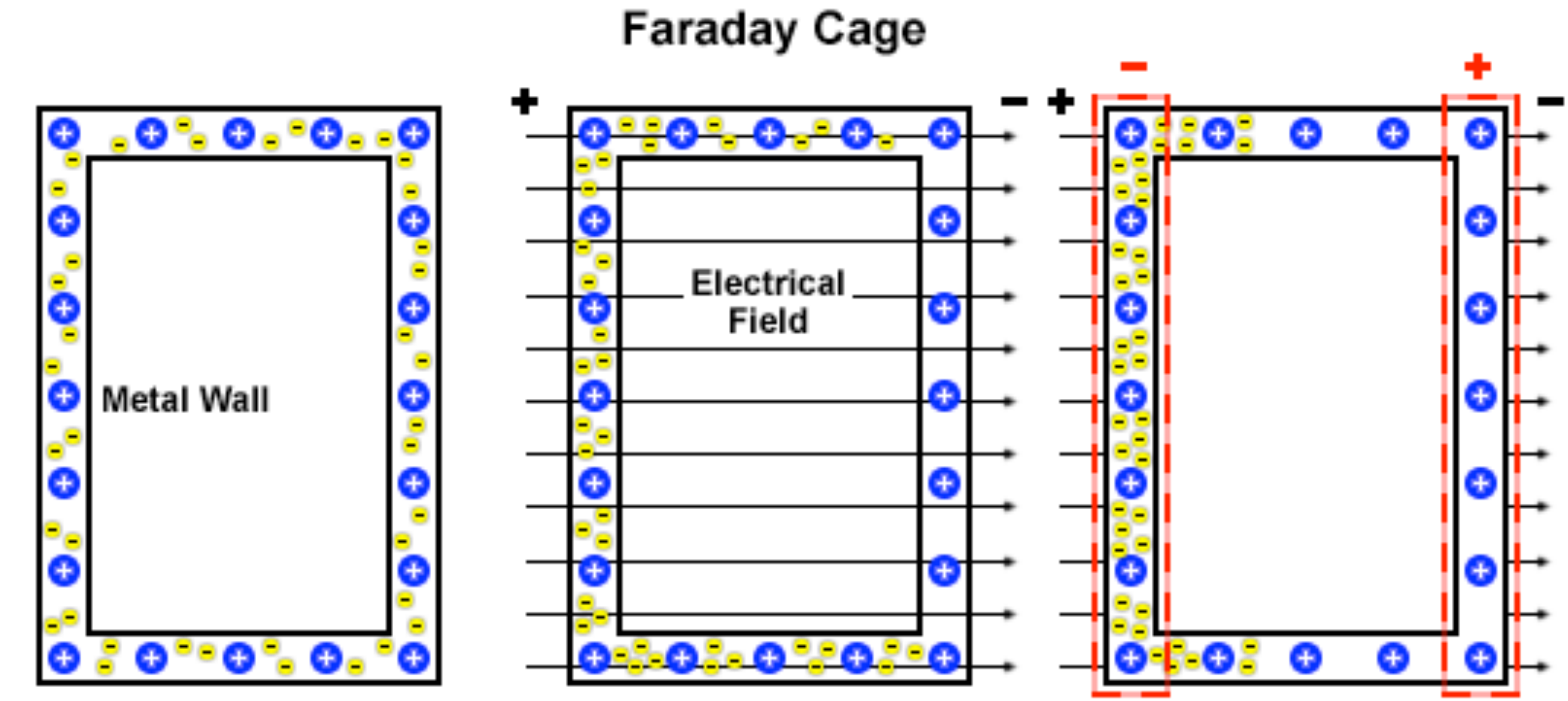
General announcements

Electrical shielding



Faraday Cage in the absence of an electrical field.

The charged particles in the wall of the Faraday cage respond to an applied electrical field.

Electrical fields generated inside the wall cancel out the applied field, neutralizing the interior of the cage.

c/o C. Vivo

Faraday Cage

c/o C. Vivo

Conductors in electrostatic equilibrium

Consider a neutral, metal conductor.

- What is true about some of the electrons in that conductor?

  They're free to move within the material - remember metallic bonding?

If no net motion of charge occurs in that conductor, it's in **electrostatic equilibrium**. (This occurs when a conductor is isolated and insulated from the ground). This means:

- *The electric field is zero everywhere* inside the conductor.

  If not, what would happen? The field would cause charge to move - not equilibrium!

- *Any excess charge* on that conductor is entirely on its surface.

  If not, what would happen? They'd repel and move towards the surface anyways!

- *The E field just outside* a charged conductor is perpendicular to its surface.

  If not, what would happen? There would be a surface-parallel component, which would make charges flow…not equilibrium!

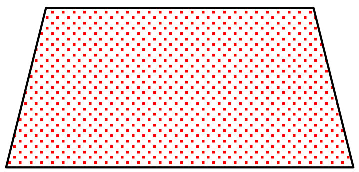
- *If irregular,* charge accumulates at sharp points (where the radius of curvature is smallest).

  Let's look at this…

Shielding

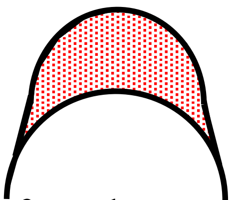
When free charge is placed on a conductor, electrical repulsion will motivate electrons to move as far away from other electrons as possible. Consequence:

Force electrons onto a flat conducting surface. At some point, the free electron population already on the surface will provide such a large repulsive force that no additionally placed electrons will make it onto the surface. When that happens, the electrons will be evenly distributed over the surface.



surface charge density evenly distributed

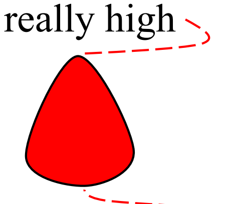
Bend the surface and you can force MORE electrons on, increasing the *surface charge density*. Why? Because there is now material between the electrons, diminishing their repulsive effect on distance electrons. This phenomenon is called SHIELDING.



surface charge density increased

Oddly shaped conductors will have different charge densities, depending upon the severity of their curvature.

The extreme: the lightning rod, a pointed piece of metal insulated from a house. It accumulates HUGES amount of charge at its end point, attracting potential lightning strikes away from the house.

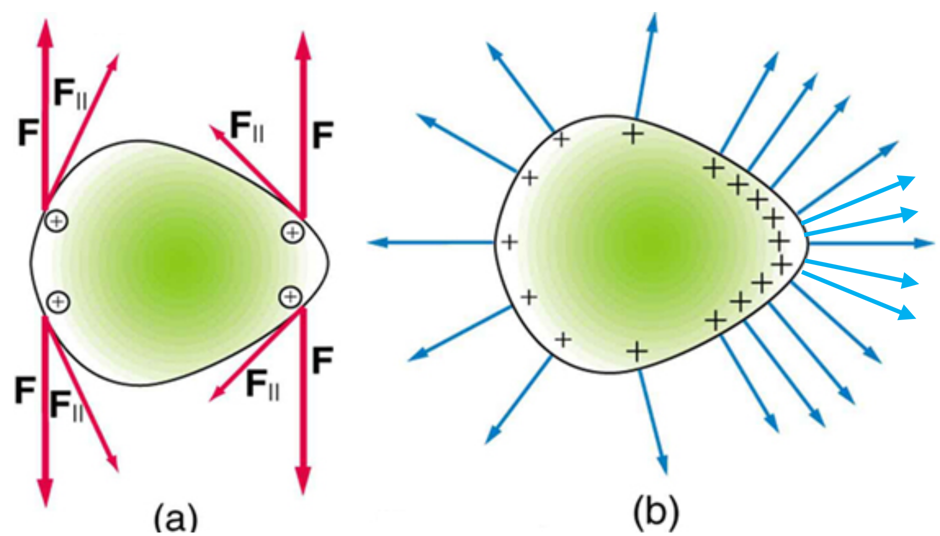


Irregularly-shaped conductors

Consider the object below. Charges on the flatter (left) end exert repelling forces, which are close to parallel to the surface, so the charges move out until repelling forces from other charges bring them to equilibrium.

Charges on the pointier (right) end exert similar repelling forces, but a much smaller component is parallel to the surface, so the charges don't move much before being brought to equilibrium.

The result? Charges gather more densely on pointier ends, to keep the electric field oriented perpendicular to the surface.



This is the principle behind lightning rods!

https://courses.lumenlearning.com/suny-physics/chapter/18-7-conductors-and-electric-fields-in-static-equilibrium/

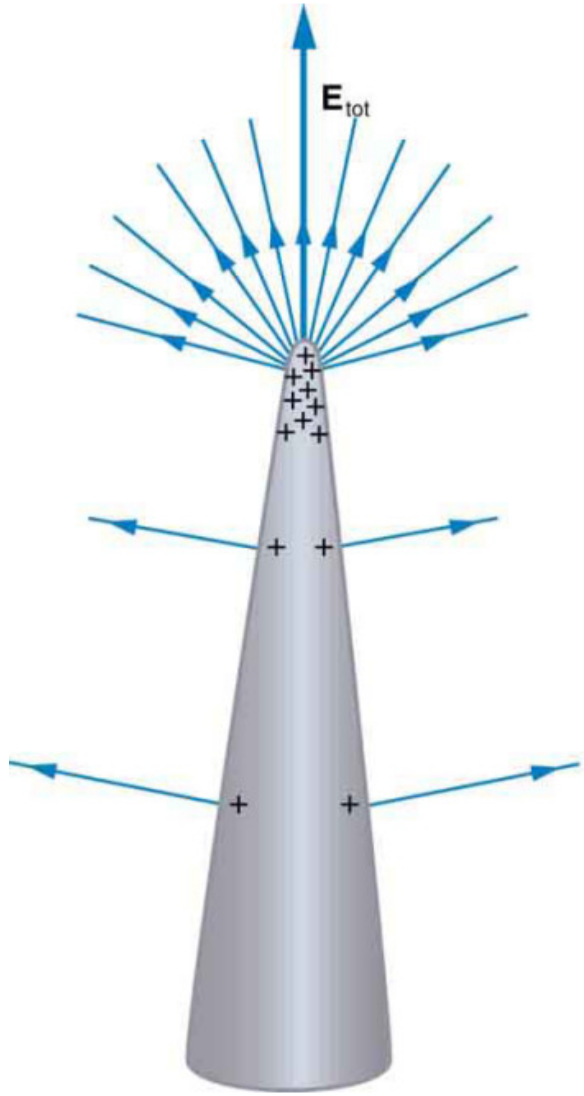
St. Elmo's fire

Why masts, church steeples, and other pointy objects?

Remember that charges want to spread out as much as possible - but can't get as far away from each other at pointy ends

This creates a stronger electric field at the pointy end

If the field is strong enough, it can ionize the air molecules and create the conditions for the various electrical phenomena we just talked about!



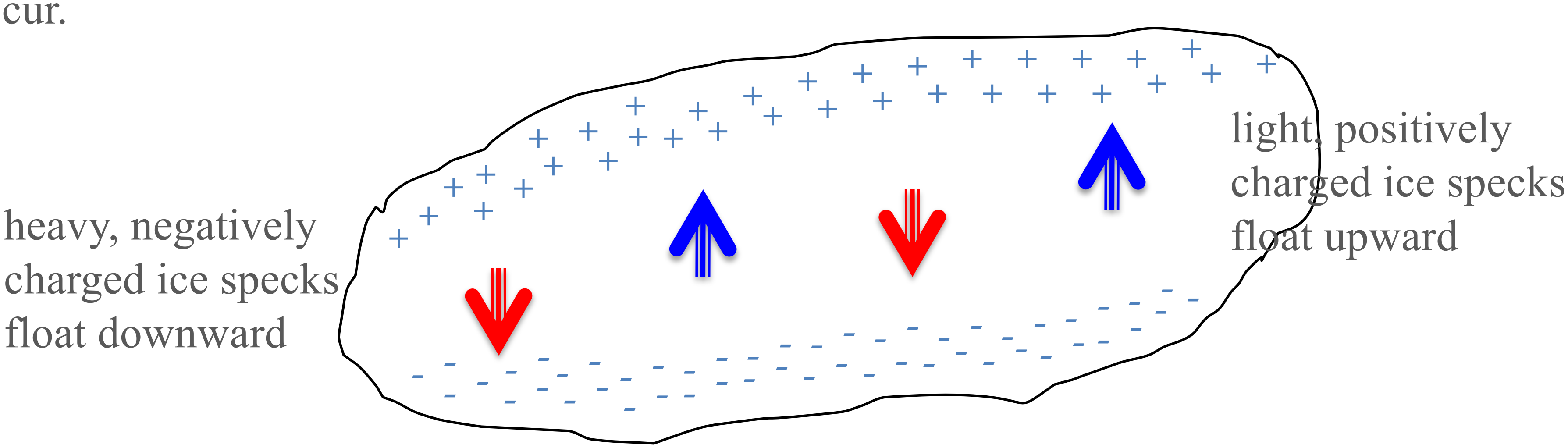
https://courses.lumenlearning.com/physics/chapter/18-7-conductors-and-electric-fields-in-static-equilibrium/

Lightning

What is lightning? How does it form?

1.) *Water crystals* in a cloud will rub against one another charging by contact.

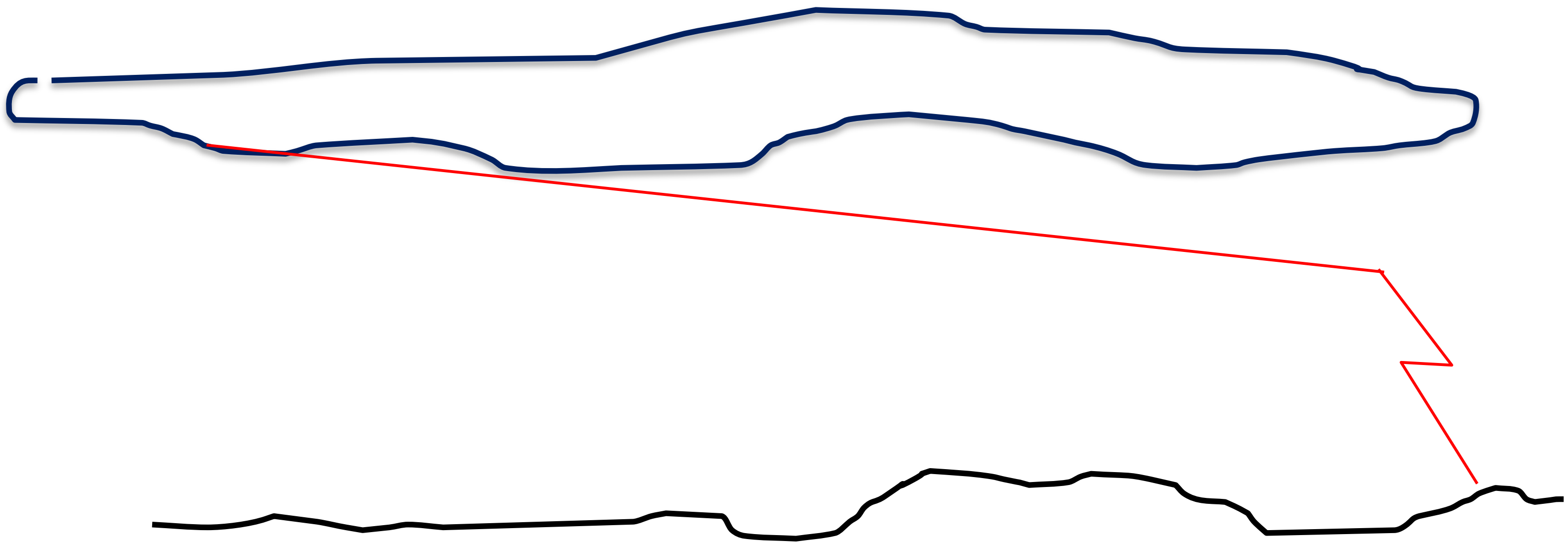
2.) *Lighter particles* tend to accumulate positive charge and “float” upward into the top part of the cloud. Heavier particles tend to accumulate negative charge and drop to bottom part of cloud. This charge separation is what creates the situation in which lightning flashes occur.



3.) *A lightning flash* will literally bore a hole, in essence creating a vacuum, through what is normally a good insulator, the atmosphere. It is the atmosphere filling in this vacuum that creates the thunder clap.

Revisiting lightning

4.) If the bottom of the cloud is negative, that charge will induce a positive charge on the earth's surface (on conductors, electrons literally flow away from the surface leaving the surface electrically positive; in insulators, we get the Van der Waal effect making even insulators look electrically positive on their surface).



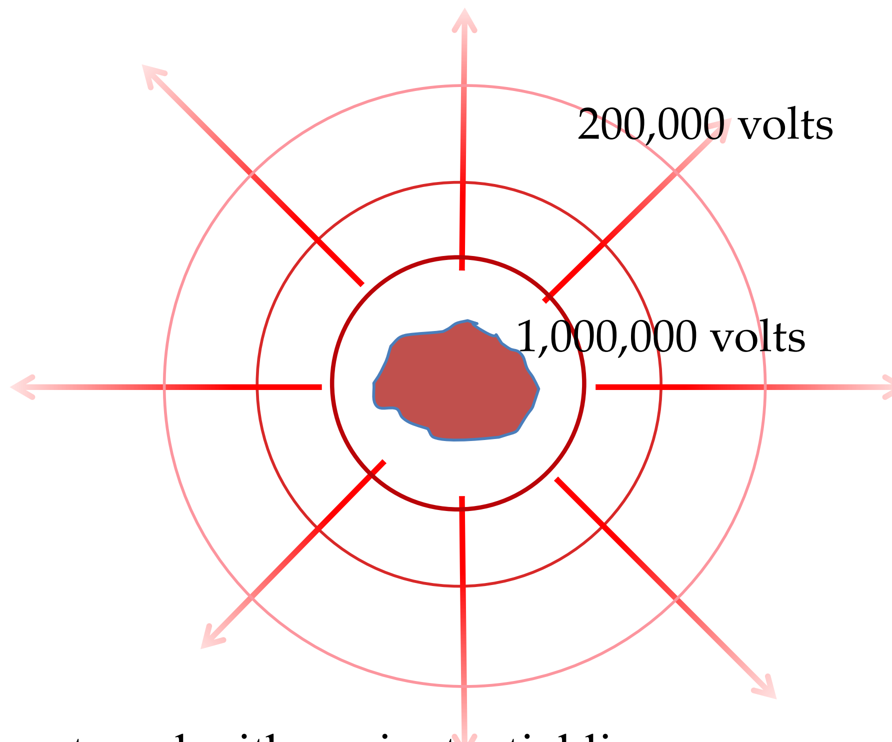
5.) Lightning can strike from storms several miles away (the path a strike takes is more or less the path of least resistance, and that is not always directly downward). This is where the expression, "From out of the blue," came from. It is possible to have a strike when the sky overhead is clear.

Some numbers

6.) There are approximately *100 strikes per second* worldwide. A single strike can generate temperatures of 25,000-30,000 degrees and can fuse sand into nodules. A single strike can generate 30,000 to 300,000 amps of current and dump 500,000,000 joules of energy.

7.) One of the problems associated with being close to a lightning strike is that when the strike's energy is dumped into the ground, it creates what is called *an electrical potential gradient*. That is, the voltage right next to the tree, for instance, is considerably higher than the voltage just a few feet from the tree. If you happen to be spanning that distance because your feet are spread apart, you will find yourself with a huge **voltage difference** between your feet. That will produce an enormous electric field through your body and can result in death.

tree trunk as viewed from above at a particular instant:



energy radiates outward with equipotential lines being circles that diminish with time

So…

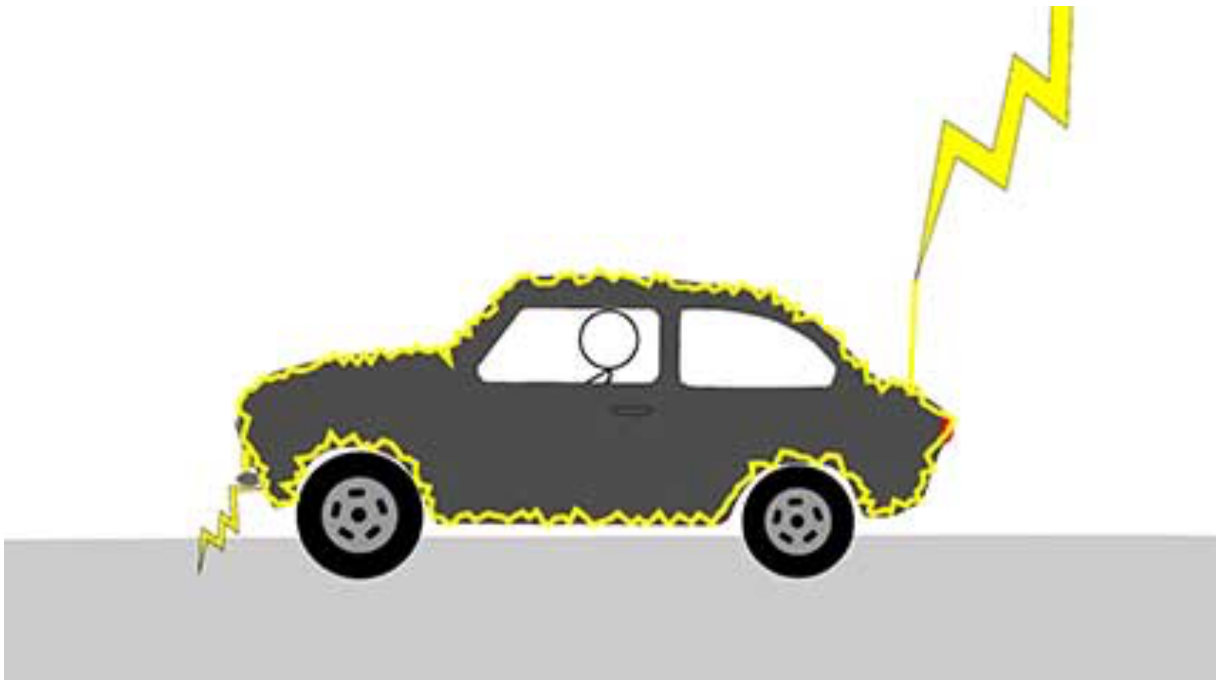
Based on what you learned last unit, where would you rather be during a lightning storm:

- In your car?
- Under a tree?
- WHY?

http://www.abc.net.au/news/2018-01-09/sydney-hit-by-fierce-lightning-storm-but-hot-weather-to-return/9313516

Remember shielding?

In a lightning strike, the frame of your car acts like a Faraday cage!
It's <u>not</u> the rubber tires that keeps you safe.



[Minute Physics - car + lightning strike]()

[Actual footage of a car lightning strike]()

Ball lightning

What is it?

- Uncommon event (up to 20-25 seconds)
- Looks like a small ball of lightning that often appears in windows, in airplane cockpits, down chimneys

Not well understood - one working theory is that leftover ions from lightning strikes accumulate on windows or buildings (instead of being grounded), and those ions "pile up" and create an electric field that can get through the glass -- this gives electrons inside the window enough energy to ionize nearby air molecules, creating a glowing ball.

(John Lowke, CSIRO)

Ball Lightning - "Globe of Fire Descending into a Room" in "The Aerial World," by Dr. G. Hartwig, London, 1886. P. 267. Library Call Number QC863.4 H33 1886. Image ID: libr0524, Treasures of the NOAA Library Collection

St. Elmo's Fire

A similar phenomenon is St Elmo's Fire, often seen on the masts of ships and mentioned in many works of literature

"Everything is in flames, — the sky with lightning, — the water with luminous particles, and even the very masts are pointed with a blue flame."
— Charles Darwin, 1832

"... sometime I'ld divide,
And burn in many places; on the topmast,
The yards and bowsprit, would I flame distinctly,
Then meet and join."
— William Shakespeare, *The Tempest*

"About, about, in reel and rout, The death fires danced at night; The water, like a witch's oils, Burnt green and blue and white."
—Samuel Taylor Coleridge, *The Rime of the Ancient Mariner*

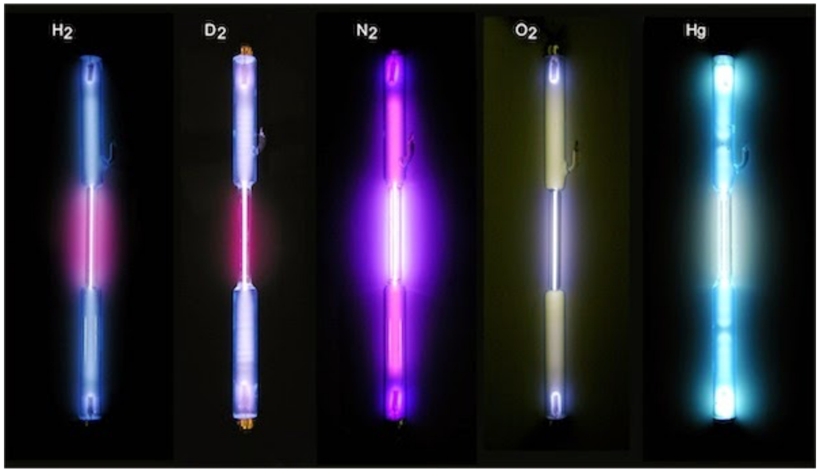
'ST. ELMO'S FIRE' ON MASTS OF SHIP AT SEA.

http://physicsbuzz.physicscentral.com/2014/10/the-ghostly-glow-of-st-elmos-fire.html

St. Elmo's fire

A strong electric field can ionize air molecules, creating a plasma

- *The strength of the field* can rip protons and electrons apart, breaking bonds and releasing energy
- *As those electrons travel* through the plasma, they interact with air molecules, and excite electrons in those molecules
  - *What's air made of?* What do you know about how those gases act under high voltage?



Discharge tubes showing various gases - our atmosphere is mostly N and O, so air molecules put out a violet/blue light.

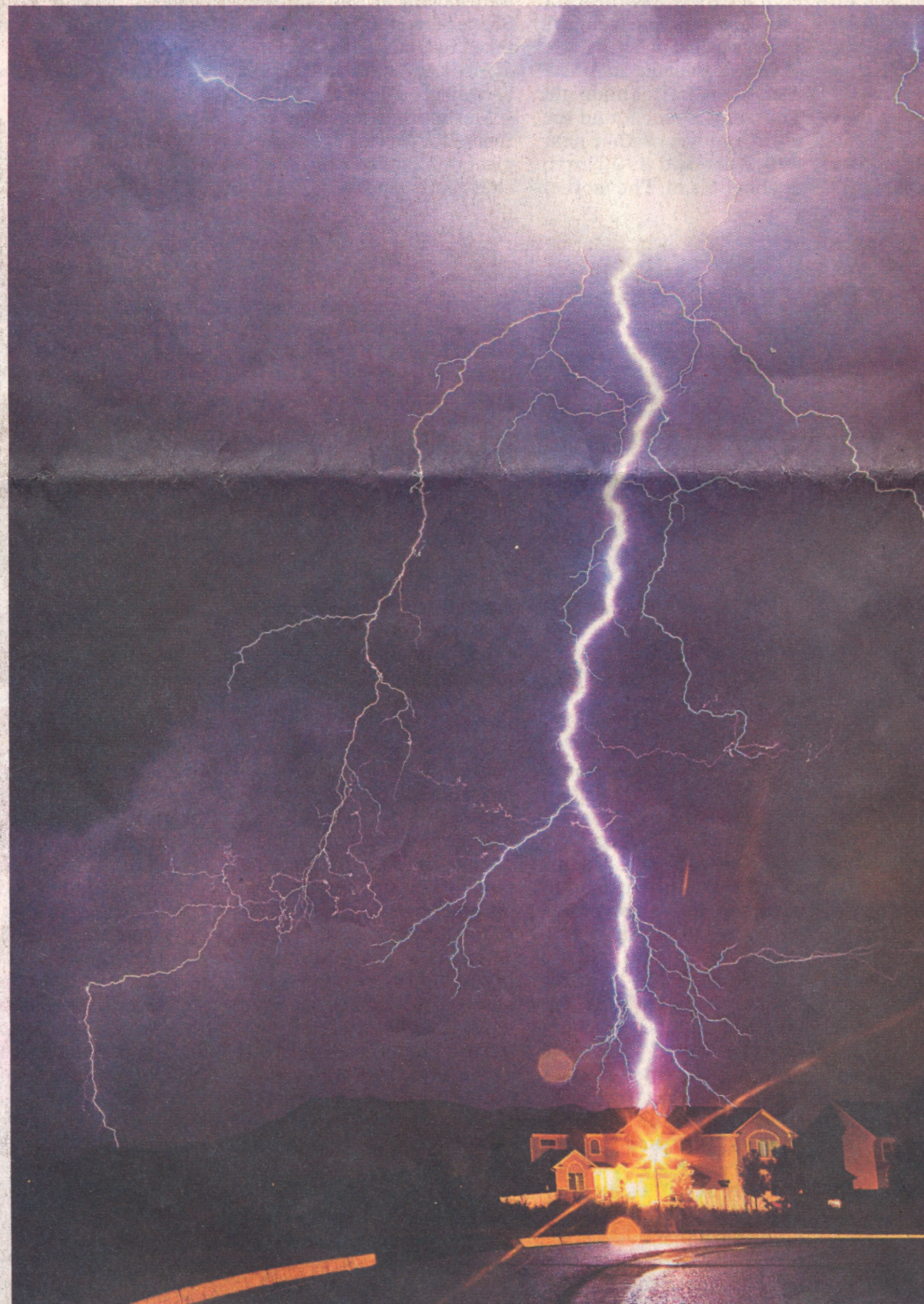
The appearance of St. Elmo's fire often heralds the end of a thunderstorm, so it's traditionally considered a good omen by sailors

http://physicsbuzz.physicscentral.com/2014/10/the-ghostly-glow-of-st-elmos-fire.html

LIGHTNING

Almost all of the photos in this presentation came from the free-picture Web site Pixdaus.

UNUSUAL LIGHT SHOW



LUKE ISLEY

Antelop
Island h
gets an

Outdoors » One-y
expected to raise $2

By TOM WHARTON
The Salt Lake Tribune

The Utah State Parks b
Thursday to establish a
on Antelope Island expec
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ers who will likely place
trophy mule deer and big
The board voted to iss
for each species — one t
draw and another to be a
the highest bidder at the a
and Hunting Conservati
Nov. 15 through Nov. 30
acres of the island.

Corroon
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committe
quality of

By JEREMIAH STETTLER
The Salt Lake Tribune

Gov. Gary Herbert is
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Utahns' quality of life, D
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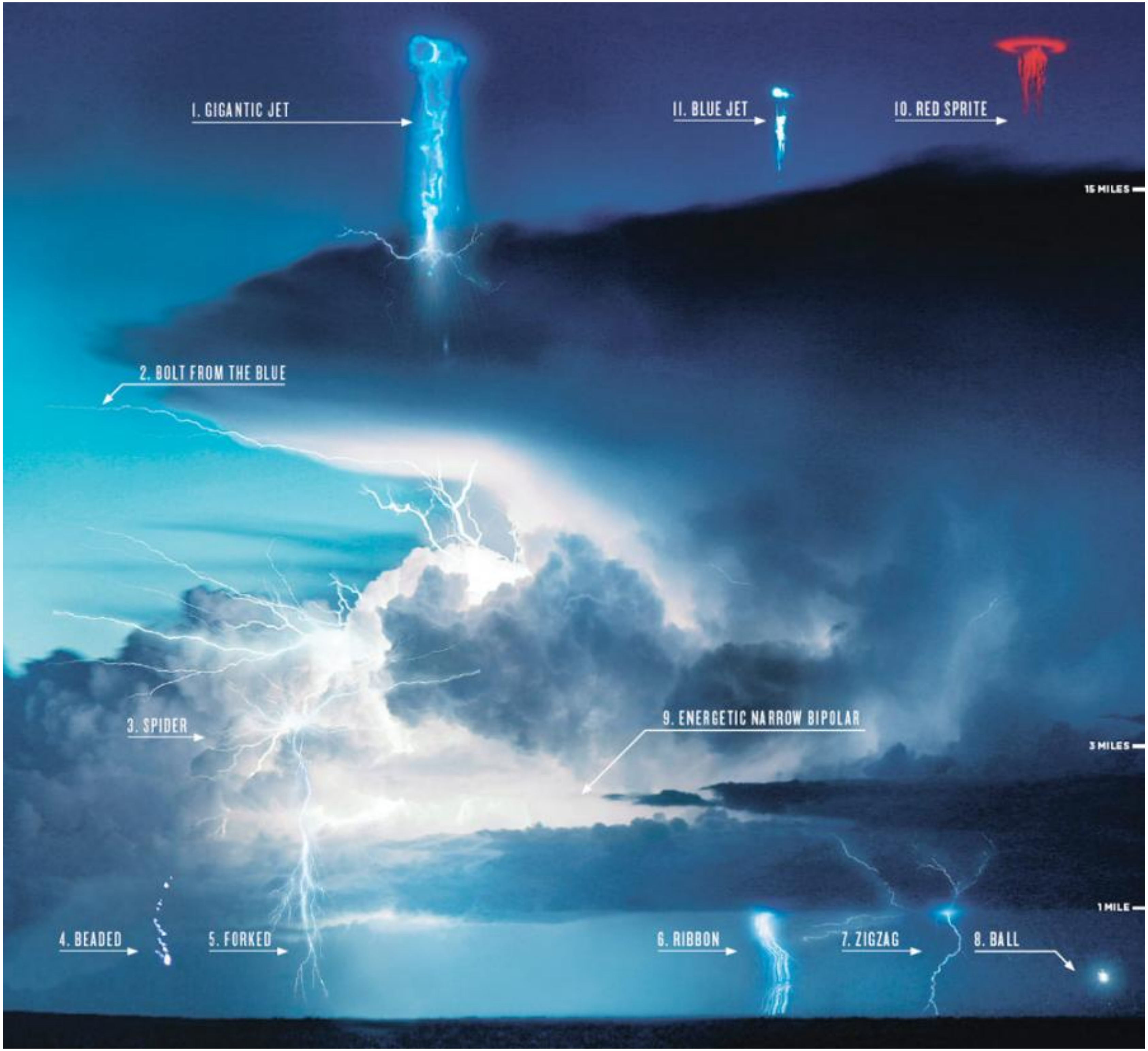
© www.extremeinstability.com


videlec.org


1. GIGANTIC JET
11. BLUE JET
10. RED SPRITE
15 MILES
2. BOLT FROM THE BLUE
3. SPIDER
9. ENERGETIC NARROW BIPOLAR
3 MILES
1 MILE
4. BEADED
5. FORKED
6. RIBBON
7. ZIGZAG
8. BALL

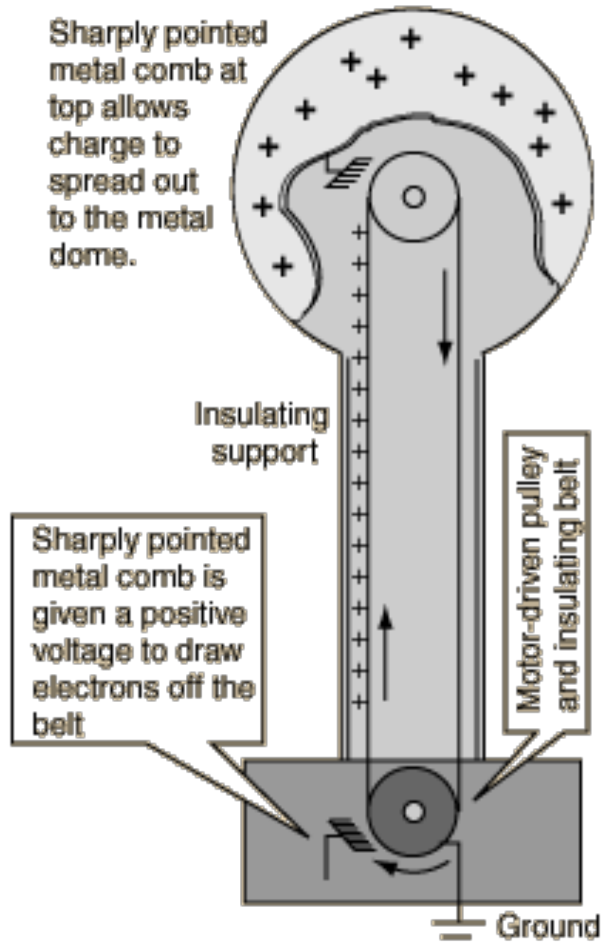

Warren Tyrer © 2009


VITALY KLIMOV

“Making” lightning

- A **Van de Graaff generator** is a commonly known device for creating large voltages with startling (but not dangerous) results
- How do you think this works?

https://spectrumscientifics.wordpress.com/2016/08/16/making-electricity-van-de-graaff-generators-and-tesla-coils/



http://hyperphysics.phy-astr.gsu.edu/hbase/electric/vandeg.html