A Chain Lying On The Ground Is 10 M Long And Its Mass Is 70 Kg. How Much Work (in J) Is Required To Raise

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Understanding the work involved in lifting objects is fundamental in physics, especially in the context of mechanics. When dealing with chains, the task becomes interesting because of the variable height at which different segments of the chain are lifted. In this article, we explore how to calculate the work required to lift a chain lying on the ground to a certain height, focusing on a chain that is 10 meters long and has a mass of 70 kilograms. We will break down the problem, discuss the underlying principles, and provide step-by-step calculations to determine the work needed in joules (J).

Understanding the Problem

Before diving into calculations, it’s essential to understand the problem’s parameters:

- Length of the chain: 10 meters
- Mass of the chain: 70 kg
- The goal: To raise the chain from lying on the ground to a certain height (commonly to a height of 10 meters, assuming lifting it to vertical position)

The key question: How much work is required to lift the entire chain to a certain height?

This problem involves concepts such as gravitational potential energy, variable heights of chain segments, and the principles of work-energy.

Fundamental Concepts in Calculating Work

Work and Energy

Work done against gravity to lift an object is stored as gravitational potential energy (GPE). The work W needed to lift an object is given by:

\[

W = \Delta U = mgh
\]

- \(m\): mass of the object
- \(g\): acceleration due to gravity (~9.8 m/s\(^2\))
- \(h\): height the object is raised

However, for extended objects like a chain, which is lifted segment by segment, the calculation involves integrating the work done on each small part of the chain as it is lifted from its initial position to its final position.

Variable Height of Chain Segments

Since the chain is lying on the ground, the lower segments are initially at height zero and need to be lifted to the final height (say, 10 meters). The upper segments are already closer to the final height and require less work.

To accurately calculate the total work, we consider the chain as a continuous mass distribution and integrate over its length.

Modeling the Chain as a Continuous Mass Distribution

Defining the Coordinate System

Let’s establish a coordinate system:

- The ground level is at \(y=0\).
- The chain extends from \(y=0\) (ground) to \(y=h\) (final height after lifting).
- The chain is lifted uniformly to a height \(h = 10\, \text{m}\).

Mass per Unit Length

The total length \(L\) of the chain is 10 meters.

Given the total mass \(M = 70\, \text{kg}\), the linear mass density \(\lambda\) (mass per unit length) is:

\[
\lambda = \frac{M}{L} = \frac{70\, \text{kg}}{10\, \text{m}} = 7\,

$$
\text{kg/m}
$$

Calculating the Work to Lift Each Segment

- Each infinitesimal segment of the chain of length dy at height y has mass:

$$
dm = \lambda\, dy
$$

- This segment initially lies on the ground at $y=0$, but as the chain is lifted, it is raised from $y=0$ to $y=h$.

- The work dW to lift this segment from height 0 to height h is:

$$
dW = dm \times g \times y
$$

because we need to raise the segment from 0 to y, and the average height it is lifted to is y.

- To find the total work, integrate over the entire length of the chain:

$$
W = \int_{0}^{L} \lambda\, y\, g\, dy
$$

Note: Since the chain is lifted all the way to height $h=10\, \text{m}$, but different segments are at different initial positions (on the ground), the work is calculated based on the difference in potential energy.

However, because the chain starts lying flat on the ground, the initial potential energy is zero, and the work done is equal to the increase in potential energy when all parts are lifted to height h.

Important Clarification:
In practice, to lift the chain to height h, the work is equivalent to lifting each segment from ground level to height h. Since all segments are lifted from height 0 to height h, the total work simplifies to:

$$
W = M \times g \times h
$$

This approach assumes the chain is lifted uniformly from ground to height h, which is a common approximation.

Calculating the Work Using the Simplified Formula

Given the total mass $M = 70\, \text{kg}$, $g = 9.8\, \text{m/s}^2$, and the height $h = 10\, \text{m}$:

$$
W = M \times g \times h
$$

$$
W = 70\, \text{kg} \times 9.8\, \text{m/s}^2 \times 10\, \text{m}
$$

$$
W = 70 \times 9.8 \times 10
$$

$$
W = 6860\, \text{J}
$$

Final Answer:

The work required to lift the entire chain to a height of 10 meters is approximately 6860 joules.

Additional Factors to Consider

While the calculation above provides a good approximation, real-world scenarios might involve additional factors:

- Friction: If lifting involves friction, more work is required.
- Acceleration: If lifting is not done slowly, additional kinetic energy is involved.
- Chain flexibility: The chain's flexibility may affect the actual work needed.
- Efficient lifting devices: The use of pulleys or cranes can reduce the physical effort, although the work done remains the same in ideal conditions.

Summary of Key Steps to Calculate Work

1. Identify the parameters: length, mass, and final height.
2. Calculate the total mass and linear density.
3. Determine the height to which the chain is lifted.
4. Use the gravitational potential energy formula: $W = Mgh$.
5. Interpret the result:

- For a chain lifted from ground level to height h:

$$
\boxed{
W = 6860\, \text{J}
}
$$

Final Thoughts

The process of calculating the work required to lift a chain demonstrates fundamental principles of physics, including the concepts of energy, work, and the importance of modeling extended objects with continuous mass distributions. Understanding these principles is crucial for practical applications, from construction to mechanical engineering, ensuring safety and efficiency in lifting operations.

Keywords: work to lift chain, gravitational potential energy, physics calculations, lifting objects, mechanics, energy, continuous mass distribution, joules, lifting work calculation

Frequently Asked Questions

What is the length of the chain lying on the ground in the problem?

The chain is 10 meters long.

What is the mass of the chain in the problem?

The mass of the chain is 70 kilograms.

What is the main physics concept involved in calculating the work to lift the chain?

The main concept is gravitational potential energy, which involves work done against gravity to lift the chain.

How do you determine the average height the chain is lifted in this problem?

Since the chain is lifted from lying on the ground to being fully raised, the average height is half of its length, i.e., 5 meters.

What is the formula for calculating work done in lifting an object in a uniform gravitational field?

Work = mass × gravitational acceleration × height (W = mgh).

How do you calculate the work required to lift the entire chain?

By considering the chain's center of mass, which is lifted to the final height, the work is W = m × g × (L/2), where L is the length of the chain.

What is the value of gravitational acceleration used in the calculation?

The standard value is approximately 9.8 m/s^2.

What is the calculated work required to lift the chain in joules?

The work is approximately 3,430 joules.

Why do we use half the length of the chain in the work calculation?

Because the chain's center of mass is initially at ground level and is lifted to the top, the average height lifted is half the length.

Can the work required vary if the chain is lifted at a different angle or speed?

Yes, the work depends on the gravitational potential energy change, which remains the same regardless of the lifting method, assuming no additional forces like friction or acceleration are involved.

Additional Resources

A Chain Lying On The Ground Is 10 M Long And Its Mass Is 70 Kg. How Much Work (in J) Is Required To Raise the chain to a certain height? This question presents a classic physics problem involving concepts of work, gravitational potential energy, and the distribution of mass along an extended object. Understanding how to approach such a problem requires breaking down the physical principles involved, applying the relevant formulas, and considering the chain's properties. In this comprehensive guide, we will explore the problem step-by-step, providing clarity on the concepts, calculations, and reasoning involved.

Understanding the Problem

Before diving into calculations, it’s essential to understand what is being asked. The problem states:

- A chain lying on the ground
- Length of the chain: 10 meters
- Mass of the chain: 70 kg
- Question: How much work (in Joules) is required to raise the chain to a certain height?

The key points are:

- The chain is initially on the ground (at zero height).
- To find the work done, we need to determine the energy required to lift all parts of the chain from their initial position to the final height.
- The problem does not specify the final height explicitly, but for the purpose of demonstration, let’s assume the chain is to be lifted to a height h (which we will define as a variable).

Note: If the problem specifies a particular height (e.g., 10 meters), you can substitute that value directly.

Conceptual Framework

Work and Gravitational Potential Energy

In physics, work done against gravity to lift an object is equal to the increase in its gravitational potential energy (GPE):

$$W = \Delta U = m g h$$

where:

- m = mass of the object (kg)

- g = acceleration due to gravity (~9.8 m/s²)
- h = height the object is raised (m)

However, this straightforward formula applies to point objects or uniform objects lifted as a whole. When dealing with extended objects like a chain, which has mass distributed along its length, the calculation becomes more nuanced.

Distributed Mass and Variable Height

Since the chain has a length of 10 meters and mass of 70 kg, its linear mass density (λ) is:

$$\lambda = \frac{\text{mass}}{\text{length}} = \frac{70\, \text{kg}}{10\, \text{m}} = 7\, \text{kg/m}$$

To find the work required to lift the entire chain, we consider the chain as composed of infinitesimal segments, each of mass dm, located at a certain height. The work to lift each segment is:

$$dW = dm \times g \times h_{segment}$$

The total work is the integral of these small contributions over the entire length of the chain.

Step-by-Step Calculation

1. Define the Coordinate System

Assuming the chain is lifted vertically from the ground (initial position at 0 m):

- Let x be the position along the chain, measured from the bottom (initially at $x = 0$)
- The chain is lifted so that its lower end reaches height h

2. Express the Position of Each Segment

If the chain is lifted uniformly from bottom to top, then:

- A segment located at position x (measured from the bottom) will be lifted from the ground to height $h + x$ (assuming the chain is being lifted from the ground to height h)
- Alternatively, if the chain is lifted vertically as a whole, each segment at position x is raised from 0 to h, but the mass distribution matters.

Assumption: The chain is lifted from lying on the ground to a height h, with the bottom end lifted to height h, and the rest of the chain follows, with each segment lifted to height h.

3. Differential Mass Element

The linear mass density:

$$\lambda = 7\, \text{kg/m}$$

The differential mass:

$$dm = \lambda\, dx$$

where dx is an infinitesimal length element.

4. Work Required to Lift Each Segment

Each segment located at x (from 0 to 10 m) starts at ground level (height 0) and is lifted to height h. The work to lift this segment:

$$dW = dm \times g \times h = \lambda\, dx \times g \times h$$

Since all segments are lifted to the same height h, the total work:

$$W = \int_{0}^{L} \lambda g h\, dx = \lambda g h \int_{0}^{L} dx = \lambda g h \times L$$

where:

- $L = 10\, \text{m}$

Thus,

$$W = \lambda g h L$$

Plugging in the known values:

$$W = 7\, \text{kg/m} \times 9.8\, \text{m/s}^2 \times h \times 10\, \text{m}$$

$$W = 7 \times 9.8 \times 10 \times h$$

$$W = 686 h\, \text{J}$$

Important: This calculation assumes the entire chain is lifted to height h simultaneously. If the chain is lifted gradually, the total work involves integrating over the variable height for each segment.

More Accurate Approach: Lifting the Chain Incrementally

In reality, lifting the chain from ground level to height h, the work depends on the average height each part of the chain is lifted.

1. Consider the Chain as a Continuous Object

- Each segment at position x (measured from the bottom) is initially on the ground (height 0).
- When lifting the chain to height h, the bottom segment is lifted from 0 to h.
- The top segment (at $x = L$) is lifted from 0 to $h + x$ if the chain is being lifted from the ground to height h.

However, in most practical scenarios, the chain is lifted vertically such that the entire chain is raised to height h, meaning each segment is lifted from ground level (0 m) to height h, regardless of its position along the chain.

2. Calculating the Work

Since the chain is uniform, and all parts are lifted to the same height h, the total work is simply:

$$W = m \times g \times h$$

where m is the total mass:

$$m = 70\, \text{kg}$$

So,

$$W = 70 \times 9.8 \times h = 686 h\, \text{J}$$

Final Calculation: Assuming a Specific Height

Suppose the goal is to lift the chain to a height of 10 meters, i.e., to the full length of the chain (which makes sense if lifting it vertically from ground to a point 10 m above). Then:

$$h = 10\, \text{m}$$

Total work:

$$W = 686 \times 10 = 6860\, \text{J}$$

Therefore:

> The work required to lift the chain from ground level to 10 meters is approximately 6860 Joules.

Additional Considerations

1. Lifting Part of the Chain

If the problem involves lifting only part of the chain or lifting it in stages, the calculation adjusts accordingly. For example, lifting half the chain to 10 meters involves only the mass of half the chain.

2. Energy Losses and Real-World Factors

In practical situations, factors such as friction, the efficiency of the lifting mechanism, and the method of lifting (e.g., pulling, using pulleys) influence the actual work done. The calculation above assumes ideal conditions with no losses.

3. Lifting at Constant Speed vs. Acceleration

The work done in lifting at a constant speed is equal to the change in gravitational potential energy. If lifting involves acceleration, additional kinetic energy is involved, increasing the work required.

Summary

Key takeaways:

- The total work to lift a uniform, extended object like a chain from ground level to a height h is:

$$ W = m g h $$

- For the specific case where the chain's length is 10 meters, mass is 70 kg, and lifted to 10 meters height:

$$ W \approx \boxed{6860\, \text{J}} $$

- The calculation hinges on understanding the distribution of mass and the height to which the chain is lifted.

Final Thoughts

Understanding the physics behind lifting objects helps in designing efficient systems and estimating energy requirements. When dealing with extended objects, considering the distribution of mass and the incremental work for each segment ensures accurate calculations. Whether for academic purposes or practical applications, mastering these principles is fundamental in physics and engineering.

Always remember: The work done is directly proportional to the mass lifted and the height lifted, assuming ideal conditions. Real-world scenarios may involve additional complexities, but the core concepts remain the same.

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