

## Chapter: 06

### Work and Energy

#### Numerical Response Questions

1. Calculate the work done in pushing a box with 150 N through distance of 5 m.

**Given Data:**

- Force  $F = 150 \text{ N}$
- Distance  $d = 5 \text{ m}$

**To Find:**

- Work done  $W = ?$

**Solution:**

The formula for work is:

$$W = F \times d$$

Substituting the known values:

$$W = 150 \text{ N} \times 5 \text{ m}$$
$$W = 750 \text{ J}$$

**Result:**

750 J

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2. A boy weighing 75 N jumps up and gains 300 J of gravitational potential energy. Find the height to which the boy will rise.

**Given Data:**

- Weight of the boy  $W = 75 \text{ N}$
- Gravitational potential energy  $E_p = 300 \text{ J}$

**To Find:**

- Height  $h = ?$

**Solution:**

The formula for gravitational potential energy is:

$$E_p = mgh$$

Where  $m = \frac{W}{g}$ , and  $g = 9.8 \text{ m/s}^2$ .

Substituting  $m = \frac{75}{9.8} \approx 7.65 \text{ kg}$ :

$$E_p = mgh$$

$$300 = 7.65 \times 9.8 \times h$$

Solving for  $h$ :

$$h = \frac{300}{7.65 \times 9.8} \approx 4 \text{ m}$$

**Result:**

$$\boxed{4 \text{ m}}$$

**3. A 5 kg steel ball is dropped from the top of a 12 m high tower. What is the kinetic energy of the ball on hitting the ground? With what velocity will it hit the ground? (Neglect air resistance).**

**Given Data:**

- Mass  $m = 5 \text{ kg}$
- Height  $h = 12 \text{ m}$
- Gravitational acceleration  $g = 9.8 \text{ m/s}^2$

**To Find:**

- Kinetic energy  $E_k = ?$
- Velocity on hitting the ground  $v = ?$

**Solution:**

- **Kinetic Energy (on hitting the ground):**

Since the ball is falling freely, its initial potential energy will be converted into kinetic energy. The formula for potential energy is:

$$E_p = mgh$$

Substituting values:

$$E_p = 5 \times 9.8 \times 12 = 588 \text{ J}$$

Thus, the kinetic energy just before hitting the ground is  $E_k = 588 \text{ J}$ .

- **Velocity on hitting the ground:**

We use the kinematic equation:

$$v^2 = u^2 + 2gh$$

Where  $u = 0 \text{ m/s}$  (initial velocity).

Substituting values:

$$v^2 = 0 + 2 \times 9.8 \times 12$$

$$v^2 = 235.2$$

Taking the square root:

$$v = \sqrt{235.2} \approx 15.3 \text{ m/s}$$

**Result:**

- Kinetic energy  $E_k = 588 \text{ J}$
- Velocity  $v = 15.3 \text{ m/s}$

**4. A 2.0 kg rock is dropped from 20 m tall building. What is the Kinetic and Gravitational Potential Energy when the rock has fallen 15 m?**

**Given Data:**

- Mass  $m = 2.0 \text{ kg}$
- Height fallen  $h_f = 15 \text{ m}$
- Initial height  $h_i = 20 \text{ m}$
- Gravitational acceleration  $g = 9.8 \text{ m/s}^2$

**To Find:**

- Kinetic energy  $E_k = ?$
- Gravitational potential energy  $E_p = ?$

**Solution:**

- **Gravitational Potential Energy (at height  $h_f = 15 \text{ m}$ ):**

$$E_p = mgh$$

Substitute the values:

$$E_p = 2.0 \times 9.8 \times 15 = 294 \text{ J}$$

- **Kinetic Energy (at height  $h_f = 15 \text{ m}$ ):**

Since the initial potential energy at  $h_i = 20 \text{ m}$  is fully converted into kinetic energy and remaining potential energy at height  $h_f = 15 \text{ m}$ , we can find the difference:

Initial potential energy:

$$E_{p_i} = 2.0 \times 9.8 \times 20 = 392 \text{ J}$$

Remaining potential energy at  $h_f = 15 \text{ m}$ :

$$E_{p_f} = 2.0 \times 9.8 \times 15 = 294 \text{ J}$$

Thus, the kinetic energy is the difference:

$$E_k = E_{p_i} - E_{p_f} = 392 - 294 = 98 \text{ J}$$

**Result:**

- Kinetic energy  $E_k = 98 \text{ J}$

- Gravitational potential energy  $E_p = \boxed{294 \text{ J}}$

**5. A rocket with a mass of 800 g is launched vertically upward with an initial speed of 30 m/s. (a) Assuming no air resistance, calculate the maximum height the rocket would reach. (b) If, due to air friction, the rocket only rises to 25 m, determine the work done against air resistance.**

**Given Data:**

- Mass  $m = 800 \text{ g} = 0.8 \text{ kg}$
- Initial speed  $v_i = 30 \text{ m/s}$
- Gravitational acceleration  $g = 9.8 \text{ m/s}^2$
- Height at maximum rise  $h = 25 \text{ m}$

**To Find:**

- (a) Maximum height  $h_{\text{max}} = ?$
- (b) Work done against air resistance  $W_{\text{air}} = ?$

**Solution:**

- **(a) Maximum height (no air resistance):**

At the maximum height, the final velocity will be zero. Using the kinematic equation:

$$v_f^2 = v_i^2 - 2gh$$

Where  $v_f = 0$ , solve for  $h_{\text{max}}$ :

$$0 = 30^2 - 2 \times 9.8 \times h_{\text{max}}$$

$$h_{\text{max}} = \frac{30^2}{2 \times 9.8} = \frac{900}{19.6} \approx 45.92 \text{ m}$$

- **(b) Work done against air resistance:**

If the rocket only rises to 25 m, the actual potential energy is:

$$E_{p_f} = 0.8 \times 9.8 \times 25 = 196 \text{ J}$$

The potential energy without air resistance would have been:

$$E_{p_i} = 0.8 \times 9.8 \times 45.92 \approx 360.76 \text{ J}$$

Thus, the work done against air resistance is the difference:

$$W_{\text{air}} = E_{p_i} - E_{p_f} = 360.76 - 196 = 164.76 \text{ J}$$

**Result:**

- Maximum height  $h_{\text{max}} = \boxed{45.92 \text{ m}}$
- Work done against air resistance  $W_{\text{air}} = \boxed{164.76 \text{ J}}$

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