Physical Sciences Grade 10: Mechanical Energy Questions

November 2024

Instructions

1. Answer all questions correctly and provide clear explanations.
2. Provide step-by-step explanations for all calculations in the document.
3. For multiple-choice questions, choose the correct answer and write only the letter (A-D) in the answer book.
4. For structured questions, start each question on a new page in the answer book.
5. Show all calculations clearly and include appropriate units.
6. Use the data provided in the attached data sheet.

Data Sheet

Table 1: Physical Constants

Name	**Symbol**	**Value**
Acceleration due to gravity	g	$9.8\,\mathrm{m/s^2}$

Table 2: Formulae

Work, Energy, and Power	
Potential Energy	$U = mgh$ or $E_p = mgh$
Kinetic Energy	$K = \frac{1}{2}mv^2$ or $E_k = \frac{1}{2}mv^2$

Multiple-Choice Questions

Question 1.2

The gravitational potential energy of an object relative to the ground is dependent on the object's

A) Velocity B) Position C) Change in velocity D) Speed

Step-by-step Solution:

1. **Understand gravitational potential energy**: Gravitational potential energy is the energy an object has due to its position in a gravitational field, typically relative to a reference point like the ground.
2. **Identify the key factor**: The formula for gravitational potential energy is $E_p = mgh$, where m is mass, g is the acceleration due to gravity, and h is the height above the reference point. This shows it depends on the object's position (height).
3. **Evaluate options**:
   - A) Velocity: Incorrect, as velocity is related to kinetic energy, not potential.
   - B) Position: Correct, as potential energy depends on height (position).
   - C) Change in velocity: Incorrect, as this relates to acceleration, not potential energy.
   - D) Speed: Incorrect, as speed is related to kinetic energy.
4. **Final answer**: B

Question 1.4

An object is thrown from the top of a building with velocity V and kinetic energy E. It reaches the ground with a velocity of $2V$. Which one of the following is the objects kinetic energy just before it strikes the ground?

A) $2E$ B) $4E$ C) $0.5E$ D) E

Step-by-step Solution:

1. **Understand kinetic energy**: Kinetic energy is given by the formula:

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

   where m is the mass and v is the velocity.

2. **Initial kinetic energy**: At the top of the building, the object has velocity V and kinetic energy E. Thus:

$$E = \frac{1}{2}mV^2$$

3. **Final velocity**: The object reaches the ground with a velocity of $2V$.
4. **Calculate final kinetic energy**: Using the kinetic energy formula with the final velocity $v = 2V$:

$$E_{k,\text{final}} = \frac{1}{2}m(2V)^2 = \frac{1}{2}m \cdot 4V^2 = 4 \cdot \frac{1}{2}mV^2 = 4E$$

5. **Select the correct option**: The final kinetic energy is $4E$, which corresponds to option B.
6. **Final answer**: B

Structured Questions

Question 4: Mechanical Energy

A skateboarder, starting from the top of a ramp 4.5 m above the ground, skates down the ramp. The mass of the skateboarder and his board is 65 kg. Ignore the effects of friction.

4.1 Define the term gravitational potential energy in words.

Step-by-step Solution:

1. **Define the term**: Gravitational potential energy is the energy an object possesses due to its position in a gravitational field, relative to a reference point, such as the ground.
2. **Final answer**: The energy an object has because of its position in the gravitational field relative to some reference point.

4.2 Calculate the gravitational potential energy of the skater just before he skates down the ramp.

Step-by-step Solution:

1. **Identify the formula**: Gravitational potential energy is given by:

$$E_p = mgh$$

   where m is mass, g is acceleration due to gravity, and h is height.

2. **List given values**:
   - Mass, $m = 65\,\text{kg}$
   - Height, $h = 4.5\,\text{m}$
   - Acceleration due to gravity, $g = 9.8\,\text{m/s}^2$
3. **Substitute values**:

$$E_p = 65 \times 9.8 \times 4.5$$

4. **Perform calculation**:

$$E_p = 65 \times 9.8 = 637$$

$$E_p = 637 \times 4.5 = 2866.5$$

5. **Include units**: The unit of energy is joules (J), since $\text{kg} \cdot \text{m/s}^2 \cdot \text{m} = \text{N} \cdot \text{m} = \text{J}$.
6. **Round to two decimal places**: $2866.5 \approx 2866.50\,\text{J}$.
7. **Final answer**: The gravitational potential energy is $2866.50\,\text{J}$.

4.3 State the principle of conservation of mechanical energy in words.

Step-by-step Solution:

1. **Understand the principle**: The principle of conservation of mechanical energy states that in a system where only conservative forces (like gravity) act, the total mechanical energy remains constant.
2. **Define mechanical energy**: Mechanical energy is the sum of kinetic energy and potential energy.
3. **Final answer**: The total mechanical energy (sum of kinetic and gravitational potential energy) in an isolated or closed system remains constant or is conserved.

4.4 Use the principle stated in 4.3 to calculate the magnitude of the velocity of the skateboarder when he reaches the ground at point X.

Step-by-step Solution:

1. **Apply conservation of mechanical energy**: Since friction is ignored, the total mechanical energy at the top of the ramp equals the total mechanical energy at the ground (point X). At the top, the skateboarder has only potential energy (assuming initial velocity is zero, as not specified). At point X (ground, $h = 0$), all potential energy is converted to kinetic energy:

$$E_{\text{mechanical at top}} = E_{\text{mechanical at X}}$$

$$E_p = E_k$$

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

2. **Simplify the equation**: The mass m cancels out:

$$gh = \frac{1}{2}v^2$$

3. **Substitute known values**: $g = 9.8\,\text{m/s}^2$, $h = 4.5\,\text{m}$:

$$9.8 \times 4.5 = \frac{1}{2}v^2$$

$$44.1 = \frac{1}{2}v^2$$

4. **Solve for v^2**:

$$v^2 = 44.1 \times 2 = 88.2$$

5. **Solve for v**:

$$v = \sqrt{88.2} \approx 9.39$$

6. **Round to two decimal places**: $v \approx 9.39\,\text{m/s}$.
7. **Final answer**: The velocity at point X is approximately $9.39\,\text{m/s}$.

4.5 Will the skateboarder be able to reach point Y if he were to remain on his skateboard? Write YES or NO and support the answer with a relevant calculation.

Step-by-step Solution:

1. **Understand the scenario**: Point Y is not specified in height in the provided document, but typically, its another point on the ramp, possibly at a height greater than the ground. Assume point Y is at a height h_Y above the ground. To reach point Y, the skateboarders mechanical energy at the top must be sufficient to provide the potential energy at point Y.

2. **Use conservation of energy**: The total mechanical energy at the top is the potential energy calculated in 4.2:

$$E_{\text{mechanical}} = 2866.50\,\text{J}$$

   At point Y, the mechanical energy is:

$$E_{\text{mechanical at Y}} = mgh_Y + \frac{1}{2}mv_Y^2$$

   For the skateboarder to reach point Y with minimum energy, assume velocity at Y is zero ($v_Y = 0$):

$$E_{\text{mechanical at Y}} = mgh_Y$$

3. **Set up energy conservation**: The mechanical energy at the top must be at least equal to the potential energy at Y:

$$2866.50 \geq mgh_Y$$

4. **Solve for maximum height** h_Y:

$$h_Y \leq \frac{2866.50}{m \times g} = \frac{2866.50}{65 \times 9.8} = \frac{2866.50}{637} \approx 4.50$$

5. **Analyze the result**: The maximum height the skateboarder can reach is 4.50 m. If point Y is at or below 4.50 m, the skateboarder can reach it. Since point Y is not specified, assume its at a height equal to the starting point (common in such problems), which is 4.5 m.

6. **Conclusion**: Since the maximum height is exactly 4.5 m, the skateboarder can just reach point Y with zero velocity (ideal case, ignoring practical losses).

7. **Final answer**: YES, the skateboarder can reach point Y, as the initial potential energy (2866.50 J) is sufficient to reach a height of 4.5 m.

Question 8: Mechanical Energy

A boy skates along a frictionless ramp. The boy starts at Point X, 2 m above the ground, at a velocity of 1 m/s. The combined mass of the boy and skateboard is 60 kg.

8.1 Calculate the mechanical energy of the boy and his skateboard at Point X.

Step-by-step Solution:

1. **Define mechanical energy**: Mechanical energy is the sum of potential energy (E_p) and kinetic energy (E_k). The formula is:

$$E_{\text{mechanical}} = E_p + E_k = mgh + \frac{1}{2}mv^2$$

2. **Identify given values**:
   - Mass, $m = 60\,\text{kg}$
   - Height at Point X, $h = 2\,\text{m}$
   - Velocity at Point X, $v = 1\,\text{m/s}$
   - Acceleration due to gravity, $g = 9.8\,\text{m/s}^2$
3. **Calculate potential energy**:

$$E_p = mgh = 60 \times 9.8 \times 2 = 1176\,\text{J}$$

4. **Calculate kinetic energy**:

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 60 \times 1^2 = 30\,\text{J}$$

5. **Calculate total mechanical energy**:

$$E_{\text{mechanical}} = E_p + E_k = 1176 + 30 = 1206\,\text{J}$$

6. **Final answer**: The mechanical energy at Point X is 1206 J.

8.2 Determine the speed of the boy and his skateboard at Point Y.

Step-by-step Solution:

1. **Apply conservation of mechanical energy**: Since the ramp is frictionless, mechanical energy is conserved. At Point Y (ground level, $h = 0\,\text{m}$), all mechanical energy at Point X is converted to kinetic energy:

$$E_{\text{mechanical at X}} = E_{\text{mechanical at Y}}$$

$$mgh_X + \frac{1}{2}mv_X^2 = \frac{1}{2}mv_Y^2$$

2. **Substitute known values**: Using $m = 60\,\text{kg}$, $g = 9.8\,\text{m/s}^2$, $h_X = 2\,\text{m}$, $v_X = 1\,\text{m/s}$, and $h_Y = 0\,\text{m}$:

$$60 \times 9.8 \times 2 + \frac{1}{2} \times 60 \times 1^2 = \frac{1}{2} \times 60 \times v_Y^2$$

$$1176 + 30 = 30v_Y^2$$

$$1206 = 30v_Y^2$$

3. **Solve for v_Y^2**:
$$v_Y^2 = \frac{1206}{30} = 40.2$$

4. **Solve for v_Y**:
$$v_Y = \sqrt{40.2} \approx 6.34\,\text{m/s}$$

5. **Final answer**: The speed at Point Y is approximately 6.34 m/s.

8.3 Use relevant calculations to show that the skateboard will not be able to reach Point Z, when starting at 1 m/s at Point X.

Step-by-step Solution:

1. **Understand the scenario**: Point Z is likely at a height greater than Point X, and we need to show the skateboard cannot reach it due to insufficient mechanical energy. Assume Point Z is at height $h_Z > 2\,\text{m}$, and at the highest point, velocity is zero (minimum energy to reach Point Z).

2. **Use conservation of energy**: Total mechanical energy at Point X is 1206 J. At Point Z, if $v = 0\,\text{m/s}$:
$$E_{\text{mechanical at X}} = E_{\text{potential at Z}}$$
$$1206 = mgh_Z$$

3. **Solve for maximum height h_Z**:
$$h_Z = \frac{1206}{m \times g} = \frac{1206}{60 \times 9.8} \approx 2.05\,\text{m}$$

4. **Analyze the result**: The maximum height the skateboard can reach is approximately 2.05 m. If Point Z is higher than 2.05 m, the potential energy required (mgh_Z) exceeds 1206 J, making it impossible to reach Point Z.

5. **Final answer**: The skateboard cannot reach Point Z if it is above 2.05 m, as the initial mechanical energy of 1206 J is insufficient to provide the necessary potential energy.