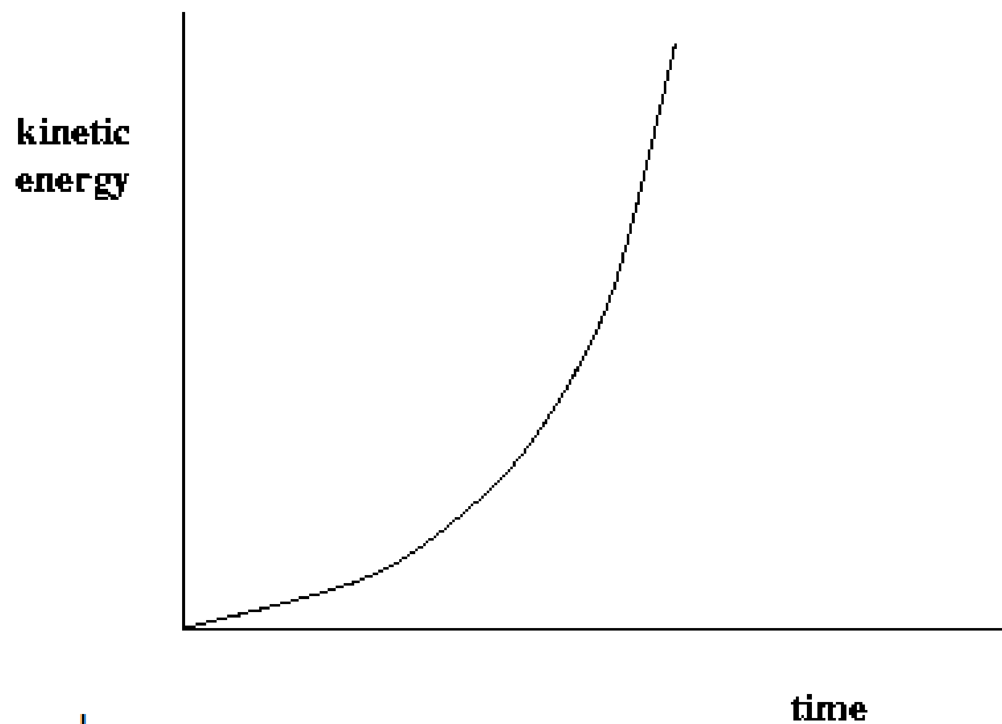
- The total mechanical energy remains constant.
- GPE decreases as KE **increases**

How do we explain the linearity of the kinetic energy graph when $T = 1/2\ mv^2$?

- Potential energy defines the capability (potential!) of the object to do work.
- Indeed, it is the negative slope of the potential curve that defines the direction of the force.
- Since $U = mgh$, the slope for gravitational potential energy for an object in freefall must be a straight line.
- It is this line that defines the force and the kinetic energy curve must be in alignment in accordance to the conservation of mechanical energy, $E_{tot} = U + T$.
- Here, the y-axis represents the total energy.

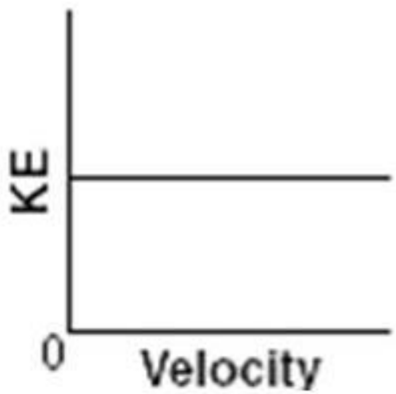
Compare





- Which graph best represents the relationship between the kinetic energy, *KE*, and the velocity of an object accelerating in a straight line?

a



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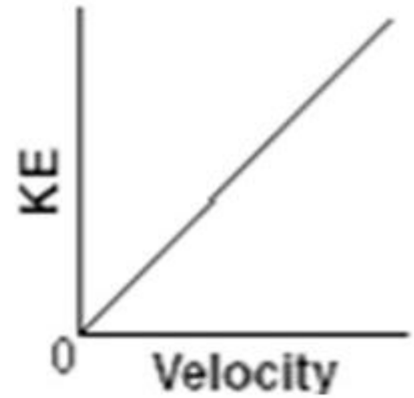

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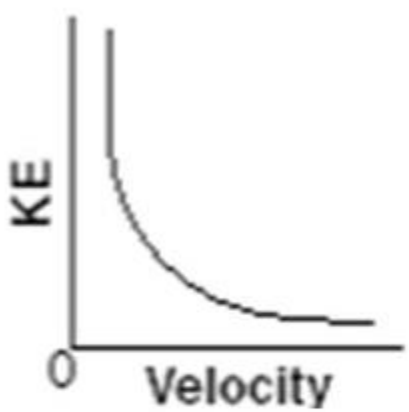

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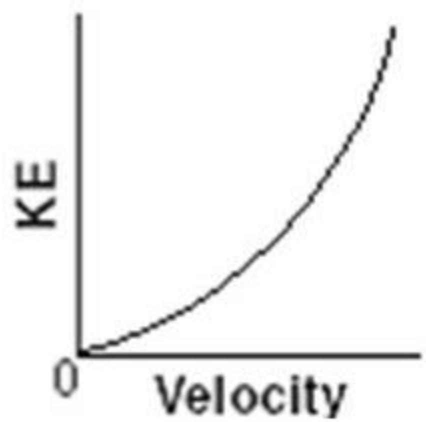
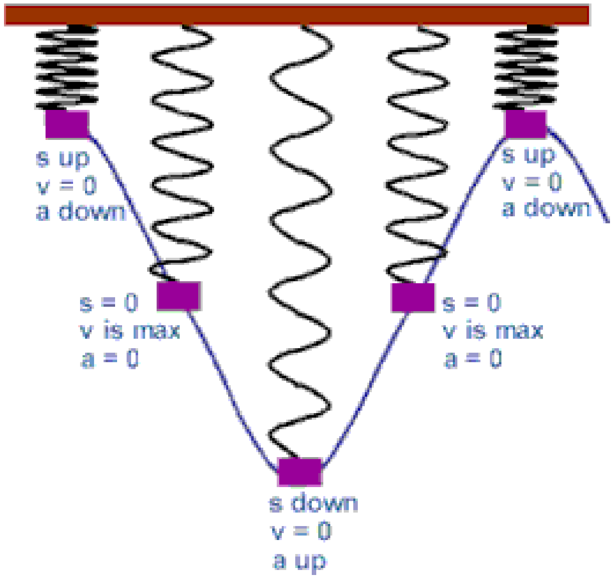


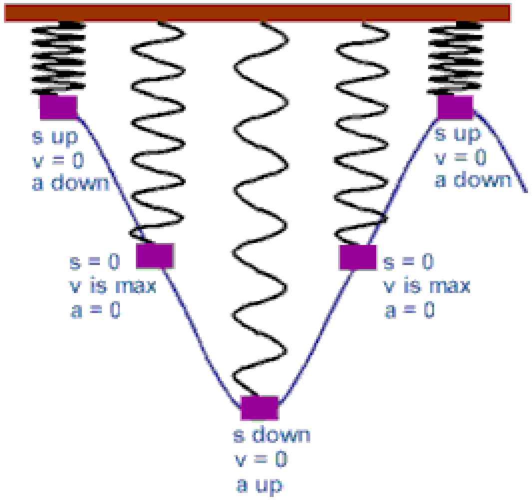
Motion and Energy Diagrams



The motion simulated on the left represents simple harmonic motion. You may assume that the system is operating only under the influence of the spring and is of sufficient distance from a gravitating body that the influence of gravity is negligible. Ignoring the presence of any nonconservative forces, create for one cycle:

a) A Position vs Time Graph
b) A Velocity vs Time Graph
c) An Acceleration vs Time Graph

Motion and Energy Diagrams



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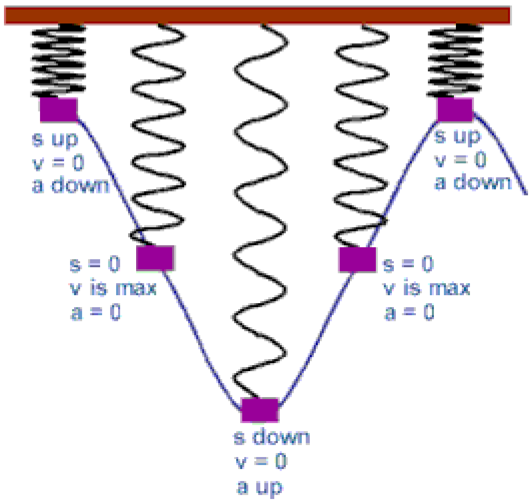

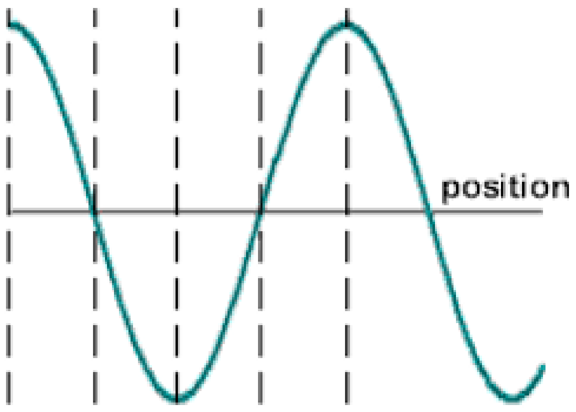

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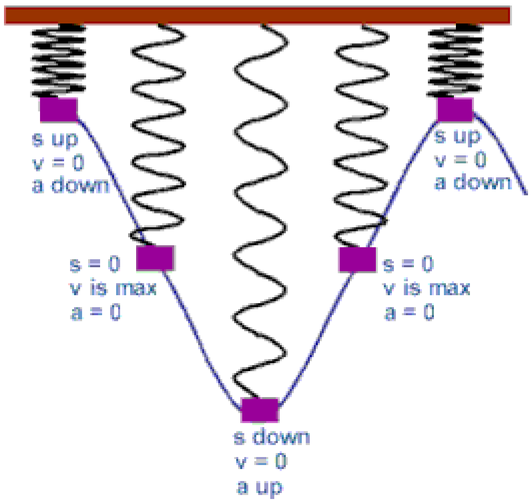

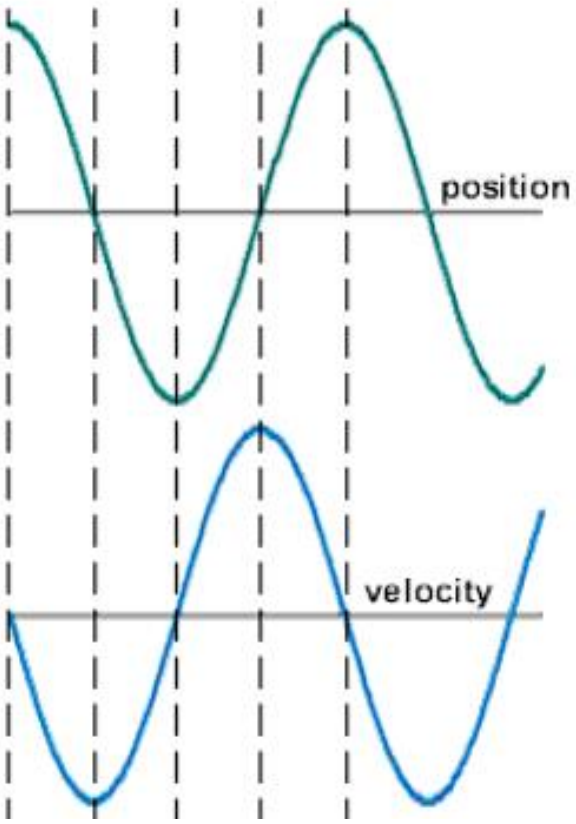

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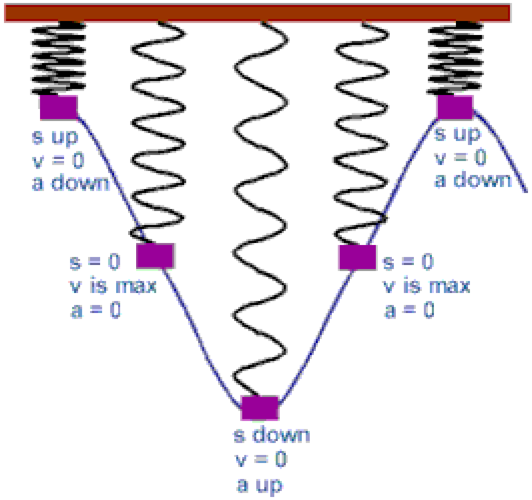

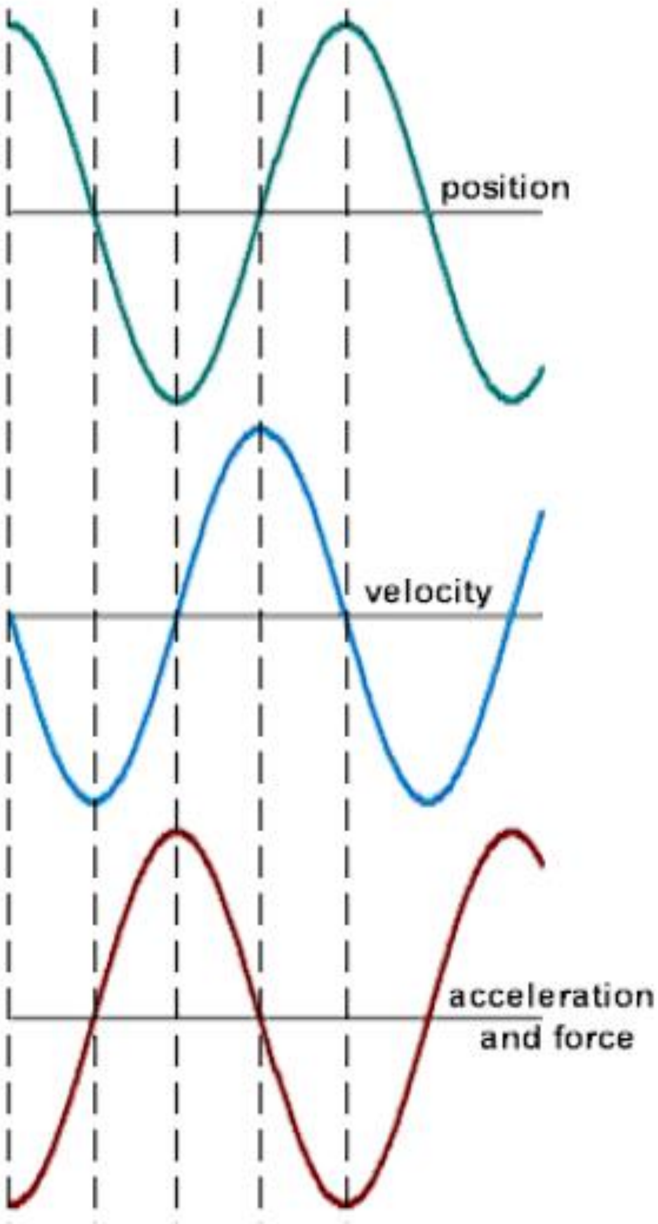

Motion and Energy Diagrams