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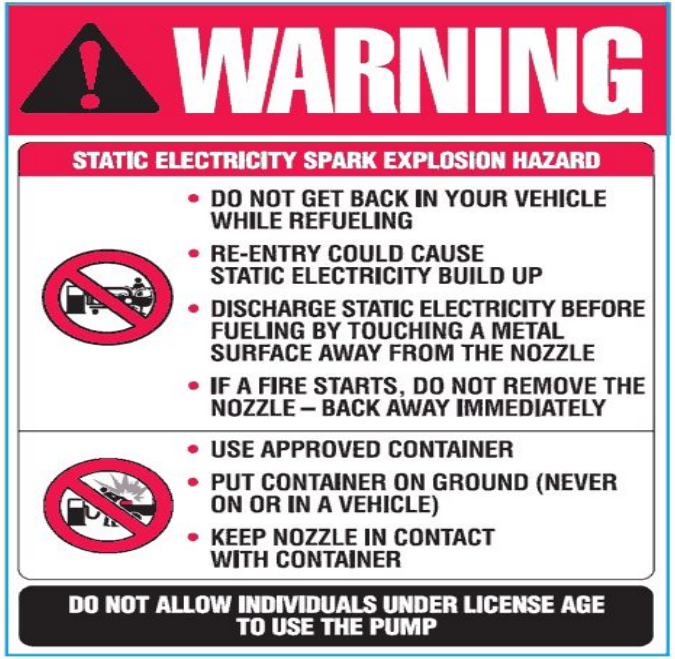
# Danger: Dielectric Breakdown when Fueling

# Inspiration & Importance

Re-entering one's vehicle while fueling increases risk of explosion due to static charge build-up.

Exploring the "danger threshold" reinforces the legitimacy of the warning.



# Experimental Question & Hypothesis

Question

- How does the combination of vehicle frame material and interior seat material affect the likelihood of causing an explosion while fueling?

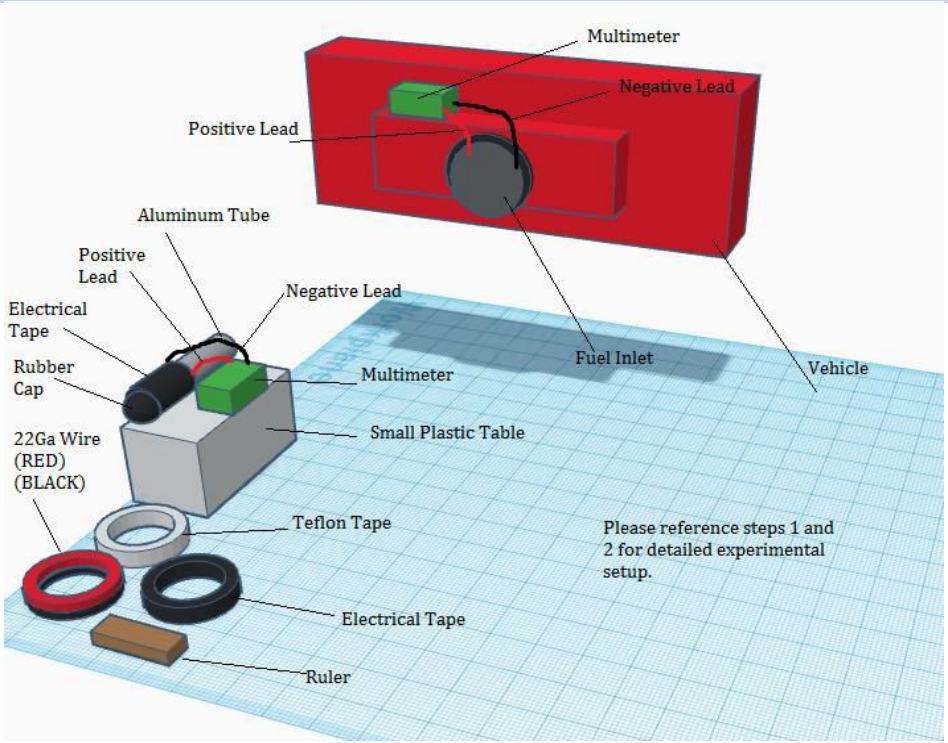
Hypothesis

- An aluminum frame and cloth seats will create the most dangerous circumstances.

# Experimental Method: Equipment

- 18” Aluminum tube, 1.5” diameter
- Ruler
- Roll of Teflon tape
- Roll of electrical tape
- Roll of 22ga coated (Red) wire
- Roll of 22ga coated (Black) wire
- 1.5” Rubber end cap
- Pair of denim jeans
- Pair of rubber sole shoes
- 2x Multimeter
- 1965 Mustang (Cleaned fuel tank, fuel inlet, and dried for three days to reduce risk of fire. Professionally done.)
- 2017 Mustang (Cleaned fuel tank, fuel inlet, and dried for three days to reduce risk of fire. Professionally done.)
- Leather Bucket Seat
- Cloth Bucket Seat

# Experimental Method Diagram



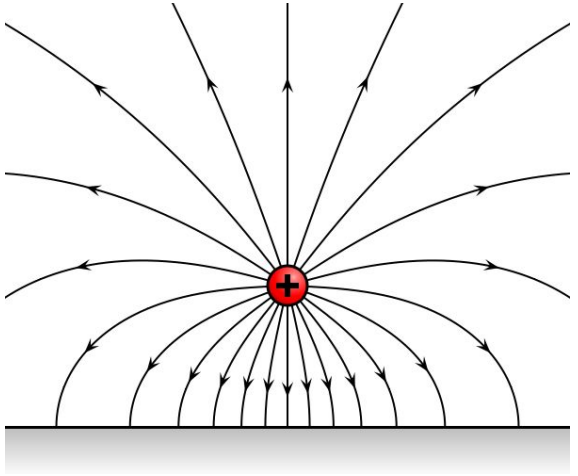
# 1

# Charges and Dielectrics

# Concepts: Electric Field

A region around a charged particle or object where a force would be exerted on other particles or objects.

In our experiment, we utilized this equation to figure out the charge needed to create a spark depending on a multitude of sources.

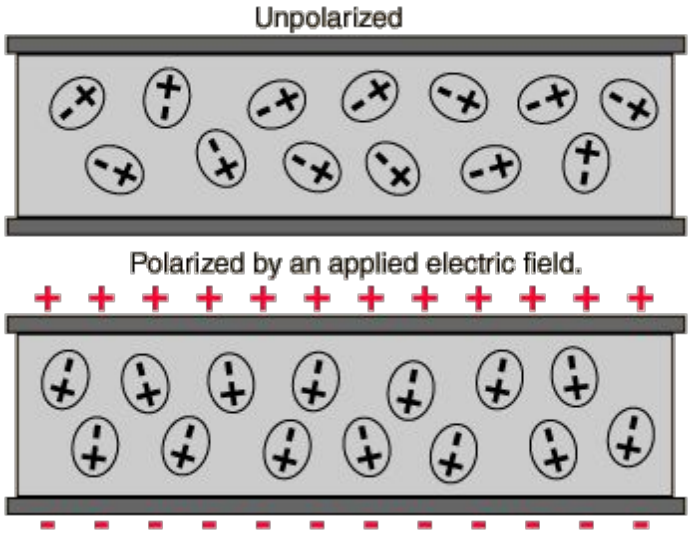


$$E = \frac{kQ}{r^2}$$

# Concepts: Dielectric Material

Dielectric material is an electrical insulator that can be polarized by an Electric Field.

The dielectric in our case is the air, which is polarized by the Electric Field of our multiple sources.



# Concepts: Capacitor

A capacitor is a device that is used to store electric charge. Specifically, a capacitor is made of two conductors and separated by an insulator.

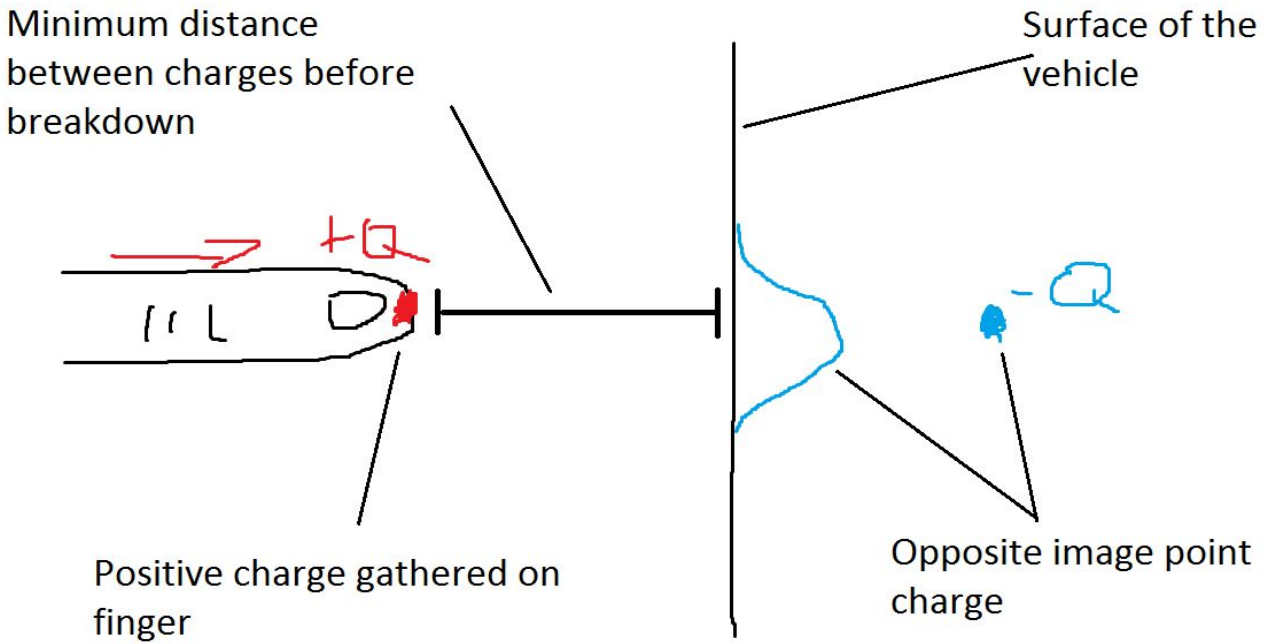
The insulator in our case is the air, which is a dielectric. The two conductors vary with our experiment.

# Concepts: Antenna* Effect

Effectively, attraction between charged particles causes charge to build up on the point that minimizes distance between the attracted particles.

* Antenna effect refers to issues w/ dielectric breakdown in integrated circuit design

# Antenna Effect Continued



## Concept: Image Charges

Image charges are a simple way to anticipate how a conductor behave near a charged object. Since the electrons in large conductors can move freely, bringing a charged object near a conductor causes a charge of opposite sign to gather on the conductor near the object.

We used this concept as a factor in calculating the electric field in our dielectric: air.

# Experimental Method: Calculations

## Electric Field due to Finger

$$E = \frac{kQ}{y}\left(\frac{1}{\sqrt{\ell^2 + y^2}}\right) = \frac{kQ}{(5 \cdot 10^{-3})}\left(\frac{1}{\sqrt{(5.08 \cdot 10^{-2})^2 + (5 \cdot 10^{-3})^2}}\right) = 3 \cdot 10^6 N/C$$

$$Q = 8.517 \cdot 10^{-8} C$$

## Electric Field due to fueling tube

$$E = \frac{kQ}{(R^2 + y^2)^{\frac{3}{2}}} = \frac{kQ}{((1.27 \cdot 10^{-2})^2 + (5 \cdot 10^{-3})^2)^{\frac{3}{2}}} = 3 \cdot 10^6 N/C$$

$$Q = 1.697 \cdot 10^{-7} C$$

## Electric Field due to Metal Panel

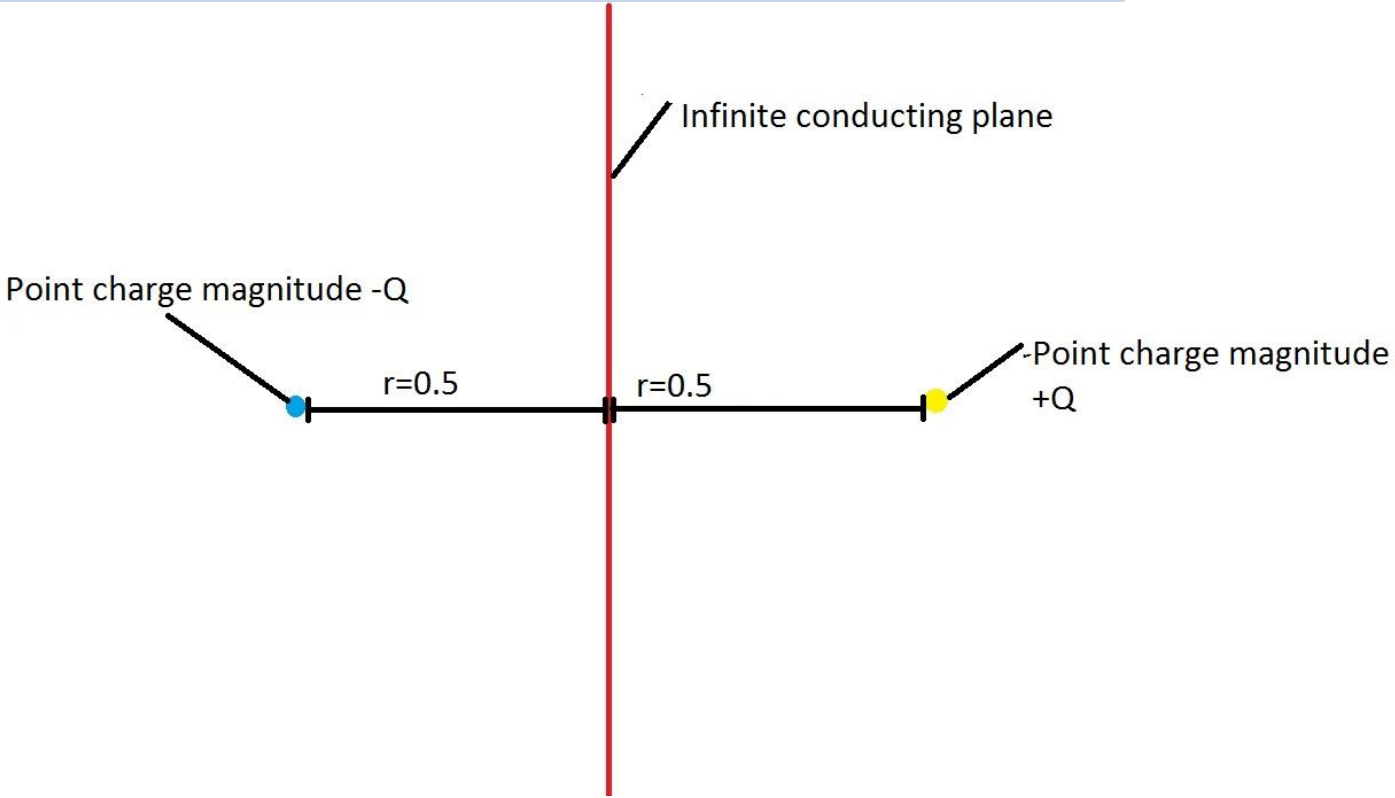
$$E = \frac{kQ}{r^2} + \frac{kQ}{r^2} = \frac{2kQ}{r^2} = \frac{2kQ}{(5 \cdot 10^{-3})^2} = 3 \cdot 10^6 N/C$$

$$Q = 14.171 \cdot 10^{-9} C$$

(Hong, 2000)
(Viktor, 2010)

Between the three, we decided to use Electric Field due to metal panel because it is the least charge needed to create a spark.

# Image Charges: Diagram



# Image Charges: Calculation

Total electric field due to a point charge on a finger near an infinite, grounded, conducting plane:

$$E = \frac{kQ}{r^2} + \frac{kQ}{r^2} = \frac{2kQ}{r^2}$$

Solving for Q we find:

$$Q = \frac{Er^2}{2k}$$

With dielectric breakdown for air at $E = 3 \times 10^6\ C$ and a distance of $r = 5 \times 10^{-3}\ m$:

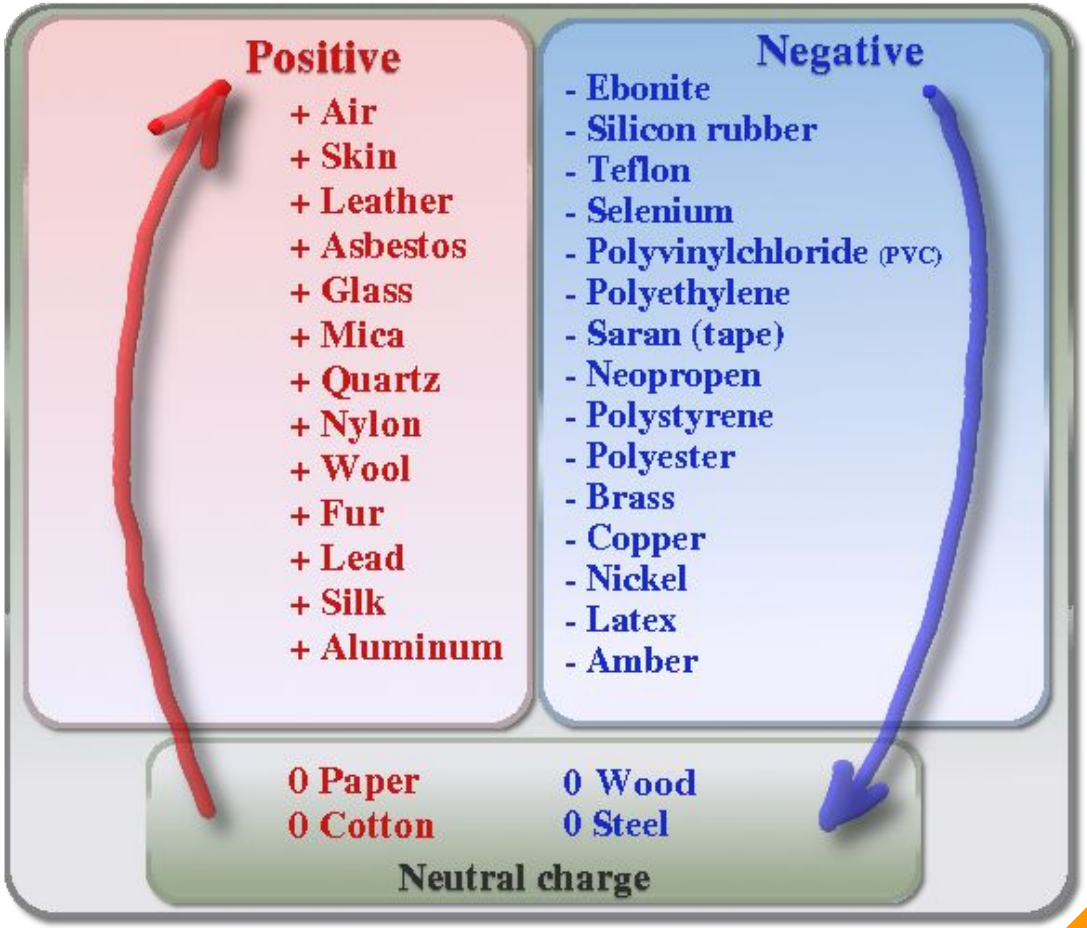
$Q = 4.171 \times 10^{-9} C$ to create a spark.

# 2

# Seat Material

# Concepts: Triboelectric Effect

Triboelectric effect occurs when certain object materials come in frictional contact with other materials. Certain materials are more likely to acquire either positive, negative, or no charge. In our context, this occurs when an individual slides on the seat. The fabric of their pants and seat material could potentially create a charge.


Positive
+ Air
+ Skin
+ Leather
+ Asbestos
+ Glass
+ Mica
+ Quartz
+ Nylon
+ Wool
+ Fur
+ Lead
+ Silk
+ Aluminum
Negative
- Ebonite
- Silicon rubber
- Teflon
- Selenium
- Polyvinylchloride (PVC)
- Polyethylene
- Saran (tape)
- Neopropen
- Polystyrene
- Polyester
- Brass
- Copper
- Nickel
- Latex
- Amber
0 Paper
0 Cotton
0 Wood
0 Steel
Neutral charge

# Experimental Method: Quantifying Charge

1. Prepare the static meter for use.
2. Place a 2 foot by 2 foot swath of polyester interior on an insulating surface, fastening its corners down so it cannot slide.
3. Place a 2 foot by 2 foot swath of denim directly on top of the polyester.
4. Place 2 plastic clasps on adjacent corners of the denim.
5. Place a 145 pounds of rubber plates on top of the fabrics.
6. Grasping the 2 plastic clasps, pull the denim across the length of the polyester (a machine can be used to perform this process as well).
7. Use the static meter to measure the static charge that has built on the denim.
8. Repeat steps 2-7 with a swath of leather interior.

# Experimental Method : Realistic method

8. Have a partner make note of any recordings from the multimeter at this time.
9. Remove the “Refueling Handle” or finger from the vehicle and place it on the table.
10. Discharge yourself on a nearby independent object.
11. Repeat steps 3 through 8 five times.
12. Sit down in the vehicle and move around in the seat while wearing your **nifty** denim jeans and rubber sole shoes. Shift in the seat constantly for one minute, making note of the method and manner to facilitate a consistent experiment.
13. Exit the vehicle without touching anything, and carefully move to the side of the vehicle.
14. Slowly approach the the vehicle with your extended finger, ensuring there is a multimeter in contact with the vehicle, while avoiding making contact with the multimeter connections.
15. Have a partner make note of any recordings from the multimeter and observations at this time.
16. Discharge yourself on a nearby independent object.
19. Repeat steps 12 through 16 five times.
20. Exchange the bucket seats and repeat steps 3 through 16.
21. Move to the second vehicle and repeat steps 2 through 19.

# Experimental Method: Calculations

## Cotton vs. Cotton

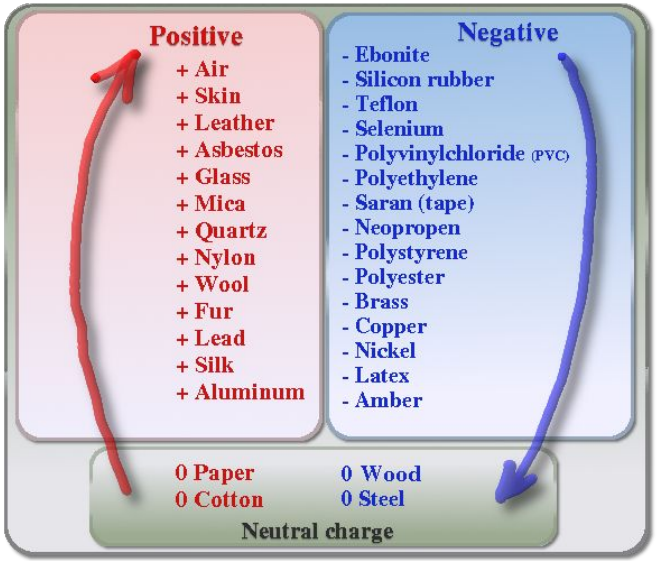
Static Charge Ratio: Ψ

Cotton is a neutral charge, thus acquiring close to 0 electrons and protons

## Cotton vs. Leather

Static Charge Ratio: 11Ψ

Leather acquires positive charge




(Static Electricity Discharge in Cars, 2014)
(Kurtus, 2016)

# 3

# Frame Material

# Concepts: Conductivity

Conductivity is the measure of a material's ability to conduct electricity.

Specifically, we are looking at the conductivity of the different frame materials of the car.

# Experimental Method: Conductivity

1. Set multimeter to resistance.
2. Place 10cm of 22 gauge aluminum wire on insulative table.
3. Touch on of the leads of the multimeter to each end of the rod and record the reading for resistance.
4. Repeat step 3 twice more.
5. Calculate resistivity based on the resistance measurement. Then, take to reciprocal of resistivity to find conductivity.
6. Repeat steps 2-5 for steel.

# Experimental Method: Calculations

## Conductivity of different Metals

- Conductivity of steel : 1.28A/Vm
- Conductivity of Aluminum : 36.9A/Vm
- Ratio constant for steel: .035
- Ratio constant for Aluminum: 28.8

(Properties Table of Stainless Steel, Metals and other Conductive Materials, n.d.)

## Conductivity Significance

The relative mass of the car as a conductor to the individual causes it to act as a ground.

Consequently, conductivity of materials is irrelevant, leaving only two variables to consider:

- Charge
- Distance between finger and vehicle

# Experiment Conclusion

- Leather seats will create greater charge compared to cotton seats.
- It’s ideal to have a steel vehicle, though conductivity is irrelevant, so
- Distance between one’s finger and the vehicle should be considered more immediately.

# References


Hong, A. (2000). *Dielectric Strength of Air*. Retrieved from The Physics Factbook: http://hypertextbook.com/facts/2000/AliceHong.shtml

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Viktor, B. A. (2010). *Proportions of Hand Segments.*

# THANKS!

Any questions?