# Elucidation of concept of electrical load

Swarna Lakshmi. R

Department of Physics
Central University of Tamil Nadu
Tiruvarur610102, India.

(*Submitted* on 03-04-2013)

## Abstract

"Electricity and Magnetism" is one of the introductory courses in Physics at Graduate level. The concept of electrical load is found to be misunderstood by a substantial percentage of students. This misunderstanding is found to hinder their performance in advanced courses on "Electricity and Magnetism" and "Electronics". The ambiguity arises due to: (a) denoting the load by the value of its resistance $R_L$, (b) denoting Power = $\frac{V^2}{R_L}$and Power = $I^2R_L$. This article elucidates this frequently used concept of electrical load. An illustrative example that can help students at introductory level to assimilate the concept of electrical load is given for use in pedagogy.

## 1. Introduction

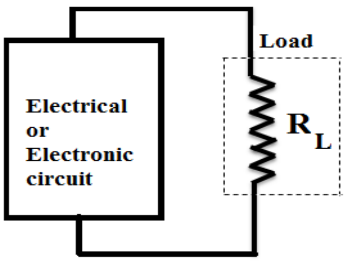
The concept of electrical load is often misunderstood by students at the introductory level. This misunderstanding is found to hinder their performance in advanced courses on "Electricity and Magnetism" and "Electronics". Circuit analysis in "Electricity and Magnetism" demands a clear cut understanding of the concept of load. Thevenin's equivalent circuit, Norton's equivalent circuit, Maximum power transfer theorem, Zener Diode as Voltage regulator are few key areas in "Basic Electronics" which requires conceptual understanding of electrical load.

The ambiguity arises due to:

a) denoting the load by the value of its resistance$R_L$
b) denoting Power $= \frac{V^2}{R_L}$ and Power = $I^2R_L$.

A detailed analysis of lapses in pedagogy leading to such erroneous conclusions by students is taken up in this study. Remedial methods are suggested to address such inadvertent errors. The need to emphasize "What electrical load means" is discussed in detail. An illustrative example that can help students at introductory level toassimilate the concept of electrical load is given for use in pedagogy.

## 2. Load and Load resistance $R_L$




Figure(i) Load of resistance $R_L$ connected to a circuit

In pedagogy, one speaks of load but denotes it by a resistor of value $R_L$ as in figure (i). Students often think that the load increases when the value of $R_L$ increases and load decreases when the value of $R_L$ decreases. But this is absolutely wrong.

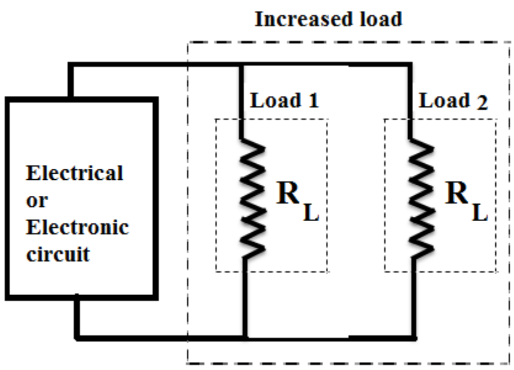



Figure (ii) Additional equipment connected in parallel indicate Increased load

Figure (ii) shows that additional equipment connected in parallel indicate increase in load. Hence the value of load resistance is halved ($R_L||R_L = \frac{R_L}{2}$), whereas the load has increased. Similarly, disconnecting of equipment not in use indicates decrease in load and the value of load resistance will be increased. The fact that load and load resistance are inversely related must be reiterated emphatically, by quoting relevant examples.

## 3. Power P, Current I, Voltage V and Load resistance $R_L$

Actually, the power consumed by equipment symbolizes its loading effect on the supply. Nonetheless, the load is directly proportional to power consumed (and load is not proportional to the value of load resistance $R_L$ as presumed by majority of students). But power consumed P can be denoted as:

$$P = I^2 R_L \qquad (1)$$

Equation (1) suggests that power consumed is directly proportional to the square of the current I and also directly proportional to the value of load resistance $R_L$. This is a serious flaw in the pedagogical approach. Though equation (1) is dimensionally flawless, it skews the student's thinking and makes one conclude that power (load) is proportional to the value of load resistance $R_L$. This can be corrected by the use of the following formula for power.

$$P = \frac{V^2}{R_L} \qquad (2)$$

Equation (2) is an apt representation that readily shows the inverse relation between power (load) and the value of load resistance $R_L$. Equation (1) suggests that the current I flowing through the load increase with increase in power consumed (or increase in the load). But it is equation (2) that readily shows that the power (load) is inversely dependent on load resistance $R_L$. Teachers should highlight this stark difference between the two equations representing power and highpoint the inverse relation between load and load resistance.

In essence, table 1 elaborates the relation between load and load resistance $R_L$.

| Load | Load resistance $R_L$ |
|---|---|
| Load is increased (by connecting additional equipment in parallel) | $R_L$ decreases |
| Load is decreased (by disconnecting some of the equipment) | $R_L$ increases |

***Table 1: Relation between load and load resistance***

## 4. Example to illustrate the difference between load and Load resistance $R_L$

Students are likely to get interested by physical examples. A well thought example can reduce the burden on tutoring. One such example is detailed below. It is adequately trimmed to incorporate almost all details discussed in sections 2 and 3.

**<u>Case A:</u> Three bulbs connected to supply**

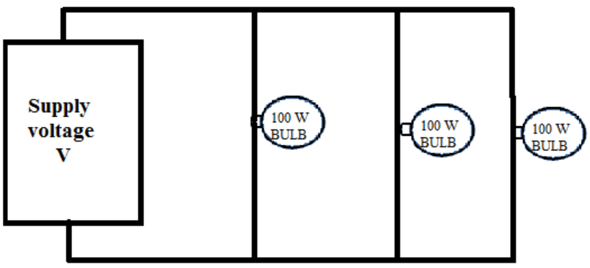



Figure (iii) Three 100 W bulbs of resistance R are connected across a supply voltage V.

Figure (iii) shows three identical 100 W bulbs connected across a supply voltage V. If the resistance of each bulb is R, the effective load resistance is given by:

$$R_L = R \| R \| R = \frac{R}{3}$$

The total power consumed by the three bulbs is:

$$load = 300\ W$$

**<u>Case B:</u> Two bulbs connected to supply**

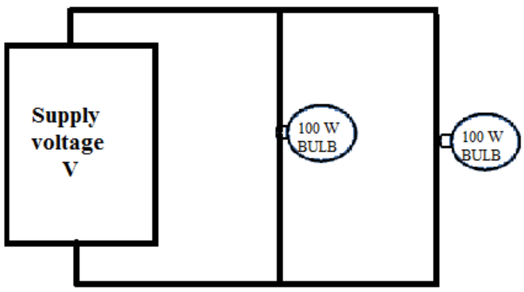



Figure (iv) Two 100 W bulbs of resistance R are connected across supply voltage V

Figure (iv) shows two identical 100 W bulbs connected across a supply voltage V. If the resistance of each bulb is R, the effective load resistance is given by:

$$R_L = R \| R = \frac{R}{2}$$

The total power consumed by the two bulbs is:

$$load = 200\ W$$

**<u>Case C:</u> One bulb connected to supply**

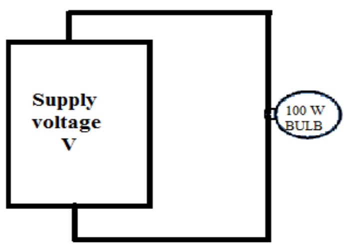



Figure (v) One 100 W bulb of resistance R is connected across supply voltage V

Figure (v) shows one 100 W bulb connected across a supply voltage V. If the resistance of the bulb is R, the effective load resistance is given by:

$$R_L = R$$

The total power consumed by one bulb is:

$$load = 100\ W$$

Table 2 is a comparative statement of the above cases:

| Case | Load | Load resistance |
|---|---|---|
| Case A: Three bulbs connected to supply | 300 W | $R_L = \frac{R}{3}$ |
| Case B: Two bulbs connected to supply | 200 W | $R_L = \frac{R}{2}$ |
| Case C:One bulb connected to supply | 100 W | $R_L =$ R |

***Table 2: Comparative statement of the three cases***

Table 2 clearly illustrates ***"When load decreases, load resistance increases and vice versa".*** Table 2 also serves as a fine example of the facts elaborated in the previous sections and compiled in Table 1.

When students work on this example, it can help them understand:

(a) Why Power = $I^2 R_L$ can be misleading, and

(b) How the formula Power $= \frac{V^2}{R_L}$ gives better insight.

## 5. Conclusion

This article elucidates on a fundamental concept that should be dealt with care.A detailed analysis of lapses in pedagogy leading to erroneous conclusions by students is taken up in this study. The problem is arising out of denoting the load by load resistance $R_L$. As a remedy, we can more appropriately denote the load by conductance / admittance,$Y_L$,because load is directly proportional to conductance / admittance $Y_L$.

## Acknowledgement:

I sincerely thank Central University of Tamil Nadu, Tiruvarur, for providing a platform for taking up teaching and research hand in hand.

## References:

[1] Resnick, Halliday and Walker, Fundamentals of Physics (Eighth edition), John Wiley (2010).

[2] .F. W. Sears, M. W. Zemansky, and H D Young, University Physics,Addison Wesley (1976)

[3] Integrated Electronics: Analog & Digital Circuit Systems – Jacob Millman & Halkias, TMH.

.