9

Circuits

9.1 Power

The power is the energy dissipated (or work done W) per unit time. The electrical power produced by an electric current I consisting of a charge Q passing through an electrical potential V every t seconds is

$$P = \frac{W}{t} = \frac{W}{Q}\frac{Q}{t} = IV. \tag{9.1}$$

In order to introduce geometry to circuit problems, we typically resort to the resistivity of the circuit, which is geometry-dependent. The resistivity ρ of a wire of cross-sectional area A, length ℓ and resistance R is

$$\rho = \frac{RA}{\ell} \tag{9.2}$$

i.e., the resistance of the wire is inversely proportional to its cross-sectional area, i.e., the resistance is also dependent upon the geometry. A smaller area gives rise to a larger resistance.

In the case of resistive loads, we can substitute Ohm's law $V = IR$ into equation (9.1) to give

$$P = I^2R. \tag{9.3}$$

When discussing resistive circuits using equation (9.3), this power is strictly the power dissipated by a resistor of resistance R when a current I is flowing through it—this power strictly concerns energy which is converted from electrical to thermal energy, over some time t. Equation (9.3) is also idealised, and assumes that all electrical energy is turned into heat. This effect is known as Joule heating.

9.2 Internal resistance

The internal resistance r is a small (but sometimes non-negligible) amount of resistance inside cells and batteries, opposing the flow of current. Internal resistance is a source of heat loss in a circuit.

The terminal potential difference across the circuit (i.e., the input voltage) is thus dependent upon the electromotive force $\mathcal{E}$ of the battery and the potential difference across the resistor Ir, i.e.,

$$V = \mathcal{E} - Ir. \tag{9.4}$$

A smaller internal resistance r means that the battery can supply more current for the same $V - \mathcal{E}$. Internal resistance is an important design consideration in engineering applications.

Which terminal p.d. and internal resistance does the national grid require?

a) low terminal p.d., low r	b) low terminal p.d., high r
c) high terminal p.d., low r	d) high terminal p.d., high r
