TOPIC:

SIMULATING LIGHTNING

Edward Raphael (2702355391)
Harry Chiu (2702357882)

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Physical Process

How Lightning strikes

For lightning strikes to occur, it requires electric discharges between electricly charged regions withing the atmosphere or between the atmosphere and the ground.

Lightning Formation

During a thunderstorm, updrafts and downdrafts caused by turbulent winds **seperates the electical charge** in a cloud. Making negative charges accumulate at the cloud's base while positive charges accumulate at the top, creating strong electric fields.

Lightning Discharge

As opposite charges attract, positive charges on the ground gets attracted to the cloud's base, accumulating in tall objects such as trees and building. A lightning strike begins with,

- A **stepped leader**, a channel of ionized air that propagates downward in steps until it reaches the ground.
- An **upward streamer** of positive charge rises to meet it completing the conductive path.
- **Return stroke** is the triggered, where massive currents flow upward, producing the bright flash. The extreme heat from the plasma channel causes rapid air expansion, creating a shockwave known as thunder.

Physics Domain

Field of physics related to Lighting strikes

- Electromagnetism,
- Thermodynamics,
- Plasma physics,

Concepts and theories

- Coloumb’s Law,
- Electrostatics,
- Gauss’s Law,
- Lorentz Force Law,.

Mathematical Background

Poisson's equation

- $\nabla^2\Phi = -\rho/\varepsilon_0$

Φ: Electric potential (V)
ρ: Charge density (C/m^3)
ε_0: Permittivity of free space (8.85×10^{-12} F/m)

Calculates the electric potential, giving the voltage distribution.

Electric Field

- $E = -\nabla\Phi$

E: Electric field (V/m)
$\nabla\Phi$: Gradient of electric potential

Determines how the charges will move and identify where the striker will occur.

Mathematical Background

Condiitions

- E ≥ E breakdown

  Lightning starts when the electric field exceeds 3.0 x 10^6 V/m

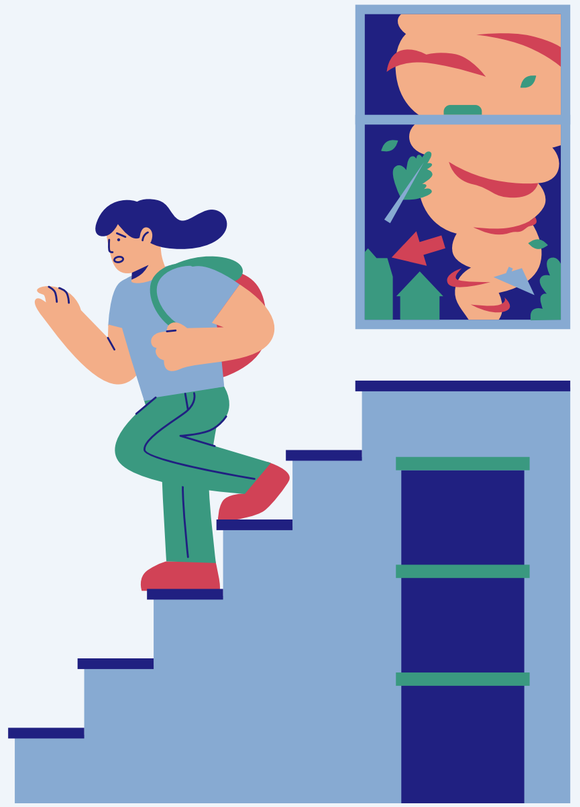
Considerations

- We can also implement the affect of tall buildings since they enhance the electric field within the area.

$$E_{\text{enhanced}}(x,y) = E_0 \left(1 + \frac{h(x,y)}{h_{\text{cloud}}}\right)$$

Applications

- Plasma Physics - Understand Controlled Discharges
- Simulating the natural branching patterns
- Weather Prediction



OUTCOMES

- Simulate lightning patterns (2D)
- Identify the behavior of lightning under scenarios
- Validate the laws of electric discharge

Thank you!

References

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