4. Work, Energy and Power

Let us assess

1. Question

Which are the factors influencing the amount of work?

Answer

In terms of physics, work is done only when the applied force produces any motion in the object(on which force is applied).

Hence, in terms of mathematical formula,

Amount of work done = force applied × displacement of the object

$W = F \times d$

So, this is observable that amount of work is dependent/influenced by two quantities:-

•Force applied on the body

•Displacement of the body.

2. Question

A boy is trying to push the concrete pillar of the building using a force of 300 N. Calculate the amount of work done by the boy.

Answer

In terms of physics, work is done only when the applied force produces any motion in the object(on which force is applied).

That is, if there is no displacement or no motion of the object on which force is applied then the work done is zero.

In the question, it is given that the force is applied on a concrete pillar, now it is obvious from the question that the pillar will not move from its place. Hence, the force of 300N applied on the pillar does not produce any motion/displacement. So if the displacement is zero,

Amount of work done = force applied × displacement of the object

Work = 300 × 0

Amount of the Work done = 0

Note:-It is necessary to use logic for these type of question for that you have to first understand the question thoroughly.

3 A. Question

A bench of mass 40 kg is brought from the first floor of the school to the second floor. The height difference between the floors is 3m.

Calculate the work done against the gravitational force when the bench is raised up.

Answer

Information from the question:-

Mass of the bench = 40 kg

Height difference or the displacement of the bench = 3 m

Note:- Always try to extract as much as information from the question as you can.

There is also an important thing mentioned in the question, that is we have to find work done against the gravitational force not any other force. So, gravitational force is always acting downward or we can say toward the centre of the earth, so if bench is transferred from one floor to another then it has done work against gravitational force.

Amount of work done = force applied × displacement of the object

We have to find the force applied on the body to find out the amount of work.

As, you know force applied = mass of the body × acceleration of the body

Hence, the body is working against the gravitational pull/force which is acting downward while the body is moving upward, so the acceleration of the body is the negative of the gravitational acceleration. Why negative, because negative sign indicate that the force is applied against the gravity or the motion is against the gravity.

Acceleration of the body = -g {g is gravitational acceleration}

= -9.8 m/s^2

Hence $\text{force applied} = \text{mass of the body} \times \text{acceleration of the body}$

Force applied = 40 × (-9.8)

= -39.2 kg m/s^2

Also,

Amount of work done = Force applied × displacement of the object

= 39.2 × 3

= -117.6 kg m^2/s^2

3 B. Question

A bench of mass 40 kg is brought from the first floor of the school to the second floor. The height difference between the floors is 3m.

What is the work done against the gravitational force if the bench is shifted from one room to another by pushing it across the floor?

Answer

In this part we have to find the amount of work done against the gravitational force when the bench is moved from one room to another by pushing it across the floor.

Now, in the previous part it is already mentioned that the gravitational force is acting downward or we can say towards the centre of the earth. While in this part the force is applied to move the body against the frictional force, there is no change in the height of the bench so, it is clear that the work is done against the frictional force not gravitational force.

Work done against gravitational force when the bench is moved from one room to another by pushing it across the floor = 0.

Note :- As there is no work done against the gravitational force but the work is done against frictional force.

4. Question

From what you have learnt of potential energy and kinetic energy, write down the form of energy possessed by the bodies given below.

(a) running train

(b) water in a dam

(c) stretched rubber band

(d) mango falling from a tree

Answer

Kinetic Energy: The energy possessed by any body/object due to its motion with a velocity/speed v is called kinetic energy.

Potential Energy: The energy possessed by any object due to its position in any field is called potential energy.

(A). As we know that the running train have a velocity, that is it will be in a motion which posses some speed/velocity from that we can conclude that it will have a kinetic energy.

(B). Water in a dam is always falling from a height or we can say it is always falling from a higher place(let's say 2^{nd} floor) to a lower place (let's say 1^{st} floor).

So, due to its higher position it has potential energy, but when it comes down to a lower position all of its potential energy is converted into kinetic energy as the water gains the speed while falling.

(C). A stretched rubber band posses potential energy because as it is stretched it is in more tensed position from its regular position or unstretched position. In simpler way, the position of the rubber band is changed from unstretched to stretched, that's why it has potential energy.

(D). The question here states that the mango is falling, mango is not attached to the tree anymore. Hence, the falling mango will have a speed that is why we will say that it has kinetic energy. But due to the fact that before reaching the ground it have also some potential energy due to its position which is obviously decreasing. So it also posses some potential energy before completely touching to the ground.

5. Question

Calculate the kinetic energy of an athlete of mass 60 kg running with a velocity 10 m/s.

Answer

Information from the question:-

Mass of the body = 60 kg

velocity of the body = 10 m/s

Kinetic Energy: The energy possessed by any body/object due to its motion with a velocity/speed v is called kinetic energy.

Mathematically,

$$\text{Kinetic energy of body} = \frac{1}{2} \times \text{mass of body} \times (\text{velocity of the body})^2$$

$$\text{Kinetic energy} = \frac{1}{2} \times m \times v^2$$

which implies Kinetic Energy $= \frac{1}{2} \times 60 \times 10$

= 300 kg m^2/s^2

6. Question

Calculate the potential energy of a stone of mass 40 kg on the terrace of a building of height 12 m.

Answer

Information from the question:-

Mass of the stone = 40 kg

Distance between the ground and the stone = 12 m

Gravitational acceleration = g = 9.8 m/s^2

Potential energy- The energy possessed by any object due to its height from the ground or the distance between the object and the ground is called potential energy.

Potential energy = Mass of the object × gravitational acceleration

× distance between the ground and the object

that is , Potential energy = m × g × h

Potential energy = 40 × 9.8 × 12

= 4704 kg m^2/s^2

7. Question

A stone of mass 2 kg is thrown upwards from the ground with a velocity of 3 m/s. When it reaches maximum height, calculate its potential energy.

Answer

Information from the question:-

Mass of the stone = 2 kg

Initial velocity of the stone, u = 3 m/s

To calculate the potential energy, we have to find the maximum height of the object.

Now, the stone is thrown upward that is it is working against gravitational force or gravitational acceleration because gravitational acceleration is always applied downward.

Hence, acceleration, a = -g = 9.8 m/s^2

The negative sign indicate that the movement is against the acceleration or the object is deaccelerating or the speed of the object is reducing.

As the motion is against the gravity and when the object reaches the maximum height the final speed of the object will be 0 m/s or we can say the object will not have any velocity when it reaches to the top because the speed of the object is continuously decreasing,

so, the final velocity v = 0 m/s

Now using the equation, $v^2 = u^2 - 2as$

Where, s: distance travelled

u: initial velocity of the object

v: final velocity of the object

a: acceleration of the object

$v^2 = u^2 - 2as$

$0^2 = 3^2 - \{2 \times (-9.8) \times s\}$

$0 = 9 - (-19.6 \times s)$

$0 = 9 + (19.6 \times s)$

$-9 = 19.6 \times s$

$s = -9/19.6$

s = -0.45 m

Again, the negative sign indicate that the stone is sent away from the earth.

So, maximum height = 0.45 m

We do not need to include the negative sign further because we only wish to find the maximum height upto which the stone went.

Potential energy = Mass of the object × gravitational acceleration

× distance between the ground and the object

that is , Potential energy = m × g × h

Potential energy = 2 × 9.8 × 0.45

= 8.82 kg m^2/s^2

8. Question

The heat of a health person beats 72 times per minute and each beat uses up about 1J of energy. Calculate

the power of the heart.

Answer

Power is defined as time taken by an object to do the work. Or we can also say rate of doing work.

Mathematically,

$$\text{Power} = \frac{\text{Work done by object}}{\text{time taken by the object}}$$

which implies, $P = \frac{w}{t}$

So, according to question the heart beats 72 times and each time it uses 1 Joule energy.

Hence, total work done by heart in one minute = 72 × 1

= 72 J

Time taken by heart to beat 72 times = 1 min = 60 s

Power = 72 / 60

= 1.2 J/s

Extended activities

1. Question

Complete the table

Energy transformation	Context
1. Mechanical Energy → Electrical energy	Working a generator
2. Electrical energy → Heat energy	
3. Electrical energy → mechanical energy	
4. Electrical energy → Light energy	

Answer

Energy transformation	Context
1. Mechanical Energy → Electrical energy	Working a generator (when any work done is used to generate electrical energy).
2. Electrical energy → Heat energy	Electric Iron or Room heater (when electrical energy is used to generate heat)
3. Electrical energy → mechanical energy	Fan/ Blender mixer (When electrical energy is used to do some work or motion)
4. Electrical energy → Light energy	Tube-light/ Bulb (When electrical energy is used to produce light)

2. Question

Check whether the power marked in the motion used for pumping water from the well in your home and the power received during the working of it are equal, by considering the time taken to fill the tank and the height of the tank.

Answer

Power indicated on the motor = 441 J

The height of the tank from the ground is = 30 m

The volume of the tank is = 1500 L

Which implies, volume of the tank = 1500 kg

Work done by the motor to completely fill the tank

= Force applied × displacement of the object

= m × g × h (force = m × a = m × g)

= 1500 × 9.8 × 30

= 441000 J

$$\text{Power} = \frac{\text{Work done by object}}{\text{time taken by the object}}$$

Time taken to completely fill the water = 1000 s

Hence,

Power = 441000 / 1000

= 441 J

Hence our observation of the power used and the power indicated on the motor match.