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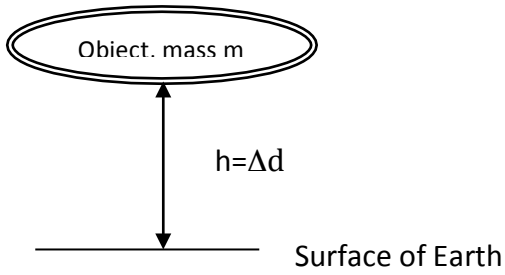
Energy Continued… (E)

Gravitational Potential Energy:

- The energy stored in an object due to its distance above the surface of the Earth.
- The energy stored depends on the mass of the object, the height above the surface, and the strength of the gravitational field.
- On Earth, the strength of the gravitational field (g) is 9.8 m/s^2.
- In this case, an object is raised some height above the surface of the Earth as shown below:



In the example to the left, the object with mass "m" that is acted on by gravity (g) is raised a certain distance above the surface of the Earth (h). The change in energy of the object is $\Delta E = mgh$ or

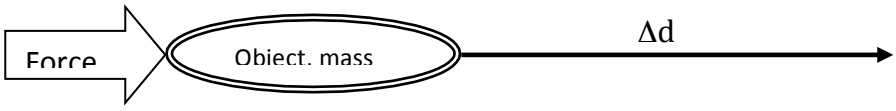
$$E_p = mgh \text{ (if } h_i=0)$$

E_p is measured in Joules
m is measured in kg
g is measured in m/s^2
h is measured in m

Note: sometimes in a word problem it is useful to select the lowest height in the problem as a reference point (call that hi = 0) and measure all changes in height (and subsequently changes in energy) in reference to that point. This is called '*relative potential energy*' and will simplify calculations.

Kinetic Energy:

- The energy acquired by an object that experiences a positive change in velocity
- A moving object has energy, and that energy is proportional to the mass and the square of the speed.
- The more mass an object has, and the faster it moves, the more energy it has, and the greater capacity it has to do work.
- In this case, energy is imparted to an object set in motion according to the following:



$$E_k = \tfrac{1}{2} mv^2$$

E_k is measured in Joules (J); **m** is measured in kg; **v** is measured in m/s.

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Practice – Kinetic and Potential Energy

1. A crane lifts a 1500 kg car 20 m straight up.
    a. How much potential energy does the car gain?
    b. How much energy does the crane transfer to the car?
    c. How much work does the crane do?

2. A 0.0400 kg rubber ball drops from a height of 5.00 m to the ground and bounces back to a height of 3.00 m above the ground.
    a. How much potential energy does the ball lose on its trip down?
    b. How much potential energy does the ball regain on its trip back up?

3. A man on a flying trapeze stands on a platform 20m above the ground, holding the trapeze. The trapeze is 10 m long and is attached to the roof 26m above the surface of the ground. The man swings down, and lets go of the trapeze on the upswing. He has a mass of 60 kg. Calculate his potential energy relative to the ground at the following heights:
    a. 20 m (on platform)
    b. 16 m (bottom of swing)
    c. 18 m (lets go of trapeze)
    d. 9 m (halfway to ground)

4. What is the kinetic energy of a 0.50 kg ball thrown at 30.0 m/s?

5. What is the mass of an object travelling at 20 m/s with a kinetic energy of 4000 J?

6. What is the speed of a 1.5 kg rock falling with a kinetic energy of 48J?

7. How much work is required to accelerate a 150 kg motorbike from 10 m/s to 20 m/s?

8. A 0.50 kg rubber ball is thrown into the air. At a height of 20 m above the ground, it is travelling at 15 m/s.
    a. What is the ball's kinetic energy?
    b. What is its gravitational potential energy relative to the ground?
    c. How much work has been done by someone at ground level throwing the ball up into the air?

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Mechanical Energy:

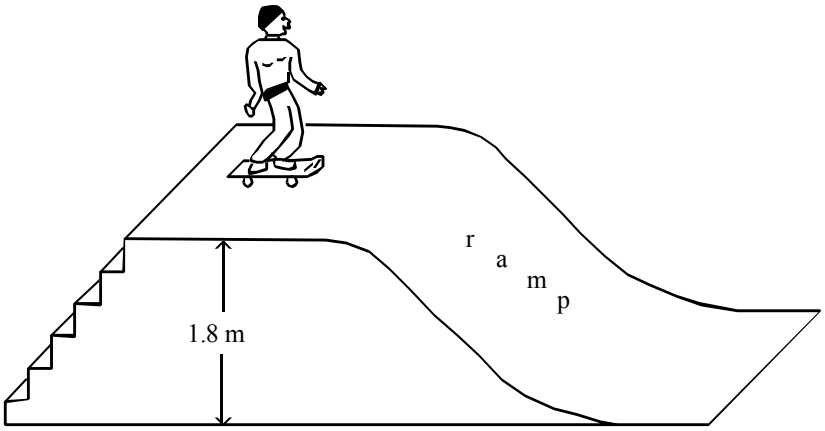
- As we have learned, it is possible to convert between one form of energy and another.
- Specifically we will see that it is possible to change potential energy into kinetic energy and vice versa.
- The sum of the potential energy and kinetic energy possessed by an object is called the mechanical energy.

$$E_m = E_p + E_k$$
$$= mgh + \tfrac{1}{2} mv^2$$

- the law of conservation of energy states that in a system without friction, the mechanical energy is always constant.

Example:

A child and his skateboard have a mass of 60 kg.
Starting from rest, he goes down a ramp whose vertical drop is 1.8 m.



What is the boy's speed at the bottom of the ramp? Disregard the effects of friction.

A) 9.0 m/s

B) 6.0 m/s

C) 3.0 m/s

D) 2.0 m/s

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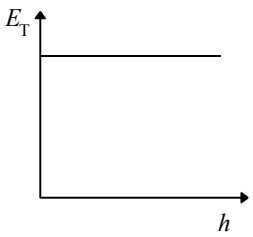
Practice Questions – Mechanical Energy

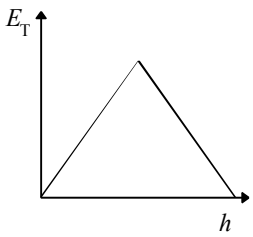
1. A football is kicked into the opposing team's zone by the *Dragons'* quarterback.

Which of these graphs shows the **total mechanical energy**, E_T, of the football as a function of its height, h? (Ignore the effects of air resistance.)

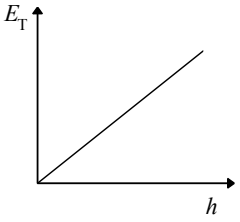
A)



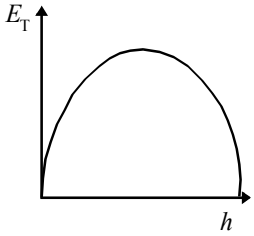
C)



B)

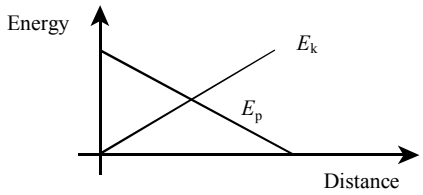


D)

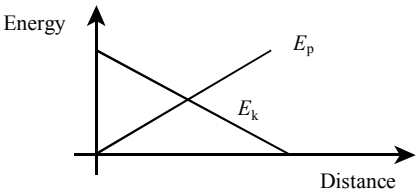


2. A cart is launched up a frictionless inclined plane. Which of the following graphs best represents the transformation of the different types of energy involved in the movement up the ramp?

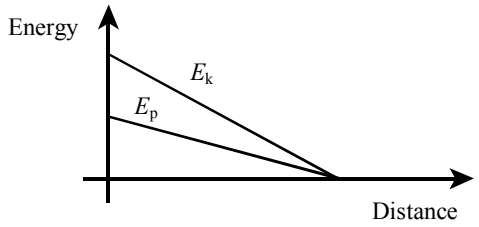
A)



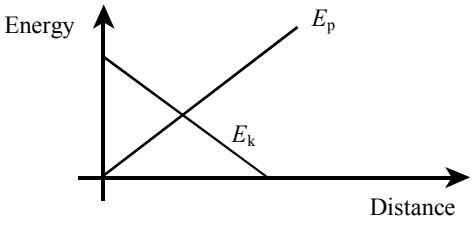
C)



B)



D)



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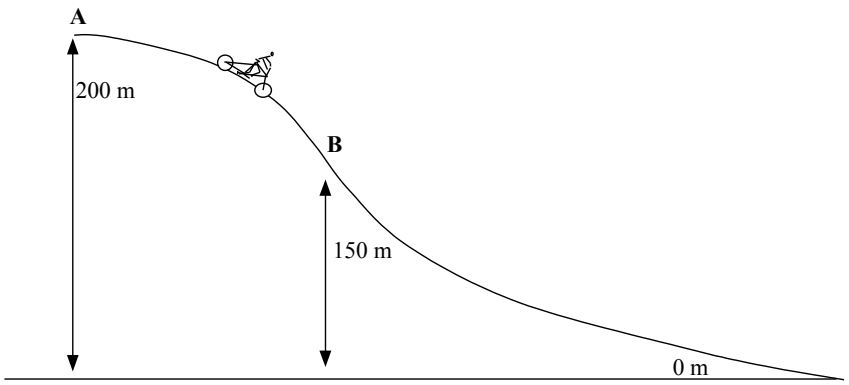
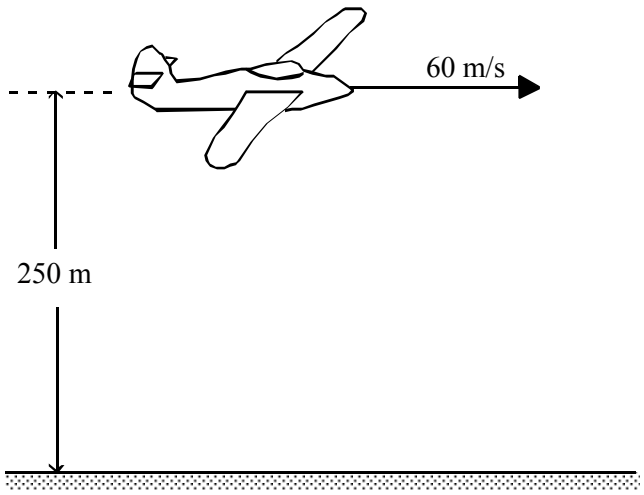
3. A mountain bike rider starts at rest at point **A,** 200 m above the base of a mountain and descends the slope without pedaling. (Friction is negligible)



What is his velocity at point B, 150 m above the base of the mountain? Show all of your work.

4. A small airplane with a mass of 1000 kg, is flying at 60 m/s at an altitude of 250 m.



What is the total mechanical energy of this airplane with respect to the ground?

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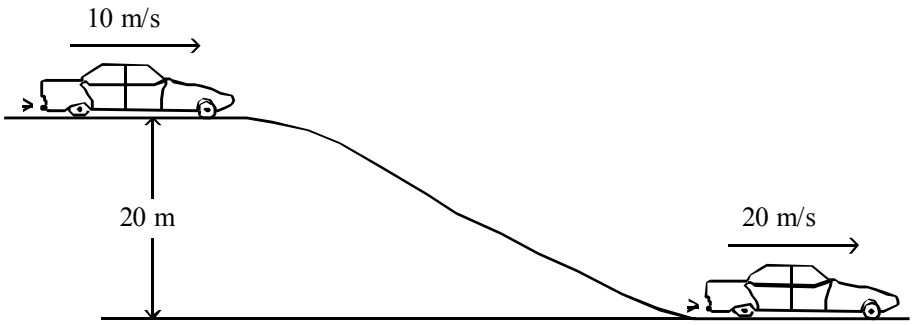
5. A car with a mass of 1 000 kg arrives at the top of a hill 20 m high at a speed of 10 m/s. At the bottom of the hill, the speed of the car is 20 m/s.



How much work was done on the car as it went downhill?

A) 1.0×10^5 J

B) 1.5×10^5 J

C) -2.0×10^4 J

D) -4.6×10^4 J

6. Calculate the total mechanical energy in each of the following situations?

A) An automobile of mass 1000 kg travelling in a straight line through a distance of 1000 m at a speed of 30 m/s.

B) An automobile of mass 1000 kg travelling in a straight line through a distance of 1000 m at a speed of 40 m/s.

C) A small plane of mass 1000 kg flying at an altitude of 1000 m at a speed of 40 m/s.

D) A small plane of mass 1000 kg flying at an altitude of 1000 m at a speed of 30 m/s.

7. An Olympic diver runs along a 3 m high diving board, jumps into the air, and dives into the pool below. The 56 kg diver has a speed of 8.0 m/s the moment she leaves the diving board. At what point is her gravitational potential energy at its maximum?

A) While she is running along the diving board

B) When she jumps into the air

C) Just before she hits the water

D) When she is under water