PHYS 2020: College Physics
Manic Monday #2

"Electricity can be dangerous. My nephew tried to stick a penny into a plug. Whoever said a penny doesn't go far didn't see him shoot across that floor. I told him he was grounded." ∼ Tim Allen

KAZZAAP! Fun & Safety with Electricity[1]

In this problem we analyze some common experience with electricity in the home, and explore what is really going on using some of your newfound ability to make computations about the character of electrical phenomena. The question we want to answer is: "*How is a human just like an electrical circuit?*"

Your dedicated instructor was ironing his *Legoland* T-shirt last evening when his wife turned on the fan in the room. Suddenly the lights went out! "All your light are belong to us!" said your instructor. "Quit that nonsense," said his wife. "We blew a fuse; go reset it." Unwittingly, she has sent a theoretical physicist to do a very practical thing. Will he survive?

Your instructor went to the breaker box to reset the fuse. When he had the box open, he noticed some dust and dirt in the bottom of the box. Without thinking, he reached to brush it away with a finger. He quickly pulled his finger away as he received an extremely painful shock. Let's consider the questions of how strong was the shock your instructor received, and how he survived to teach you another day.

A▷ A typical household fuse allows a current of 15 amps before it breaks. With a standard household voltage of 120 V, what is the maximum power that can be delivered through such a fuse?

B▷ If the room was lit by three 100 W light bulbs, and the iron uses 1100 W, what is the minimum power used by the fan?

C▷ Consider the following table describing typical effect of currents passing into the human body, and estimate the amount of current that passed through your instructor's body.

Current	**Effect**
1 mA	Threshold of sensation
8 - 15 mA	Painful shock; person able to let go
15 - 20 mA	Painful shock; Muscle control lost near point of contact, person not able to let go
20 - 50 mA	Extreme pain. Severe muscle contractions along path of current.
100 - 200 mA	Heart Fibrillation induced
200+ mA	Severe burns, heart stopped.

D▷ The internal resistance from hand to foot on an average person is about 500 Ω. If your instructor had an unusually high resistance, it may have been 600 Ω. Use this to estimate the amount of current that might have passed through your instructor. According to the table, what effect would this have had?

E▷ From your current estimate in part C, estimate what the total resistance of your instructor's body was.

F▷ The overall resistance encountered by the current depends on how conductive the human body is. The internal resistance is low because we are mostly made of water (a good conductor). Before the current can enter your body, it has to pass through your skin, which has a highly variable resistance depending on moisture. Dry skin has a resistance of about 500,000 Ω, while wet skin has a resistance of about 1000 Ω. If your skin and your insides can be thought of as two resistors in series, what is the resistance provided by your instructor's skin? Was he nervous about playing in the breaker box?

G▷ What probably could have helped your instructor was if he was wearing rubber soled shoes. The resistivity of rubber is approximately 10^{13} Ωm. Estimate he resistance of the soles of his shoes.

H▷ Assume your instructor and his shoes look like two resistors in series. Calculate the current he should have received with the resulting R_{eq}. Would he have felt a shock?

[1] Problem based on a design by K. Vick, E. Redish, and P. Cooney of the University of Maryland Physics Education Research Group. `http://www.physics.umd.edu/perg/`