PHYSICS 534

ANSWERS

EXERCISE 39 **Potential Energy Part-1 /2**

CHADWICK

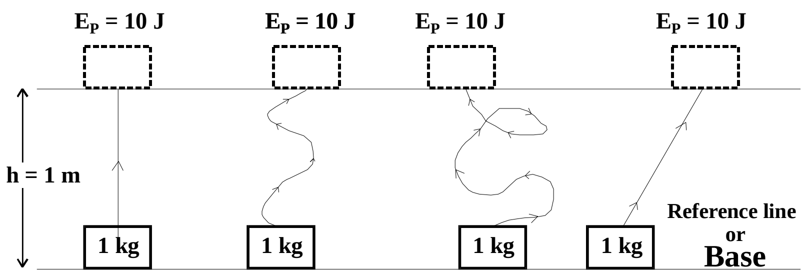
James Chadwick was awarded the Nobel prize for physics in 1935 for his discovery of the neutron.

Potential energy is stored energy because it has the "potential" of being used at a future time. The potential energy of an object, E_P, depends upon its position.

When an object is raised, work is done. The energy used to raise the object is in the form of ***gravitational*** potential energy or just simply the potential energy. The formula for potential energy is as follows:

$E_P = mgh$ where: E_P is the potential energy, in joules (J)
m is the mass of the object, in kilograms (kg)
g is the acceleration due to gravity (9.8 m/s^2 or for simplicity 10 m/s^2)
h is the height the object is raised, in metres (m)

Note: In raising an object, the potential energy gained by the object does not depend upon the path of the object. That is, the height is the perpendicular distance from the horizontal. In the illustration below, a 1 kg object is raised 1 metre. In each case, the potential energy ***gained*** by the object is 10 J.



➢ **IMPORTANT**: The potential energy of a system depends upon where we choose the ***base*** for the height, h.

The Law of Conservation of energy states that energy cannot be created nor destroyed. Thus, when an object is raised, work is done and the object stores the energy in the form of potential energy. When the object falls freely, the potential energy in converted into kinetic energy. Gradually, as the object falls down, the loss in potential energy becomes the gain in kinetic energy. However, at all points during the fall, the total energy is the sum of the potential energy plus the kinetic energy and remains constant. $E_T = E_P + E_K$

☝ **REMEMBER**: Most mechanical processes involve exchanges in kinetic, potential and work energy.

....

Hint: In solving energy problems involving the inclined plane, separate the energy calculations into three parts as listed below:

① Work to overcome friction [W = fs] (If the system is ideal, then skip this part)

② Work to accelerate the object [ΔE_K] (Consider the inclined plane as an ideal horizontal plane)

③ Work to raise object [ΔE_P or W = wg = mgh]

+ **Note**: **Use 10 m/s² for the acceleration due to gravity.**

1. A 20 kg object is raised 3 metres. Calculate the work done and tell where the energy went.

E_P = mgh = (20 kg)(10 m/s²)(3 m) = 600 J
Work goes to the object in the form of E_P.

2. A ball is thrown up in the air. Explain the change in energy of the ball while going up and while coming back down.

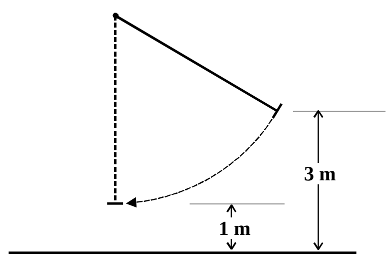
a) Going up: [illegible]

b) Coming down: [illegible]

3. A 1400 kg car is travelling at 10 m/s. Upon arriving at a hill, the car is allowed to coast. How ***high*** up the hill will the cart rise before coming to a stop? [5 m]

$$E_P = E_K$$
$$mgh = \frac{1}{2}mv^2$$
$$h = \frac{v^2}{2g} = \frac{(10\ m/s)^2}{2(10\ m/s^2)} = 5\ m$$

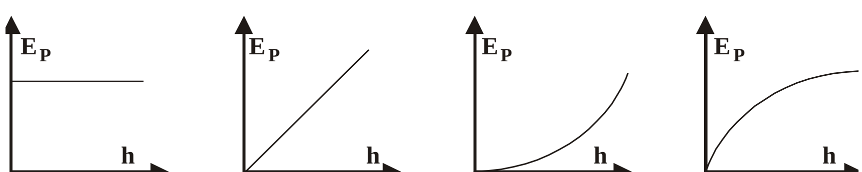
4. An empty swing is at its highest point 3 m from the ground and at its lowest point 1 m from the ground. What is its maximum speed at its lowest point? [6.3 m/s]



$$E_K = E_P$$
$$\frac{1}{2}mv^2 = mgh$$
$$v^2 = 2gh$$
$$v = \sqrt{2gh} = \sqrt{2(10\ m/s^2)(2\ m)} = 6.3\ m/s$$

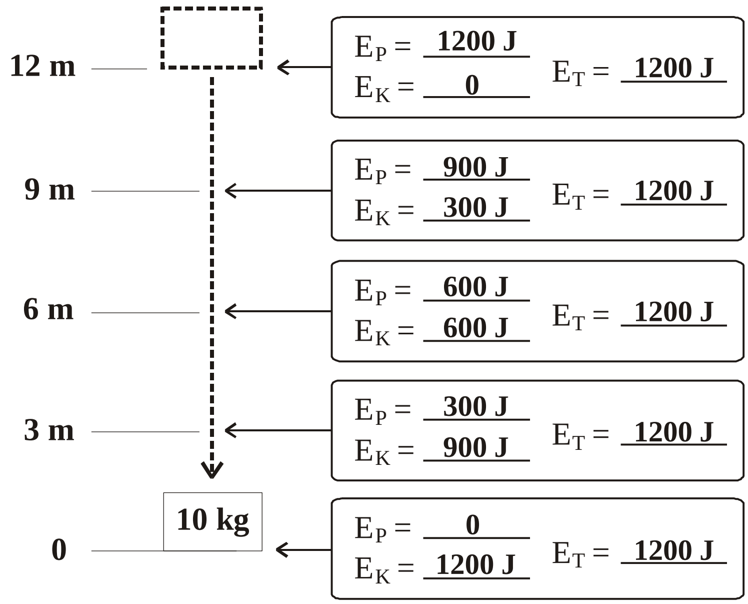
3 m − 1 m

5. An object is thrown vertically upward. Which graph represents the potential energy of the object as a function of its height?

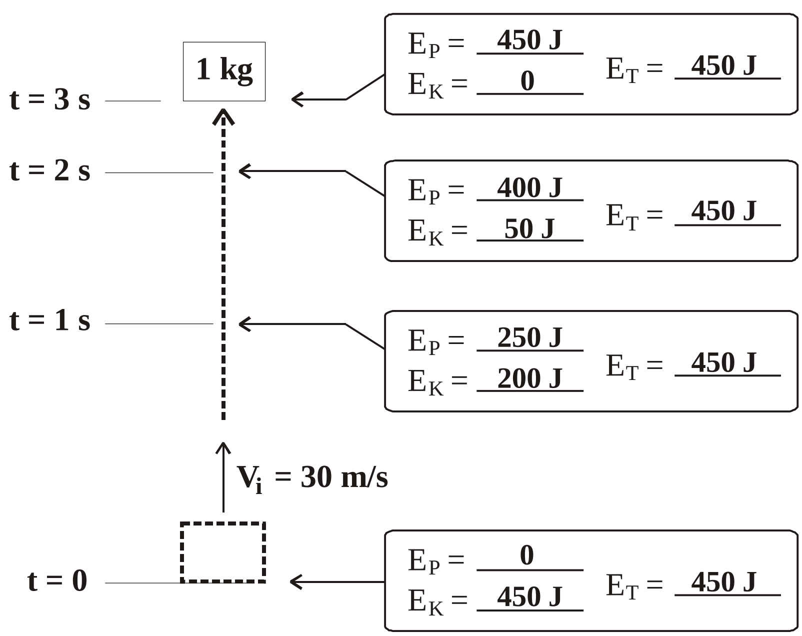


(A) **(B)** **(C)** **(D)**

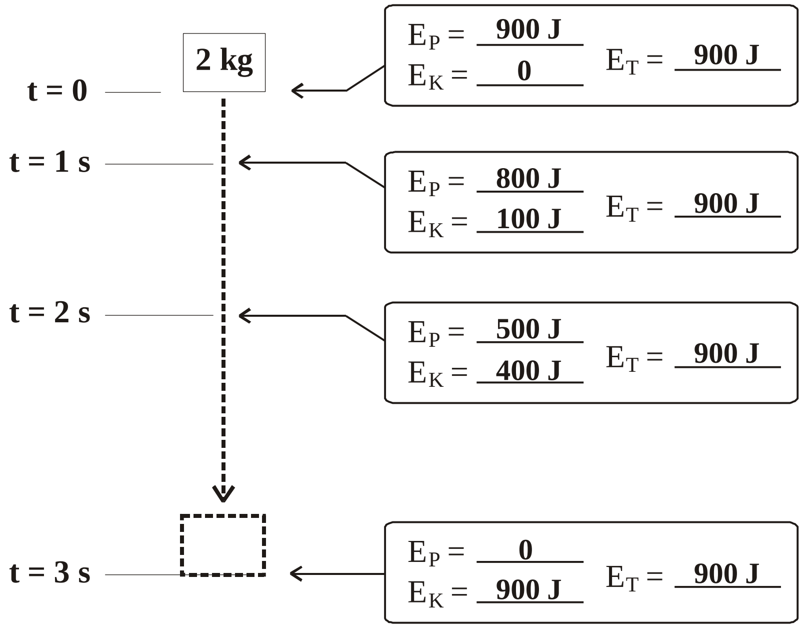
6. A 10 kg object falls from a height of 12 m. Fill in the potential, kinetic and total energy of the object at the given points.



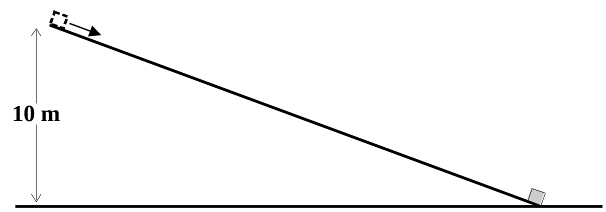
7. A 1 kg mass is fired into the air with a vertical velocity of 30 m/s. Fill in the potential, kinetic and total energy of the object for each second it rises.



8. A 2 kg object falls from rest. Fill in the potential, kinetic and total energy of the object for the first 3 seconds of fall.



9. An object starts from rest and slides down a frictionless ramp from a height of 10 m. What is the speed of the object at the bottom of the ramp? [14 m/s]



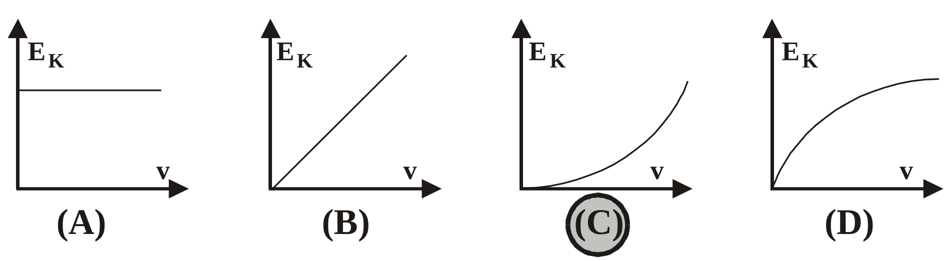
$$E_K = E_P$$

$$\frac{mv^2}{2} = mgh$$

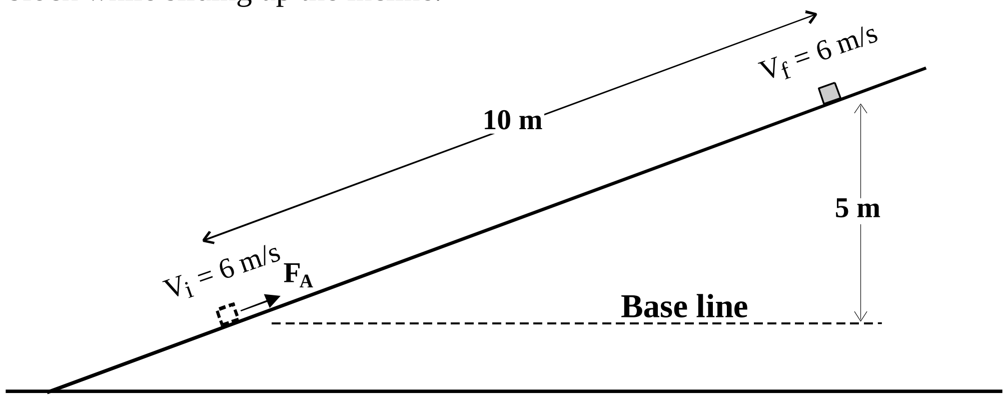
$$\therefore \quad v^2 = 2gh$$

$$v = \sqrt{2gh} = \sqrt{2(10\ m/s^2)(10\ m)} = \sqrt{200\ m^2/s^2} = 14.1\ m/s = 14\ m/s$$

10. Which of the following graphs correctly illustrates the relationship between the kinetic energy of a car versus its velocity?



11. A 20 kg block is pushed up an incline at a ***constant velocity*** of 6 m/s by a force applied ***parallel*** to the incline (F_A). As illustrated in the diagram below, the incline is 10 m long and 5 m high. Assuming the system is frictionless, answer the following questions concerning the block while sliding up the incline.



Part-A: ***Work done to accelerate the block.***

a) What is the change in velocity? (Δv) 0

b) What is the acceleration? 0

c) What is the initial E_K of the block? (Use $E_K = ½mv^2$) 360 J

d) What is the final E_K of the block? (Use $E_K = ½mv^2$) 360 J

e) How much ***kinetic energy*** did the block gain? (ΔE_K) 0

Part-B: ***Work done to raise the block (relative to base line).***

f) What is the weight of the block? 200 N

g) What height is the block raised? 5 m

h) How much work is done to raise the block? (Use $E_P = wh$) 1000 J

i) What is the initial E_P of the block? (Use $E_P = mgh$) 0

j) What is the final E_P of the block? (Use $E_P = mgh$) 1000 J

k) How much ***potential energy*** did the block gain? (ΔE_P) 1000 J

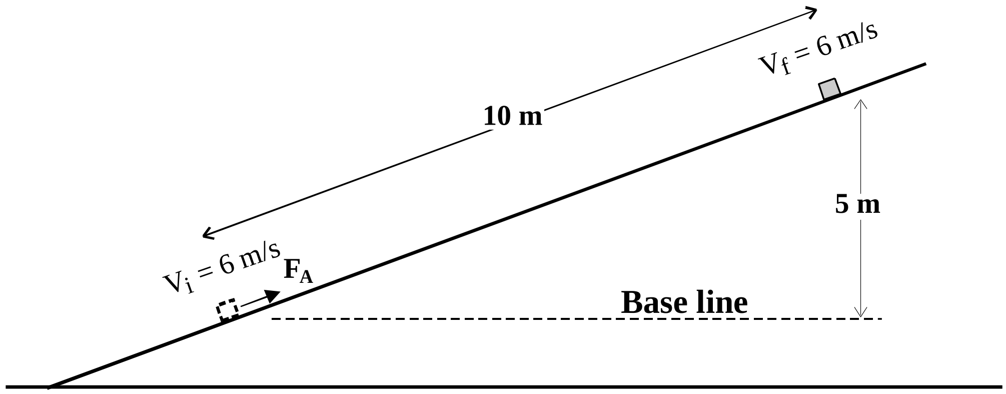
Part-C: ***Work done to overcome friction.***

l) What is the frictional force? 0

m) What work is done to overcome friction? (Use W = fs) 0

n) What is the ***total work*** done? (W_T) 1000 J
(W_T = Increase in E_K + Increase in E_P + work to overcome friction)

12. A 20 kg block is pushed up an incline at a ***constant velocity*** of 6 m/s by a force applied ***parallel*** to the incline (F_A). As illustrated in the diagram below, the incline is 10 m long and 5 m high. If the force of friction is 20 N, answer the following questions concerning the block while sliding up the incline.



Part-A: ***Work done to accelerate the block.***

a) What is the change in velocity? (Δv) ______ 0

b) What is the acceleration? ______ 0

c) What is the initial E_K of the block? (Use $E_K = ½mv^2$) ______ 360 J

d) What is the final E_K of the block? (Use $E_K = ½mv^2$) ______ 360 J

e) How much ***kinetic energy*** did the block gain? (ΔE_K) ______ 0

Part-B: ***Work done to raise the block (relative to base line).***

f) What is the weight of the block? ______ 200 N

g) What height is the block raised? ______ 5 m

h) How much work is done to raise the block? (Use $E_P = wh$) ______ 1000 J

i) What is the initial E_P of the block? (Use $E_P = mgh$) ______ 0

j) What is the final E_P of the block? (Use $E_P = mgh$) ______ 1000 J

k) How much ***potential energy*** did the block gain? (ΔE_P) ______ 1000 J

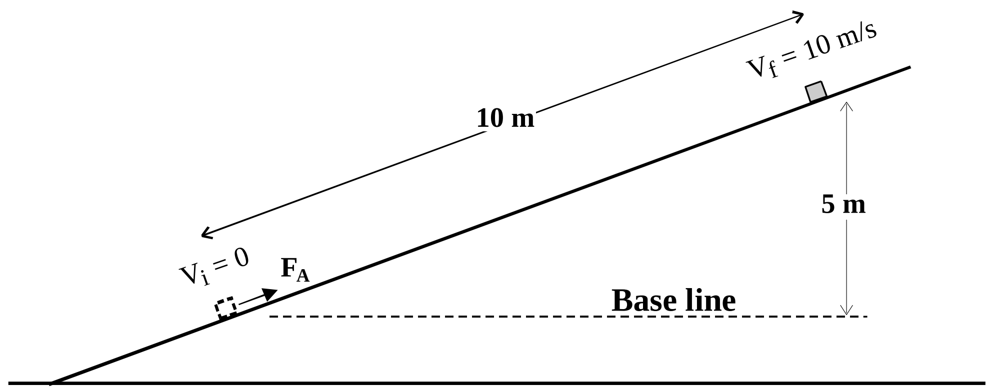
Part-C: ***Work done to overcome friction.***

l) What is the frictional force? ______ 20 N

m) What work is done to overcome friction? (Use $W = fs$) ______ 200 J

n) What is the ***total work*** done? W_T ______ 1200 J
(W_T = Increase in E_K + Increase in E_P + work to overcome friction)

13. Starting from rest, a 20 kg block is pushed 10 m up an incline resulting in a final velocity of 10 m/s. As illustrated in the diagram, the force applied (F_A) acts ***parallel*** to the incline thereby raising the block 5 m. Assuming there is no friction, answer the following questions concerning the block while sliding up the incline.



Part-A: ***Work done to accelerate the block.***

a) What is the change in velocity? (Δv) ___10 m/s___

b) What is the acceleration? (Use $2as = v_f^2 - v_i^2$) ___5 m/s²___

c) What is the initial E_K of the block? (Use $E_K = ½mv^2$) ___0___

d) What is the final E_K of the block? (Use $E_K = ½mv^2$) ___1000 J___

e) How much ***kinetic energy*** did the block gain? (ΔE_K) ___1000 J___

Part-B: ***Work done to raise the block (relative to base line).***

f) What is the weight of the block? ___200 N___

g) What height is the block raised? ___5 m___

h) How much work is done to raise the block? (Use $E_P = wh$) ___1000 J___

i) What is the initial E_P of the block? (Use $E_P = mgh$) ___0___

j) What is the final E_P of the block? (Use $E_P = mgh$) ___1000 J___

k) How much ***potential energy*** did the block gain? (ΔE_P) ___1000 J___

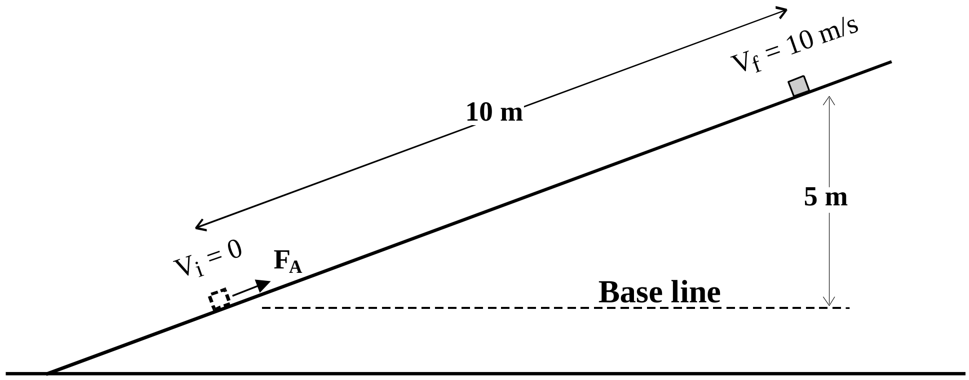
Part-C: ***Work done to overcome friction.***

l) What is the frictional force? ___0___

m) What work is done to overcome friction? (Use $W = fs$) ___0___

n) What is the ***total work*** done? (W_T) ___2000 J___
(W_T = Increase in E_K + Increase in E_P + work to overcome friction)

14. Starting from rest, a 20 kg block is pushed 10 m up an incline resulting in a final velocity of 10 m/s. As illustrated in the diagram, the force applied (F_A) acts **parallel** to the incline thereby raising the block 5 m. If the force of friction is 20 N, answer the following questions concerning the block while sliding up the incline.



Part-A: ***Work done to accelerate the block.***

a) What is the change in velocity? (Δv) — 10 m/s

b) What is the acceleration? (Use $2as = v_f^2 - v_i^2$) — 5 m/s²

c) What is the initial E_K of the block? (Use $E_K = ½mv^2$) — 0

d) What is the final E_K of the block? (Use $E_K = ½mv^2$) — 1000 J

e) How much ***kinetic energy*** did the block gain? (ΔE_K) — 1000 J

Part-B: ***Work done to raise the block (relative to base line).***

f) What is the weight of the block? — 200 N

g) What height is the block raised? — 5 m

h) How much work is done to raise the block? (Use $E_P = wh$) — 1000 J

i) What is the initial E_P of the block? (Use $E_P = mgh$) — 0

j) What is the final E_P of the block? (Use $E_P = mgh$) — 1000 J

k) How much ***potential energy*** did the block gain? (ΔE_P) — 1000 J

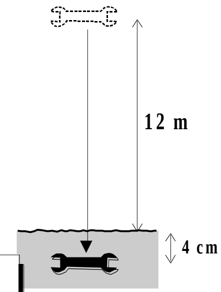
Part-C: ***Work done to overcome friction.***

l) What is the frictional force? — 20 N

m) What work is done to overcome friction? (Use $W = fs$) — 200 J

n) What is the ***total work*** done? (W_T) — 2200 J
(W_T = Increase in E_K + Increase in E_P + work to overcome friction)

15. A tool whose mass is 600 g, falls 12 m into a box of sand. If the tool sinks 4 cm into the sand calculate the (average) stopping force of the sand. [1 800 N]



Note: E_P at the top = E_K at the bottom

$$E_P = mgh = (0.6\text{ kg})(10\text{ m/s}^2)(12\text{ m}) = 72\text{ J}$$

$$W = Fs$$

$$F = \frac{W}{s} = \frac{72\text{ J}}{0.04\text{ m}} = 1800\text{ N}$$

❖❖❖❖❖❖❖❖❖❖❖❖❖