7.4 – Energy Diagrams

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Energy Diagrams

- Potential energy is an energy of position.
  - The gravitational potential energy depends on the height of an object.
  - The elastic potential energy of a spring depends on its displacement from equilibrium.

- An *energy diagram* shows a system's potential energy *and* total energy as a function of position.

FIGURE 10.30 The energy diagram of a particle in free fall.

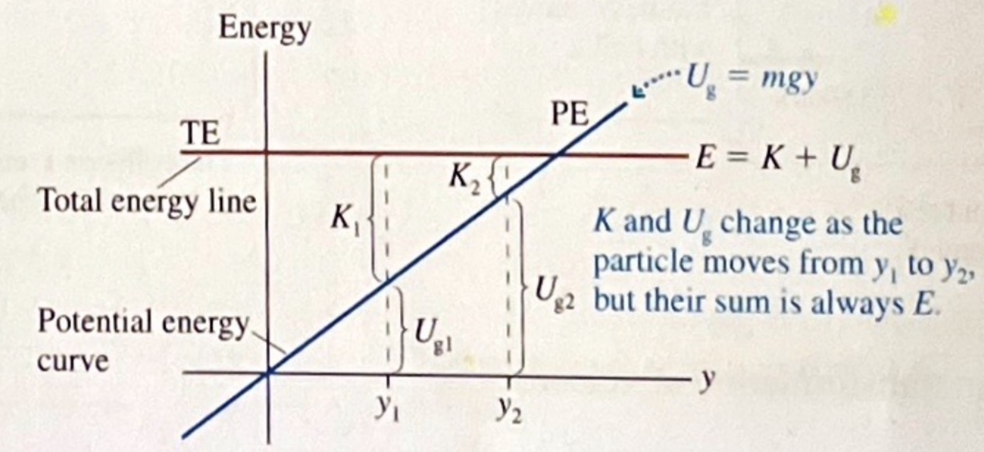
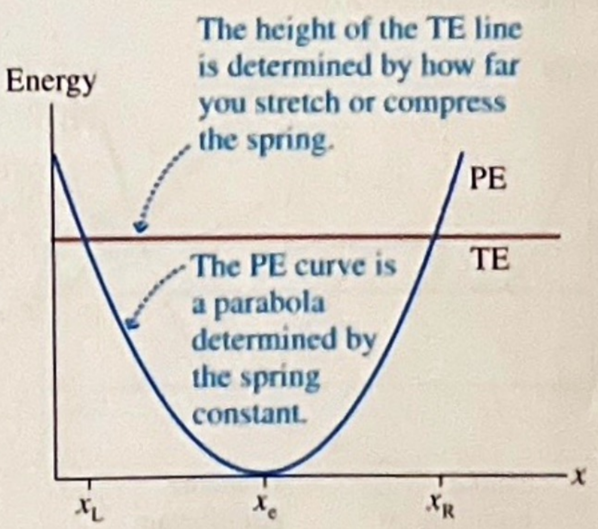


FIGURE 10.32 The energy diagram of a mass on a horizontal spring.



Energy Diagram Example
A Particle in Free-fall

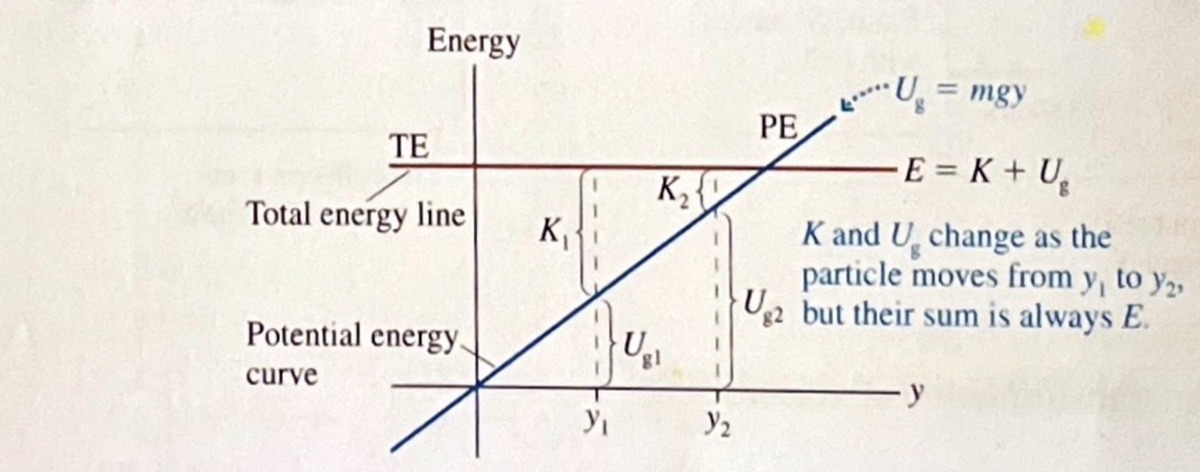
- The energy diagram of a particle in free fall includes the total energy *(TE)* and the gravitational potential energy *(U_g)*.

- $TE = K + U_g$ is constant since the energy is conserved.

- At the origin, the potential energy is zero. Since $TE = K + U_g$ this means that ALL the energy is kinetic. At the origin, the speed of the particle is at its maximum.

- When the particle is at its maximum height, $TE = U_g$ since there is no more available kinetic energy.

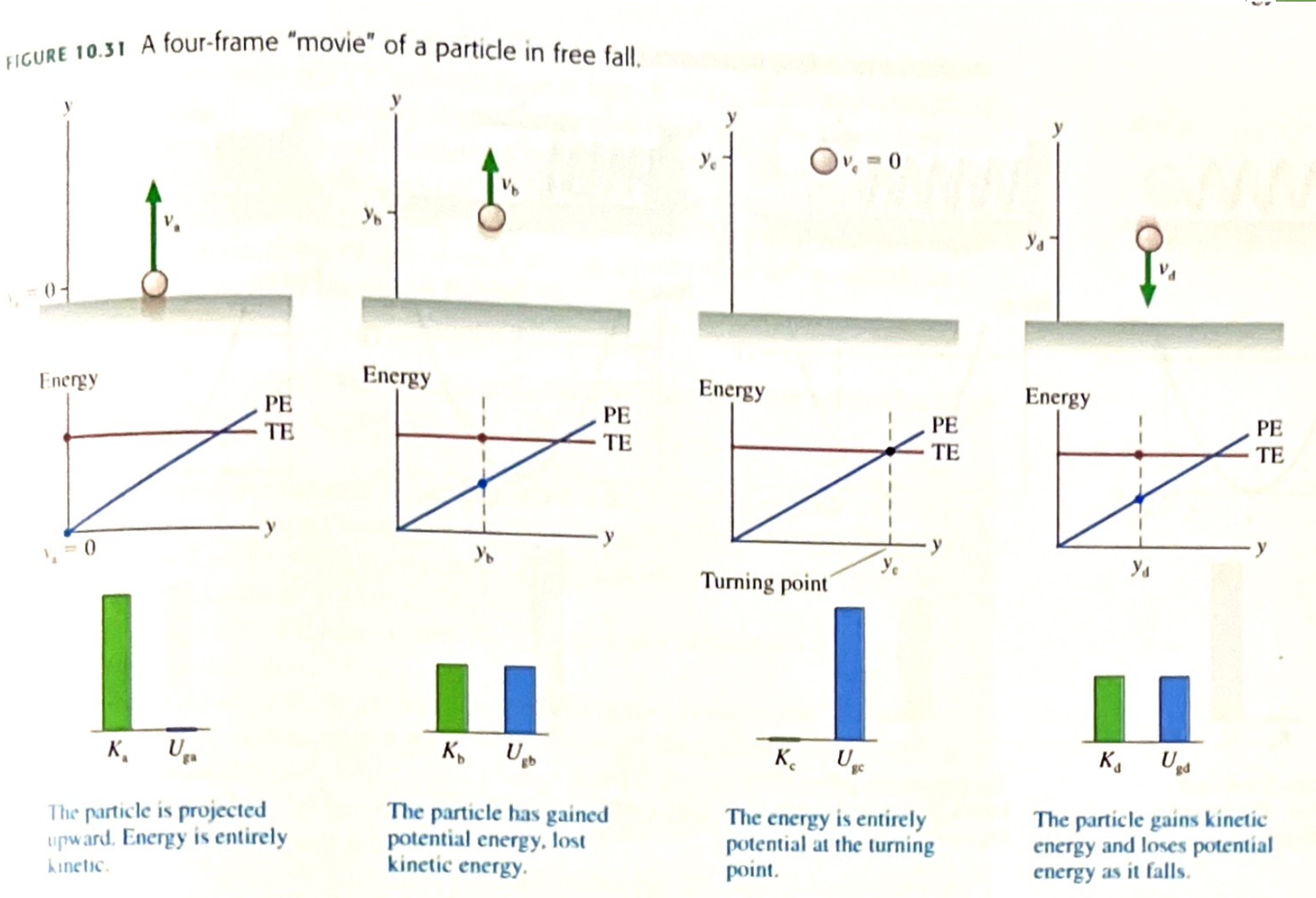
FIGURE 10.30 The energy diagram of a particle in free fall.



- It is not possible for $U_g > TE$ since this would require the kinetic energy of the particle to be negative.

- (kinetic energy can't be negative!)

Energy Diagram Example
A Particle in Free-fall



Energy Diagram Example
A Particle on a Spring

Consider the potential energy of a mass on a horizontal spring:
$U_{\mathrm{sp}} = \frac{1}{2}k(\Delta x)^2$

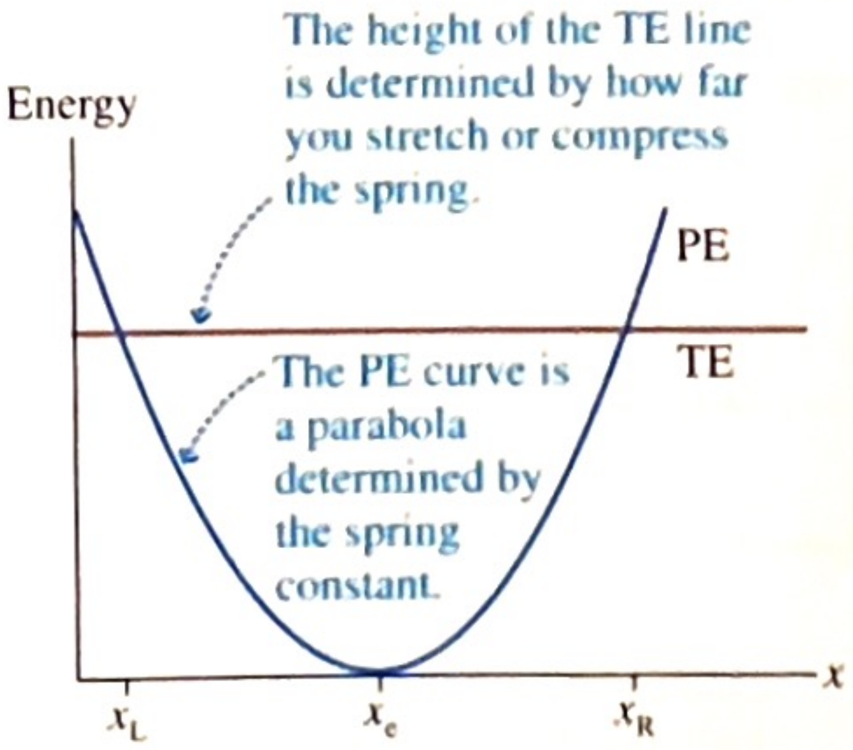
The total energy of the system is: $TE = K + U_{\mathrm{sp}} = \frac{1}{2}mv^2 + \frac{1}{2}k(\Delta x)^2$

The curve of the parabola is determined by the value of k. It is centered on the equilibrium position of the spring, x_e.

Whether the string is stretching or compressing, $K, U_{\mathrm{sp}} > 0$.

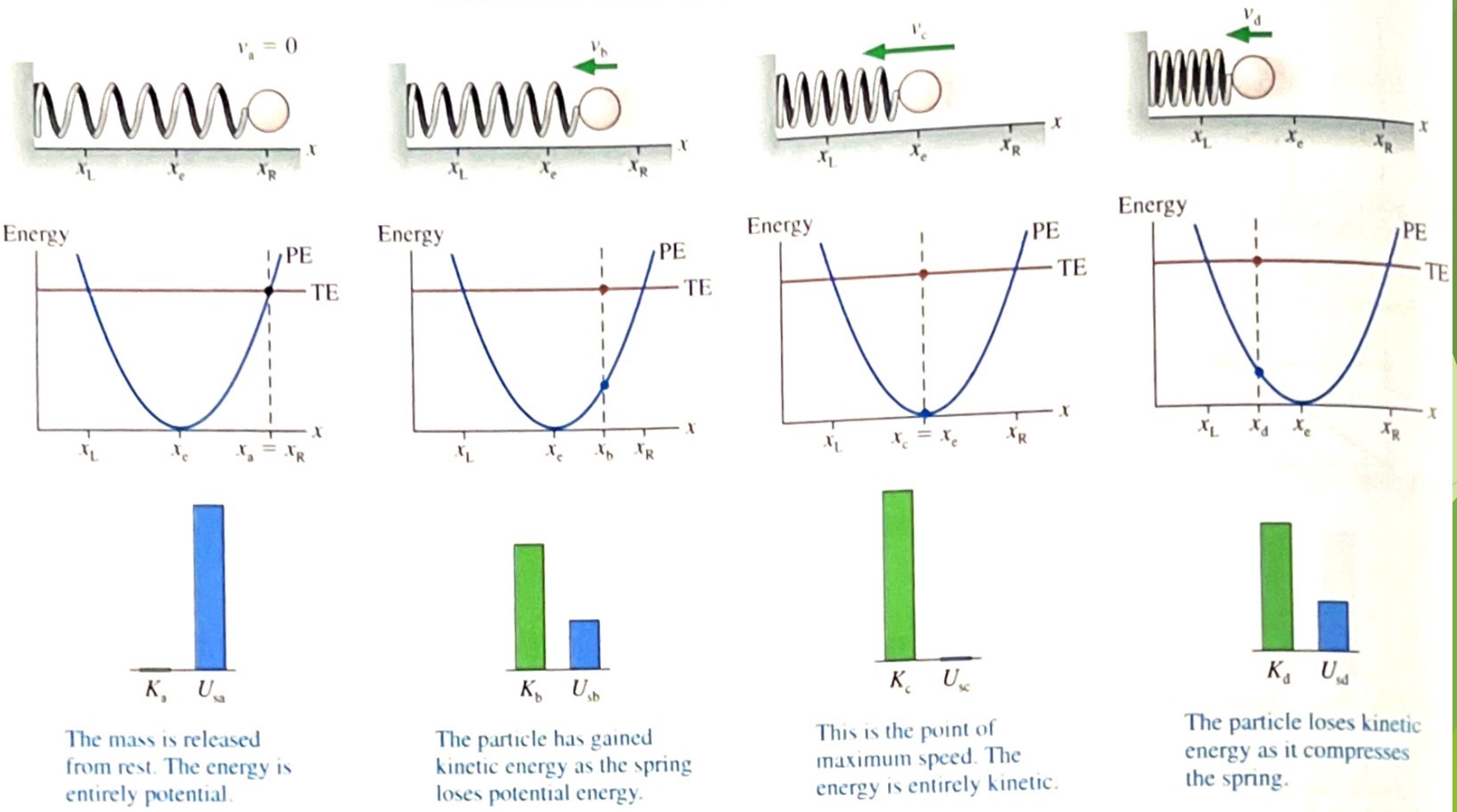
x_L and x_R are turning points. $TE = U_{\mathrm{sp}}$. There is no kinetic energy.

FIGURE 10.32 The energy diagram of a mass on a horizontal spring.



Energy Diagram Example
A Particle on a Spring

FIGURE 10.33 A four-frame movie of a mass oscillating on a spring.



Equilibrium Positions

- Consider the general PE/TE plot presented here…
- The slope of the potential energy shows where the particle is speeding up and slowing down. $K = TE - U$.
- Positions x_2 and x_4 are stable equilibria.
  - Small changes in position around these points will cause a particle to oscillate.
- Position x_3 is an unstable equilibrium.
  - A particle placed at this exact point will not move but adding a small change will cause the particle to move away from the point.

FIGURE 10.34 A more general energy diagram.

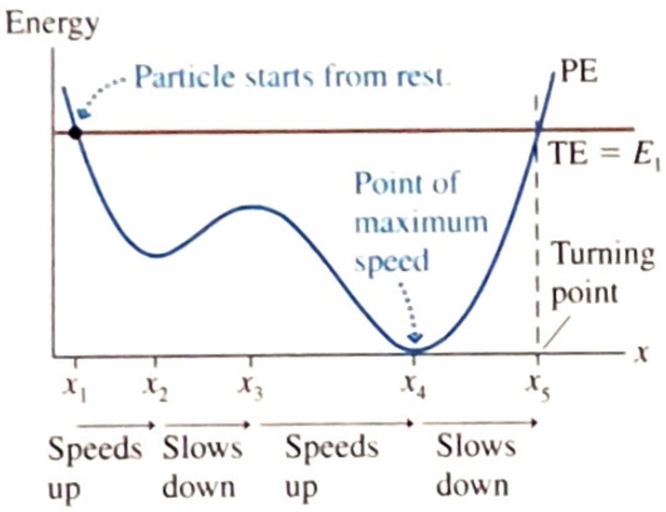
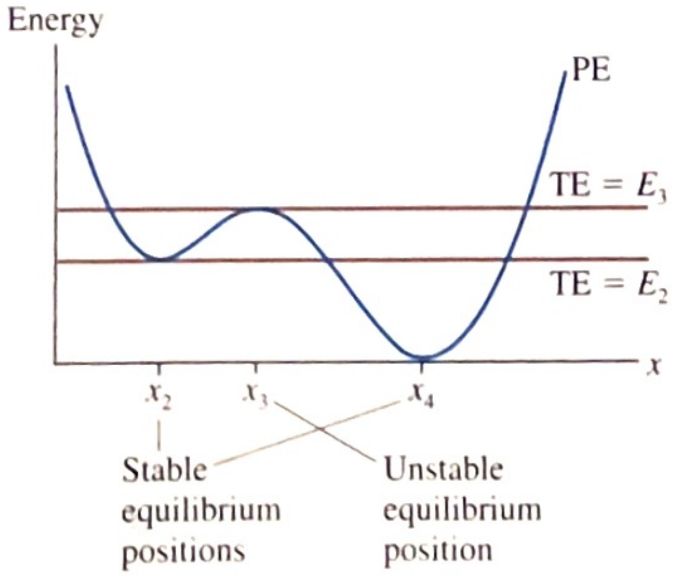


FIGURE 10.35 Points of stable and unstable equilibrium.



Interpreting Energy Diagrams

- The distance from the axis to the PE curve is the particle's potential energy. The distance from the PE curve to the TE line is the particle's kinetic energy. Their sum, K + U, doesn't change.

- A point where the TE and PE lines cross is a turning point. The particle reverses direction.

- The particle cannot be at a point where the PE curve is above the TE line.

- The PE curve is determined by the properties of the system.

- A minimum in the PE curve is a point of stable equilibrium. A maximum in the PE curve is a point of unstable equilibrium.