

Chapter: 06

Work and Energy

Short Response Questions

1. A car is moving with a constant speed along a straight road. Is there any work done on the car?

When a car moves with constant speed, there is no change in its kinetic energy. Since work is done when there is a displacement in the direction of the force, and in this case, the car's speed remains constant, no work is done on the car. Work is done only when the car's speed increases or decreases.

2. Does the work done in raising a box up in a building depend upon how fast it is raised up? Through which path? To how much height?

The work done in raising a box is independent of the speed at which it is raised. The work depends only on the force applied (which is equal to the weight of the box) and the height it is raised. The path of the displacement does not affect the work done, as work is only concerned with the vertical distance traveled. The height to which the box is raised is the determining factor for the work.

3. Work done on the body either speeds it up, slows it down. Keeping it in mind, explain how much work is done by centripetal force on an orbiting satellite?

Centripetal force acts perpendicular to the motion of an orbiting satellite and does not contribute to the change in the satellite's speed. Since work is the product of force and displacement in the direction of the force, and centripetal force does not change the satellite's direction of motion in a way that affects speed, the work done by centripetal force is zero.

4. A car has kinetic energy E_k . By what factor will its kinetic energy change if its velocity is doubled?

Kinetic energy is given by the formula $E_k = \frac{1}{2}mv^2$. If the velocity is doubled, the new kinetic energy becomes $E_k' = \frac{1}{2}m(2v)^2 = 4 \times \frac{1}{2}mv^2$. Therefore, if the velocity is doubled, the kinetic energy increases by a factor of 4.

5. A bullet is fired from a gun, and it penetrates into a sand wall and stops. Where does its kinetic energy go?

The kinetic energy of the bullet is transferred to the sand wall as it penetrates and stops.

This energy is primarily transformed into heat, sound, and internal energy of the sand particles as they are displaced by the bullet. Some energy is also dissipated in the form of vibrations within the wall.

6. An LED light bulb has an efficiency of 80%. Does it violate the conservation of energy principle?

No, an LED light bulb does not violate the conservation of energy principle. The principle states that energy cannot be created or destroyed, only converted from one form to another. In the case of the LED light bulb, 80% of the electrical energy is converted into light energy, and the remaining 20% is converted into heat, which is a form of energy transformation, not a violation of conservation.

7. How does using renewable energy sources contribute to reducing environmental impact compared to non-renewable sources?

Renewable energy sources, such as solar, wind, and hydroelectric power, produce little to no greenhouse gas emissions or air pollution during energy generation. This contrasts with non-renewable sources like fossil fuels, which release harmful pollutants and contribute to global warming. Renewable sources are sustainable and do not deplete over time, making them environmentally friendly.

8. Will we eventually rely entirely on renewable energy sources? Why or why not?

It is unlikely that we will rely entirely on renewable energy sources in the near future. While renewable sources are increasingly efficient and environmentally friendly, current technology and infrastructure still depend on non-renewable sources for energy storage, grid stability, and base-load power generation. However, the transition towards renewables is expected to continue growing as technology advances.

9. How can increasing the power of a machine impact its energy consumption?

Increasing the power of a machine typically means that more work is being done in less time. This results in a higher rate of energy consumption, as power is defined as the rate at which work is done or energy is used. A more powerful machine will consume more energy to accomplish the same tasks more quickly.

10. A perpetual engine has an efficiency equal to 1. Why will it not work?

A perpetual engine with an efficiency of 1, meaning 100% efficiency, would violate the first and second laws of thermodynamics. According to these laws, no machine can operate without some energy loss to friction, heat, or other forms of energy dissipation. Therefore,

such a machine is impossible, as it would require a continuous energy supply without any loss.

Long Response Questions

1. Define work and its unit. Describe the conditions for maximum and minimum work.

Definition:

In physics, work is defined as the transfer of energy when a force acts on an object, causing it to move a certain distance in the direction of the applied force. Mathematically, it is given by:

$$W = F \times d \times \cos(\theta)$$

Where:

- W is the work done (in joules, J)
- F is the force applied (in newtons, N)
- d is the displacement of the object (in meters, m)
- θ is the angle between the force and the displacement direction

Unit of Work:

The unit of work is the **joule (J)**, where:

1 Joule = 1 Newton \times 1 meter

It is the amount of work done when a force of 1 N acts on an object and displaces it by 1 meter in the direction of the force.

Conditions for Maximum and Minimum Work:

- Maximum work occurs when the angle $\theta = 0^\circ$, meaning the force is applied in the same direction as the displacement ($\cos(0^\circ) = 1$).
 - Minimum work occurs when the angle $\theta = 90^\circ$, meaning the force is applied perpendicular to the direction of displacement ($\cos(90^\circ) = 0$), resulting in no work being done.
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2. What is kinetic energy? Derive its expression by using graphical analysis.

Definition:

Kinetic energy is the energy possessed by an object due to its motion. The faster an object moves, the more kinetic energy it has.

Expression for Kinetic Energy:

To derive the expression for kinetic energy, consider a constant force F acting on an object of mass m . The object moves with an acceleration a over a displacement d .

From Newton's second law:

$$F = ma$$

Now, the work done by the force in moving the object through a displacement d is:

$$W = F \times d$$

Substitute $F = ma$:

$$W = ma \times d$$

Using the kinematic equation:

$$v^2 = u^2 + 2ad$$

Where:

- v is the final velocity
- u is the initial velocity
- a is the acceleration
- d is the displacement

If the object starts from rest ($u = 0$):

$$v^2 = 2ad$$

Thus, the displacement d can be written as:

$$d = \frac{v^2}{2a}$$

Substitute this value of d into the work formula:

$$W = ma \times \frac{v^2}{2a} = \frac{1}{2}mv^2$$

Thus, the kinetic energy E_k of the object is:

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

This expression shows that the kinetic energy of an object is proportional to its mass and the square of its velocity.

3. What is potential energy? What are its different types? Show that gravitational potential energy is equal to the product of mass m , gravitational field strength g , and height h .

Definition:

Potential energy is the energy possessed by a body due to its position or configuration. It is the stored energy that can be converted into kinetic energy.

Types of Potential Energy:

1. **Gravitational Potential Energy (GPE):** Stored by objects due to their position in a gravitational field, e.g., a book placed on a shelf.
2. **Elastic Potential Energy (EPE):** Stored in objects that can be stretched or compressed, such as springs or rubber bands.
3. **Chemical Potential Energy (CPE):** Stored in chemical bonds, e.g., in food, fuels, or batteries.
4. **Electrostatic Potential Energy (EPE):** Stored in charged particles within an electric field.

Gravitational Potential Energy Derivation:

The gravitational potential energy of an object is given by:

$$E_p = mgh$$

Where:

- E_p is the gravitational potential energy (in joules, J)
- m is the mass of the object (in kilograms, kg)
- g is the gravitational field strength (approximately 9.8 m/s^2 on Earth)
- h is the height of the object above the reference point (in meters, m)

This equation shows that the gravitational potential energy is directly proportional to the mass of the object, the gravitational field strength, and the height at which the object is positioned.

4. What is meant by energy conversion and energy conservation?**Energy Conversion:**

Energy conversion refers to the process of changing energy from one form to another. For example, in a power station, the chemical energy in fossil fuels is converted into thermal energy, which is then converted into mechanical energy, and finally into electrical energy.

Energy Conservation:

Energy conservation is the practice of using less energy by being more efficient and reducing unnecessary energy consumption. It involves utilizing energy more wisely to ensure its availability for future generations.

Both energy conversion and conservation are vital concepts in the sustainable use of resources and minimizing the environmental impact of energy use.

5. Describe how useful energy may be obtained from natural resources.

Useful Energy from Natural Resources:

- **Fossil Fuels:** Chemical energy stored in fossil fuels like coal, oil, and natural gas can be converted into electricity and mechanical energy through combustion.
- **Solar Energy:** Solar cells convert sunlight directly into electrical energy. Solar thermal systems can convert heat from sunlight into electricity or heat for domestic use.
- **Wind Energy:** The kinetic energy of wind is captured by wind turbines and converted into electricity.
- **Hydroelectric Energy:** The gravitational potential energy of water in reservoirs is converted into kinetic energy, which drives turbines connected to generators.
- **Geothermal Energy:** Heat from the Earth's interior is used to produce steam, which drives turbines to generate electricity.
- **Biomass:** Organic materials like wood, agricultural residues, and waste are burned or converted into biofuels, which release energy when combusted.

Natural resources provide various forms of energy, and these can be harnessed using appropriate technologies to meet the growing global energy demand.

6. Differentiate between renewable and non-renewable energy sources with examples. Write down advantages and disadvantages of each in reference to their availability and environmental impact.

Renewable Energy Sources:

- **Examples:** Solar, wind, hydroelectric, geothermal, and biomass energy.
- **Advantages:**
 - Renewable and inexhaustible.
 - Environmentally friendly with minimal greenhouse gas emissions.
 - Sustainable, as they do not deplete over time.
- **Disadvantages:**

- Intermittent availability (e.g., solar energy is not available at night).
- High initial installation costs.
- May require large areas for energy capture (e.g., wind farms or solar panels).

Non-Renewable Energy Sources:

- **Examples:** Coal, oil, natural gas, and nuclear energy.
- **Advantages:**
 - High energy density, providing large amounts of energy from small quantities.
 - Reliable and consistent energy supply.
 - Infrastructure for extraction and use is well-established.
- **Disadvantages:**
 - Limited and finite resources.
 - Environmental pollution (e.g., carbon emissions from burning fossil fuels).
 - Habitat destruction from mining and drilling activities.
 - Radioactive waste from nuclear energy.

Renewable sources are preferred for long-term sustainability, but non-renewable sources still play a crucial role due to their energy density and infrastructure. However, the environmental impact of non-renewable sources is a growing concern.
