TAP 121-1: Internal resistance of power supplies

Answer the following questions for practice in making calculations about the internal resistance of power supplies.

Torch batteries, car batteries, EHT supplies and solar cells

1. A typical hand-held torch runs off two 1.5 V cells, yet has a lamp rated at 2.5 V, 0.5 A. Explain how the potential difference across the lamp can actually be 2.5 V as rated. What is the internal resistance of each cell, supposing them to be identical?

2. A typical car battery has an emf of 12 V, and must provide a current of 80 A to the starter motor. Why must the car battery have a very low internal resistance? If the internal resistance is 0.05 Ω, find the potential difference across this internal resistance when the starter motor is running. Why is starting the car with the headlights on likely to affect their brightness?

3. Some school laboratories have EHT (Extra High Tension) power packs giving up to

   3000 V. For safety, they are provided with a 50 MΩ resistor in series with the supply. What is the maximum current able to be drawn from the supply? Approximately what potential difference would there be across a torch bulb connected across such a supply?

4. A student experimenting with a solar cell connects a 1000 Ω voltmeter across it and observes a potential difference of 1.0 V. Using a different, extremely high resistance digital voltmeter, the reading is larger, 1.2 V. Why the difference? What is the internal resistance of the solar cell?

Practical Advice

These are intended to be simple practice questions. It is helpful to remember that the internal resistance of a cell is not likely to remain constant as the cell is used, and that other effects such as polarization of the cell also affect the pd obtained from it.

Alternative Approaches

It is useful for the class to check that torch bulbs are very commonly rated at less than the emf of the dry batteries they use. Taking various examples, the range of values the makers of torches expect for the internal resistance of dry cells can be estimated.

It is also useful to review power supplies available in the laboratory, looking to see which must have low internal resistance and which normally need extra protective resistance added.

Social and Human Context

Dry cells power all sorts of portable equipment besides torches. Some, such as television or video control handsets, can run for years on one set of batteries. Others, such as palm-top computers and 'organizers', use up batteries very quickly.

Answers and Worked Solutions

1. The two 1.5 V cells provide an emf of 3 V in series. If the current flowing is 0.5 A as stated, then for the potential difference across the internal resistance to be 0.5 V (that is, 3 V–2.5 V) the internal resistance of the cells combined would need to be 1 Ω. The cells are in series so the resistance of each is 0.5 Ω.
2. The battery must have a low internal resistance so as to be able to deliver a current of 80 A from an emf of only 12 V. If the internal resistance is 0.05 Ω then the potential difference across this with a current of 80 A flowing is 4 V. Thus the potential difference across the 12 V battery drops to 8 V. This is a big enough change to dim headlights rated at 12 V.
3. The maximum current is 60 μA. A torch bulb has a resistance of only a few ohms, so connected across such a supply the potential difference across it would be very near to zero, with a current of only 60 μA through it.
4. The 1000 Ω voltmeter draws a current from the cell, of 1 mA when it reads 1.0 V. If the cell has internal resistance some of its emf will be used in driving the current through the cell. A voltmeter with very high resistance draws very little current, and reads nearer to the emf of the cell. If the emf is 1.2 V then 0.2 V is used in driving the current of

   1 mA through the internal resistance, which is therefore 200 Ω.

External References

This activity is taken from Advancing Physics Chapter 2, 220S