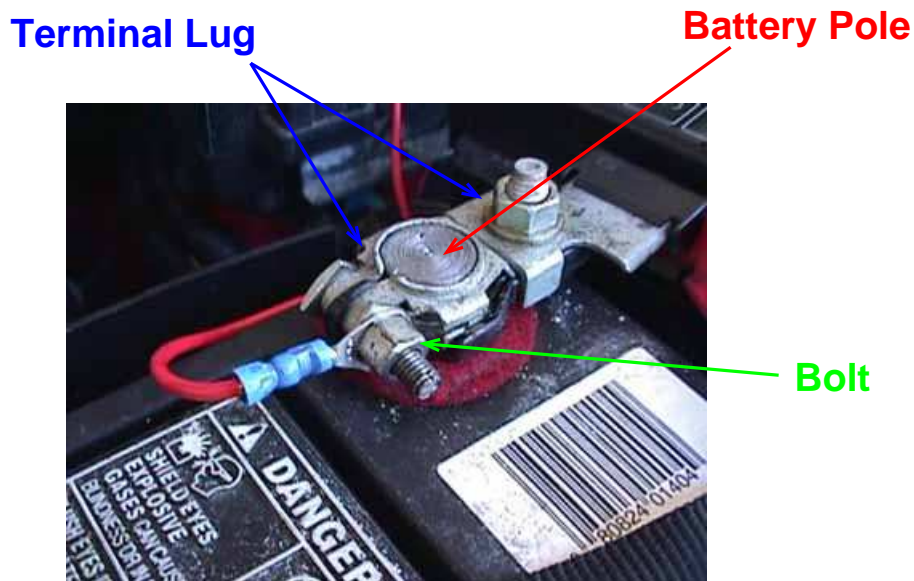


Physics 122: Practice Problem of the Day

Problem #10: Car Talk Puzzler

Wednesday February 3, 2009

The following is a precisely true story:



A week ago Wednesday I tried and failed to start our 1995 Toyota Camry. The battery was dead. This was not surprising, since we had been warned by a mechanic who installed new tires on the car several weeks ago that the battery was likely to fail soon. In particular he pointed to the top of the battery which was covered with considerable corrosion, saying “It looks like someones chemistry experiment.”



Corroded battery terminal

On Saturday morning I pushed the snow off the car, and set about to remove the dead battery. This turned out to be quite difficult because of the high level of corrosion, especially near the negative (ground) terminal. In fact, the bolt that normally allowed for the tightening and loosening of the terminal lug onto the negative pole of the battery was frozen and could not be turned. After some effort with a large flat screw driver and some elbow grease, I was able to shimmy the terminal lug off of the dead battery. I scraped away as much corrosion as possible from the terminals cables, and then I put the dead battery into my mini-van and drove to the auto parts store to purchase a new battery.

I installed the new battery, again pushing and prying to get the frozen terminal lug onto the negative pole of the new battery. The car started like a charm. Problem fixed, apparently.

The next morning I came to the car. The interior lights worked fine, but when I turned the ignition, nothing happened.

At the time, my guess was that the battery had discharged overnight because I must have accidentally left some electrical system on – although I did not see anything obviously left on. I brought the minivan over to the car and set up the jumper cables to start the car with the apparently dead (new!) battery. The car turned over – somewhat reluctantly – and – alarmingly – there was a small puff of smoke rising from beneath the hood in the vicinity of the negative terminal of the battery where I had the cable from the minivan connected. Now I was puzzled. Why the smoke? Was something wrong with the way I had installed the battery? Was there something wrong with my new battery? I drove the car around for the rest of the day and it worked perfectly, no problem.

Now we come to Monday night. My wife is planning to take the Camry to the Akron Airport the next morning and will leave it there for a few days so it will be ready for her when she returned from New York. I get in the car to pull it out of the driveway – and once again it does not start! Argh!

It's freezing cold and pitch dark so I tell my wife I will look at it in the morning before she has to go to the airport. My wife is very intelligent but she is not comfortable with the idea of “messing with cars” and the fact that the Camry appears to be unreliable is now very worrisome.

The next morning, while my wife is using the mini-van to take the kids to school, I go out to the car with my little “multi-meter” that can measure voltage, current, and also resistance. I make three measurements and suddenly I *immediately* understood what the problem is. Furthermore, when my wife gets back from dropping off the kids, I show her under the hood of the (now running) Camry. I say, “Don't worry, if the car does not start when you return to it in the airport parking lot, all you need to do is **this** and then it should start right up.”

- Explain why the car failed to start after the new battery was installed. What exactly is the problem and why does this problem intermittently prevent the car from starting?
- What were the three measurements that I made with my multi-meter and what do they show?
- Explain the puff of smoke.
- I showed my wife a “work around” that would reliably get the car started. Basically “**this**” was an action that she could easily perform without any tools that would ensure that the car would start. What action corresponds to “**this**” and why does this solve the problem.
- What is the long-term solution to the problem and how expensive will this fix be?

Hints on the next page:

Important Hints and Clues:

1. The key to understanding the problem is a central and fundamental concept in circuits that we have already looked at in Physics 122.
2. The starter of a car needs a fairly large amount of power to work – several kilowatts or more. If for some reason this amount of power is not available to the starter motor, the engine will not start.
3. In contrast, the power required by the interior lights of the car is only a few watts. The lights worked fine every time. The battery was not “dead”.
4. The new battery I bought was rated for 600 Amps cold start. That’s a pretty good quality battery.
5. The new battery is *not* defective in any way.
6. The puff of smoke from the negative terminal is an important clue.
7. Every time the car failed to start with the new battery was a time *after* it had been driven around. Sometimes, after driving around for a while the car would start fine, but other times it would not. However, every time the car failed to start, it had been moved since the last time it started.
8. Again, the new battery was never dead and never discharged. I knew this because of my meter which measured the voltage of the battery.
9. The second and third critical measurements with my meter were measures of resistance. When I measured the resistance between the *positive* pole of the battery and the back of the positive terminal lug, I found it to be about 0.2 Ohms. But when I measured the resistance between the *negative* pole of the battery and the back of the negative terminal lug, I found it to be about 20 Ohms. That’s when I figured it out.
10. the fact that there was corrosion from the old battery and the fact that the bolt on the negative terminal lug is frozen are critically important clues. These two facts are the fundamental “causes” of the problem.