

2. A 60 W Filament Lamp Is Powered By The 240 V Mains Electricity Supply. The Lamp Is Switched On.(a)

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When examining electrical devices such as a 60 W filament lamp powered by a 240 V mains supply, it is essential to understand the fundamental principles of electrical power, voltage, current, and resistance. This article provides a comprehensive analysis of how a filament lamp operates under these conditions, exploring the relationships between voltage, current, resistance, and power. We will delve into the physics behind filament lamps, how they convert electrical energy into light and heat, and the implications of different parameters on their operation.

Understanding the Basic Concepts: Power, Voltage, Current, and Resistance

Before analyzing the specific case of the 60 W filament lamp, it is vital to understand some foundational electrical concepts:

Electrical Power (P)

- Defined as the rate at which electrical energy is converted into other forms of energy (light, heat, motion).
- Measured in Watts (W).
- Calculated as:

$$P = V \times I$$

where V is voltage in volts (V) and I is current in amperes (A).

Voltage (V)

- The electric potential difference between two points.
- In household systems, standard mains voltage is typically 240 V in many countries.
- Provides the 'push' that drives current through the electrical components.

Current (I)

- The flow of electric charge.
- Measured in amperes (A).
- The amount of charge passing through a conductor per unit time.

Resistance (R)

- The opposition to the flow of current.
- Measured in ohms (Ω).
- For a filament lamp, resistance varies with temperature, usually increasing as the filament heats up.

Operational Details of a 60 W Filament Lamp with 240 V Supply

When a 60 W filament lamp is connected to a 240 V mains supply and switched on, several critical factors influence its operation:

Calculating the Current Draw

Using the power formula:

$$[P = V \times I]$$

Rearranged to find current:

$$[I = \frac{P}{V}]$$

Substituting the known values:

$$[I = \frac{60\text{ W}}{240\text{ V}} = 0.25\text{ A}]$$

Thus, the lamp draws a current of 0.25 A when operating at full power.

Determining the Resistance of the Filament

Using Ohm's law:

$$[R = \frac{V}{I}]$$

Substituting the known values:

$$[R = \frac{240\text{ V}}{0.25\text{ A}} = 960\text{ }\Omega]$$

This indicates that at the operating temperature, the filament's resistance is approximately 960 Ω .

The Physics of Filament Lamps

Filament lamps operate based on the principle that an electric current passes through a thin wire filament, typically made of tungsten. The electrical resistance of tungsten causes the wire to heat up when current flows, producing light and heat.

How the Filament Converts Electrical Energy into Light and Heat

- Resistive Heating: As electrons move through the tungsten filament, collisions with atoms generate heat.
- Incandescence: The high temperature causes the filament to glow, emitting visible light.
- Efficiency: The process is not very energy-efficient, as much of the electrical energy is emitted as heat rather than visible light.

Temperature Dependence of Resistance

- The resistance of tungsten increases significantly as temperature rises.
- At room temperature, the filament's resistance is much lower (~around 150-200 Ω).
- When heated to operational temperatures (~2500–3000°C), resistance reaches around 960 Ω , as calculated earlier.
- This increase in resistance leads to a higher voltage drop across the filament at high temperature.

Electrical Power and Resistance Relationship in the Filament

The relationship between power, voltage, and resistance in the filament can be summarized as:

$$P = \frac{V^2}{R}$$

Rearranged:

$$\left[R = \frac{V^2}{P} \right]$$

Using the known values:

$$\left[R = \frac{(240)^2}{60} = \frac{57600}{60} = 960\, \Omega \right]$$

which confirms previous calculations.

Implications of Power and Voltage on the Lamp's Operation

Understanding how voltage and power influence the filament's behavior is vital for both practical applications and safety considerations.

Voltage Variations and Their Effects

- Increase in Voltage: If voltage rises above 240 V, the current increases, causing the filament to heat more and potentially burn out sooner.
- Voltage Drop: Fluctuations in mains voltage can change the brightness and lifespan of the lamp.

Power Ratings and Safety

- Lamps are rated for specific power and voltage; exceeding these ratings can lead to overheating and failure.
- Ensuring the supply voltage matches the rated voltage enhances lifespan and safety.

Practical Applications and Considerations

In real-world scenarios, several factors influence the operation of a filament lamp:

- **Voltage Stability:** Maintaining voltage close to 240 V ensures consistent brightness and longer lifespan.
- **Wiring and Connections:** Proper wiring reduces resistance in the circuit, preventing voltage drops.

- **Temperature Control:** The filament's temperature affects light output and longevity; too high temperatures accelerate wear.
- **Energy Efficiency:** Since filament lamps convert most electricity into heat, they are less energy-efficient compared to modern LED lighting.

Conclusion

The operation of a 60 W filament lamp connected to a 240 V mains supply involves a complex interplay of electrical principles. The key points to remember are:

- The lamp draws approximately 0.25 A of current.
- Its filament resistance at operational temperature is about 960 Ω .
- The conversion of electrical energy into light and heat is governed by the resistive properties of tungsten.
- Variations in supply voltage directly impact the brightness, lifespan, and safety of the lamp.

Understanding these principles aids in designing, operating, and maintaining electrical lighting systems efficiently and safely. Proper knowledge of the relationships between power, voltage, current, and resistance ensures optimal performance and prolongs the life of filament lamps used in everyday applications.

Frequently Asked Questions

What is the current drawn by a 60 W filament lamp powered by a 240 V supply?

The current can be calculated using the formula $I = P / V$, so $I = 60 \text{ W} / 240 \text{ V} = 0.25 \text{ A}$.

How does the power rating of the lamp relate to its brightness?

Generally, a higher wattage lamp produces more light and appears brighter; hence, a 60 W lamp is moderately bright compared to lower wattage bulbs.

What happens to the filament in the lamp when it is

switched on?

The filament heats up rapidly due to electrical resistance, producing visible light and heat energy.

Why is the filament in a 60 W lamp made of tungsten?

Tungsten has a high melting point and good electrical resistance, making it ideal for producing light without melting quickly.

What safety precautions should be taken when handling a lit filament lamp?

Avoid touching the hot filament, keep the lamp away from water, and ensure the power supply is switched off before handling or replacing the bulb.

How does the voltage supply affect the functioning of the 60 W lamp?

If the supply voltage is higher than 240 V, the lamp may become brighter but could burn out faster; if lower, it may be dimmer or not function properly.

What is the significance of the lamp's power rating in terms of energy consumption?

A 60 W lamp consumes 60 joules of energy per second when in use; over time, this determines its energy cost and efficiency.

Can the lamp operate at voltages different from 240 V?

It can operate at different voltages if designed for such, but using it at a different voltage may affect brightness and lifespan; it is best to use the specified voltage.

What is the relationship between power, voltage, and current in the lamp?

The power (P) equals voltage (V) multiplied by current (I), so $P = V \times I$; for this lamp, a 60 W power at 240 V corresponds to a current of 0.25 A.

Additional Resources

A 60 W Filament Lamp Is Powered By The 240 V Mains Electricity Supply. The Lamp Is Switched On.

Introduction

In the realm of everyday lighting, the humble filament lamp remains a cornerstone of illumination technology, despite the advent of LED and fluorescent alternatives. Its operation, rooted in classical physics, offers an insightful case study into electrical power consumption, resistance, and thermal effects. This review investigates the fundamental principles governing a 60 W filament lamp powered by a 240 V mains supply, exploring the physics, engineering considerations, safety implications, and practical applications associated with such systems.

Understanding the Basic Electrical Principles

Power, Voltage, and Resistance: The Core Relationship

At the heart of the filament lamp's operation lies Ohm's Law and the power formula:

- Power (P) = Voltage (V) $\times$ Current (I)

- Resistance (R) = V / I

- Power (P) = $V \times I = V^2 / R$

Given the lamp's rated power of 60 W and supply voltage of 240 V, we can derive key electrical parameters.

Calculating Resistance of the Filament

Using the power equation:

$$R = \frac{V^2}{P} = \frac{(240\text{ V})^2}{60\text{ W}} = \frac{57,600}{60} = 960\text{ }\Omega$$

Thus, the filament's resistance when cold is approximately 960 Ω . However, this resistance is not constant during operation.

The Dynamic Nature of the Filament Resistance

Resistance Variation with Temperature

The filament in a typical incandescent lamp is usually made of tungsten due to its high melting point and favorable electrical properties. Tungsten's resistance at room temperature is substantially lower than at operational temperature.

- At room temperature: Resistance is roughly 1/10th of its operating value (~96 Ω).
- At operating temperature (~2500°C): Resistance increases significantly, often by a factor of 10 or more, reaching approximately 960 Ω as calculated.

This resistance change is central to understanding the lamp's operation:

- When switched on, the filament initially heats up rapidly, increasing resistance.
- The increased resistance reduces the current slightly from the initial surge.

Thermal Effects and Incandescence

The current passing through the filament heats it to incandescence—emitting visible light due to blackbody radiation. The temperature of the filament directly influences luminous efficacy and lifespan.

Analyzing the Power Consumption and Operation

Initial Surge and Steady-State Conditions

When the lamp is first switched on:

- The cold filament resistance (~96 Ω) allows a higher initial current:

$$I_{\text{initial}} = \frac{V}{R_{\text{cold}}} = \frac{240\text{ V}}{96\text{ }\Omega} \approx 2.5\text{ A}$$

- Power during initial surge:

$$P_{\text{initial}} = V \times I_{\text{initial}} = 240\text{ V} \times 2.5\text{ A} = 600\text{ W}$$

This exceeds the rated 60 W, but this is an instantaneous transient. The filament heats quickly, increasing resistance to around 960 Ω .

At steady state:

$$I_{\text{steady}} = \frac{V}{R_{\text{hot}}} = \frac{240\text{ V}}{960\text{ }\Omega} = 0.25\text{ A}$$

and

$$P_{\text{steady}} = V \times I_{\text{steady}} = 240\text{ V} \times 0.25\text{ A} = 60\text{ W}$$

which matches the rated power.

Implications of Power Calculations

This analysis demonstrates why the filament's resistance and current vary during startup:

- The initial high current (inrush current) can cause stress and potential filament failure over time.
- The stable operating current maintains the filament at high temperature, providing consistent illumination.

Safety and Operational Considerations

Electrical Safety

- Voltage Compatibility: The lamp is designed for 240 V supply; deviations can cause overcurrent or insufficient illumination.
- Fusing and Circuit Protection: Proper fuses and circuit breakers prevent overloads and short circuits.

Mechanical and Thermal Safety

- Filament Fragility: Tungsten filaments are brittle at high temperatures; mechanical shocks can cause breakage.
- Heat Dissipation: The glass bulb and surrounding fixtures must handle the heat generated.

Energy Efficiency and Lifespan

- Incandescent lamps like this are less energy-efficient compared to modern LEDs, but their simplicity offers reliability.
- Lifespan is typically limited to 1000 hours, primarily due to tungsten evaporation and filament thinning.

Practical Applications and Broader Impacts

Usage Scenarios

- Domestic lighting: bedrooms, living rooms, where warm light is desired.
- Decorative lighting: chandeliers, vintage fixtures.
- Educational demonstrations: illustrating basic electrical principles.

Environmental and Economic Considerations

- Higher energy consumption contributes to larger carbon footprints.
- Transitioning to energy-efficient alternatives is encouraged, but understanding traditional filament lamps remains relevant.

Engineering and Design Insights

Material Choices

- Tungsten is preferred for its high melting point and stable resistance at high temperatures.

Filament Design

- Thin, coiled filament increases resistance and light emission efficiency.
- Coiling reduces the filament's length and aids in heat dissipation.

Power Ratings and Compatibility

- Ensuring the lamp's power rating matches supply voltage is crucial for longevity and safety.

Conclusion

The operation of a 60 W filament lamp powered by a 240 V mains electricity supply exemplifies fundamental electrical and thermal physics principles. From the initial surge in current to the steady-state incandescence, the lamp embodies a delicate balance of material properties, electrical design, and thermal management. Despite the rise of energy-efficient lighting, understanding these classical systems provides insight into fundamental engineering principles and highlights the importance of safety and proper design in everyday electrical devices. As we move towards sustainable solutions, such analyses remain vital in appreciating both the historical significance and the engineering challenges of traditional incandescent lighting.

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Note: This article is intended for educational and review purposes, providing a comprehensive analysis of the operational principles of a 60 W filament lamp powered by 240 V mains supply.

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