

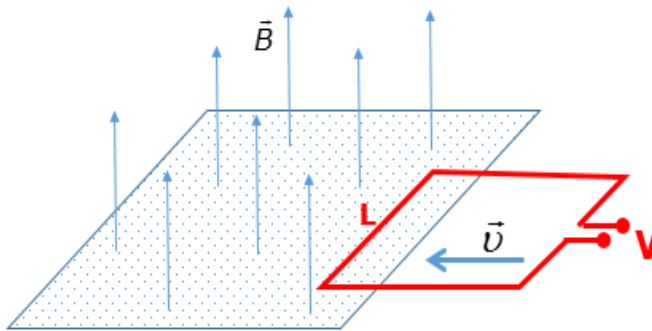
Due: 15 Oct 2025

Energy: Science, Technology, and Society

Problem Set 6

Indicate assistance obtained with each of the tasks defined below, e.g., by naming web source (Wikipedia, Google/Gemini, ChatGPT,...) and a (summary) prompt.

1. Mechanical Energy-to-Electricity Conversion

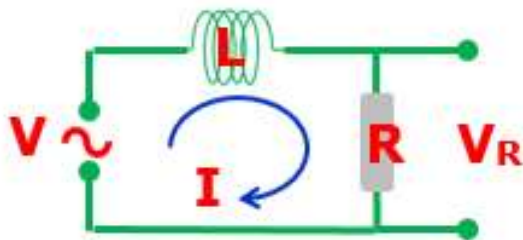


Consider a spatial domain filled with a uniform magnetic field $\vec{B}(\vec{r}) = B_0 \cdot \vec{k}$ aligned with the z direction, defined by the unit vector \vec{k} . As illustrated in the sketch, an open quadratic wire loop with side length L is moved with a constant velocity $\vec{v} = -v \cdot \hat{i}$, from the outside into that domain, in neg-

ative x-direction and perpendicular to the field.

- Use Faraday's Law to derive a relation between the *emf* (= voltage V) induced at the ends of the loop, the field strength B_0 , length and the speed v of the wire loop.
- Consider a quadratic wire coil of inside area $A=L^2=0.1\text{m}^2$ rotating at $f=60\text{Hz}$ in a magnetic field of strength $B=0.5\text{ T}$. How many turns must the coil have to generate an electric current of 1000A for an Ohm resistance of $R = 1\ \Omega$ of the coil?

2. Electrical Transmission Lines



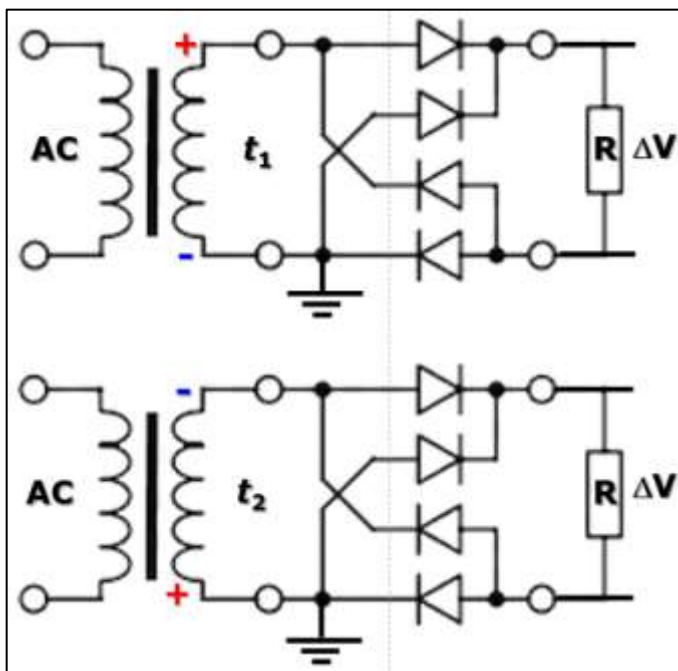
A significantly simplified section of the electric grid loaded with transformers etc. may look like the circuit diagram shown in the sketch, with inductance L and Ohm resistance R . Assume the voltage applied at the circuit has the form $V(t) = V_0 \cdot \sin(\omega t)$ or, in complex rendition, $V(t) = V_0 \cdot e^{i\omega t}$, driving

the current $I(t) = I_0 \cdot \sin(\omega t + \varphi)$, or $I(t) = I_0 \cdot e^{i(\omega t + \varphi)}$. The distribution of voltages along the circuit is determined by Kirchhoff's Laws.

- What is the voltage drop $V_R(t)$ measured across the resistor R ?
- Derive an expression for the phase shift φ of the current I , measured at R , as a function of the circuit elements.

Hint: The calculations are easier when done in a form using complex numbers and Euler's Relation $e^{i\alpha} = \cos \alpha + i \cdot \sin \alpha$.

3. Diode Full-Wave Rectifier



The diagrams show a diode rectifier circuit inductively coupled to an AC generator at two different times, t_1 and t_2 , with the instantaneous polarities indicated at the transformer coils. Conducting connections between wires are indicated as solid dots. One conductor wire is held at a constant electrical ground reference potential $V_{ref} = 0V$.

- On each of the diagrams, mark the pathways of the electrical currents I_{tech} and $I_{electron}$ corresponding to the instantaneous polarities.
- Indicate the electrical polarities (+ or -) on the load resistor R and the sign of the voltage drop ΔV over the resistor.