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When considering physical activity and energy expenditure, understanding the concept of power is essential. In this scenario, a person exerting a force of 600 newtons runs up a staircase that is 2.5 meters high in just 2 seconds. The question arises: how much power has this individual generated during this effort? To answer this, we need to explore the principles of physics that relate force, work, and power, and then perform the necessary calculations. This article will delve into the mechanics behind this problem, providing a comprehensive understanding of how to determine the power output involved in such a physical activity.

Understanding the Basics: Force, Work, and Power

Before diving into the calculations, it's important to clarify some fundamental concepts in physics:

Force

Force is any interaction that, when unopposed, will change the motion of an object. It is measured in newtons (N). In this scenario, the person exerts a force of 600 N against gravity to ascend the stairs.

Work

Work is done when a force causes an object to move in the direction of the force. It is calculated as:

$$\text{Work (W)} = \text{Force (F)} \times \text{Displacement (d)} \times \cos(\theta)$$

where θ is the angle between the force vector and the displacement vector. Since the force and displacement are in the same direction (upward), $\cos(0^\circ) = 1$, simplifying the calculation to:

$$\text{W} = \text{F} \times \text{d}$$

Power

Power is the rate at which work is done or energy is transferred over time. It is measured in watts (W), where:

$$\text{Power (P)} = \text{Work (W)} / \text{Time (t)}$$

Understanding these concepts allows us to analyze the problem systematically.

Calculating the Work Done by the Person

The first step is to determine how much work the person performs while running up the stairs.

Step 1: Determine the Displacement in the Direction of Force

The vertical height of the stairs is given as 2.5 meters, which is the displacement in the direction of gravity and the force exerted by the person.

Step 2: Calculate the Work Done

Since the force exerted by the person is 600 N and the vertical displacement is 2.5 meters, the work done against gravity is:

$$W = F \times d$$

$$W = 600 \text{ N} \times 2.5 \text{ m}$$

$$W = 1500 \text{ Joules}$$

This is the amount of energy the person uses to lift their body up the stairs.

Determining the Power Output

Next, we analyze how quickly this work was performed to find the power.

Step 3: Calculate Power

The time taken to climb the stairs is 2 seconds. Therefore, the average power output is:

$$P = W / t$$

$$P = 1500 \text{ J} / 2 \text{ s}$$

$$P = 750 \text{ Watts}$$

This indicates that, on average, the person exerted a power of 750 watts during the ascent.

Interpreting the Results

The calculated power output provides insight into the physical effort involved:

- High Power Output: 750 W is a significant amount of power, comparable to the output of a high-performance athlete during intense activity.
- Energy Expenditure: The energy expenditure of 1500 Joules shows the amount of work done against gravity.
- Efficiency Considerations: In real-world scenarios, factors such as acceleration, efficiency of muscle

use, and energy lost as heat mean the actual energy expended could be higher.

Additional Factors to Consider

While the calculations above provide a good estimate, several additional factors can influence the actual power output:

1. Body Mass and Weight

Given that the person exerts 600 N of force, their mass can be calculated as:

$$m = F / g$$

$$m = 600 \text{ N} / 9.81 \text{ m/s}^2 \approx 61.15 \text{ kg}$$

This indicates the person's mass is approximately 61.15 kilograms, which aligns with typical human mass.

2. Running vs. Walking Dynamics

Running involves dynamic movements, including acceleration, which can increase the power required beyond the simple calculations based on vertical displacement alone.

3. Mechanical Efficiency

The human body is not 100% efficient, with some energy lost as heat and in muscle mechanics. Actual metabolic energy expenditure may be higher than the calculated work.

Practical Applications and Implications

Understanding power output in such activities is valuable in various fields:

Sports Science and Training

Coaches analyze athletes' power to optimize training for sprinting, climbing, and other high-intensity activities.

Health and Fitness Monitoring

Measuring power can help assess cardiovascular health and muscular strength.

Design of Exercise Equipment

Manufacturers design stair climbers and fitness machines based on the power output expectations of users.

Conclusion

In summary, a person exerting a force of 600 newtons to ascend a 2.5-meter-high staircase in 2 seconds performs approximately 1500 Joules of work and generates an average power of about 750 watts during the activity. This calculation highlights the significant physical effort involved in quick stair climbing and emphasizes the importance of understanding fundamental physics principles when analyzing human movement and energy expenditure. Whether for athletic training, health assessments, or designing fitness equipment, grasping how to compute power in such contexts is essential for advancing knowledge in exercise science and biomechanics.

Keywords: Power calculation, physics of stair climbing, work and energy, human biomechanics, athletic performance, exercise science

Frequently Asked Questions

What is the power exerted by a person who runs up a 2.5-meter-high staircase with a weight of 600 N in 2 seconds?

The power exerted is 750 watts, calculated using $\text{power} = \text{work} / \text{time}$, where $\text{work} = \text{weight} \times \text{height} = 600 \text{ N} \times 2.5 \text{ m} = 1500 \text{ Joules}$. So, $\text{power} = 1500 \text{ J} / 2 \text{ s} = 750 \text{ W}$.

How is the work done by the person calculated in this scenario?

The work done is calculated by multiplying the person's weight (force) by the height climbed, so $\text{Work} = 600 \text{ N} \times 2.5 \text{ m} = 1500 \text{ Joules}$.

What assumptions are made in calculating the power in this problem?

It is assumed that all work is converted into mechanical energy overcoming gravity, ignoring air resistance and other forces, and that the person's weight remains constant during the climb.

If the person took 4 seconds instead of 2 seconds, what would be the power exerted?

The work remains the same at 1500 Joules, but with 4 seconds, the power would be $1500 \text{ J} / 4 \text{ s} = 375 \text{ W}$.

Watts.

Why is power an important measure in this context?

Power indicates how quickly the person can perform work, reflecting their strength and endurance during physical activity.

Can the power be expressed in units other than watts? If so, which?

Yes, power can also be expressed in horsepower, where 1 horsepower is approximately 745.7 watts. In this case, about 1.005 horsepower.

What factors could affect the actual power output in real-life scenarios?

Factors include the person's efficiency, technique, energy losses due to air resistance or fatigue, and whether the movement is purely vertical or involves horizontal components.

Is the calculated power purely mechanical, or does it include metabolic energy expenditure?

The calculated power reflects the mechanical work done against gravity; however, actual metabolic energy expenditure is typically higher due to inefficiencies and energy losses in the body.

How does the height of the stairs influence the power calculation?

The height directly affects the work done ($\text{work} = \text{force} \times \text{height}$). Increasing the height increases the work and thus the power required to climb in a given time.

Additional Resources

Understanding Power in Human Motion: An In-Depth Analysis of a Person Running Up Stairs

When analyzing physical exertion and biomechanics, the concept of power plays a central role. Power, in physics, is defined as the rate at which work is done or energy is transferred over time. In the context of a person running up stairs, calculating power provides insight into the person's muscular effort, energy expenditure, and overall physical capability. This detailed review aims to dissect the problem of a 600-newton individual ascending a staircase 2.5 meters high in 2 seconds, and to understand precisely how much power is involved in this activity.

Defining the Problem: Key Parameters and Assumptions

Before diving into calculations, it's essential to clarify the parameters and assumptions involved:

- Person's weight (force due to gravity): 600 N
- Height of the staircase: 2.5 meters
- Time taken to ascend: 2 seconds
- Additional considerations: Whether to account for only gravitational potential energy, the total work done including kinetic energy, and the person's mass.

Converting weight to mass:

Since weight (force) (W) is related to mass (m) by:

$$W = m \times g$$

where (g) is acceleration due to gravity ($\sim 9.81 \text{ m/s}^2$):

$$m = \frac{W}{g} = \frac{600 \text{ N}}{9.81 \text{ m/s}^2} \approx 61.02 \text{ kg}$$

Thus, the individual's mass is approximately 61 kg.

The Concept of Work and Energy in Climbing Stairs

When a person climbs stairs, they perform work against gravity to increase their potential energy. The total work done, assuming no losses, is primarily the increase in gravitational potential energy, but it's also important to recognize that some energy is spent overcoming friction, air resistance, and internal muscular inefficiencies.

Work done (W) :

$$W = \text{Change in gravitational potential energy} = m \times g \times h$$

where:

- (m) is the mass,
- (g) is acceleration due to gravity,
- (h) is the height ascended.

Additional factors:

- Kinetic energy: If the person starts from rest and reaches a certain speed, kinetic energy should be considered.
- Muscular effort and metabolic energy: Real-world energy expenditure exceeds the simple work calculation due to inefficiencies.
- Assumption of vertical ascent: For simplicity, we assume the person climbs a straight, vertical path, though stairs are typically inclined; the height remains the same.

Calculating the Work Done: Gravitational Potential Energy

Given the parameters:

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\[
m = 61\, \text{kg}
\]
\[
h = 2.5\, \text{m}
\]
\[
g = 9.81\, \text{m/s}^2
\]
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The work done in raising the person to that height:

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\[
W = m \times g \times h = 61.02\, \text{kg} \times 9.81\, \text{m/s}^2 \times 2.5\, \text{m}
\]
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Calculating:

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\[
W \approx 61.02 \times 9.81 \times 2.5 \approx 61.02 \times 24.525 \approx 1495.8\, \text{J}
\]
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Interpretation: The person expends approximately 1496 joules of energy to reach the top of the stairs, purely based on gravitational potential energy increase.

Calculating Power: Rate of Work Done

Power is defined as the work done over a period of time:

$$P = \frac{W}{t}$$

where:

- W is the work done,
- t is the time taken.

Using the calculated work:

$$P = \frac{1495.8 \text{ J}}{2 \text{ s}} = 747.9 \text{ W}$$

Result: The average power output during the ascent is approximately 748 watts.

Interpreting the Power Output: Context and Significance

To understand whether this power level is plausible or extraordinary, consider:

- Comparison with human power outputs: Top athletes can sustain around 400-600 W during intense efforts such as cycling or running. A burst of nearly 750 W indicates a very high, albeit brief, exertion level.
- Energy efficiency: Human muscles are about 20-25% efficient; thus, actual metabolic energy expenditure is higher than the mechanical work performed.

Adjusted for efficiency:

Assuming 25% efficiency:

$$\text{Metabolic energy} = \frac{\text{Mechanical work}}{\text{Efficiency}} = \frac{1495.8 \text{ J}}{0.25} = 5983 \text{ J}$$

Energy expenditure over 2 seconds:

$$\text{Average metabolic power} = \frac{5983 \text{ J}}{2 \text{ s}} \approx 2991.5 \text{ W}$$

This indicates that the person's body would need to generate approximately 3 kW of metabolic power during this activity, which aligns with strenuous, short-duration efforts.

Considering Additional Factors in Power Calculation

While the above calculation provides a theoretical estimate based on work against gravity, real-world factors influence actual power:

1. Kinetic Energy Contributions

If the individual accelerates during ascent, kinetic energy becomes relevant:

$$KE = \frac{1}{2} m v^2$$

Suppose the person's top speed at the end of the climb:

- Assuming uniform acceleration:

$$v = \frac{\text{distance}}{\text{time}} = \frac{2.5, \text{ m}}{2, \text{ s}} = 1.25, \text{ m/s}$$

Kinetic energy:

$$KE = 0.5 \times 61.02, \text{ kg} \times (1.25)^2 \approx 0.5 \times 61.02 \times 1.5625 \approx 47.7, \text{ J}$$

This is relatively small compared to potential energy, but including it:

$$\text{Total work} = \text{Potential energy} + \text{Kinetic energy} \approx 1496 + 48 = 1544, \text{ J}$$

Adjusted power:

$$P = \frac{1544, \text{ J}}{2, \text{ s}} \approx 772, \text{ W}$$

The difference is minimal, but acknowledging kinetic energy makes the calculation more precise.

2. Energy Losses and Muscular Inefficiencies

Actual physical effort exceeds the minimal work calculated because of:

- Internal muscle inefficiencies
- Overcoming internal resistance
- Maintaining balance and posture

Thus, real power output, measured in metabolic terms, surpasses the mechanical power calculated.

3. Inclined Stairs and Realistic Climbing Path

In practice, stairs are inclined rather than vertical. The length of the stairs (hypotenuse) is longer than the height:

$$l = \frac{h}{\sin{\theta}}$$

where θ is the angle of incline. The actual work would then depend on the distance traveled along the incline and the force exerted along that path.

Summary of Key Findings

Aspect	Calculation / Insight	Approximate Value
Person's mass	Derived from weight	~61 kg
Work done (potential energy)	mgh	~1496 J
Kinetic energy (if any)	$0.5mv^2$	~48 J
Total work	Potential + Kinetic	~1544 J
Average power output	W / t	~772 W
Adjusted for muscular efficiency	$\text{Work} / \text{efficiency}$	~2992 W (metabolic power)

Implications and Real-World Context

Understanding these calculations extends beyond academic interest; it has practical implications:

- Physical training: Athletes training for sprinting or stair climbing can use such estimates to gauge exertion levels.
- Biomechanics research: Helps in designing ergonomic stairs and assessing human performance.
- Health and fitness: Provides a framework for understanding calorie expenditure during stair climbing.
- Engineering applications: Designing exercise equipment or assessing the energy requirements for robotic or prosthetic systems.

Final Thoughts: Limitations and Further Considerations

While the calculations above provide a solid foundation, several limitations should be acknowledged:

- Simplified assumptions: No account for air resistance, internal muscular inefficiencies, or biomechanical complexities.
- Short-duration activity: Human power outputs vary with duration; peak power can be higher than average power estimates.
- Individual

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