# F6-2: Mutual Inductance - Transformers

*NB: Students are advised to perform experiment F6-1 Self Inductance before attempting F6-2.*

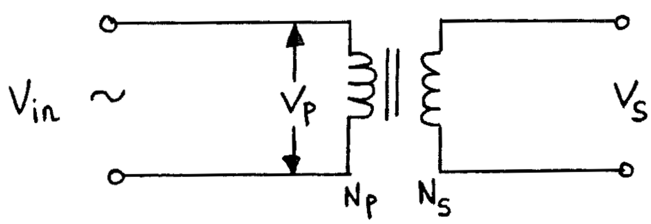
## Apparatus

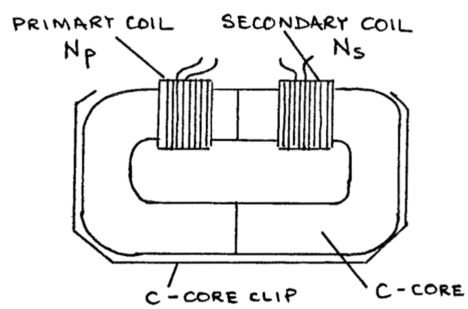
Coils 300 turns & 150 turns; wire for 20 turn & 10 turn coils; 2 iron C-cores; C-core clip; 10Ω and 5Ω resistors; CRO (oscilloscope); AC power supply; connecting leads (5 short).

*NB: This experiment requires mains electricity.*

## Procedure

1. Construct the following:




   a. Using $N_p$ = 150 turns, $N_s$ = 10 turns. Measure and set $V_{in} = V_p$ = 4V peak. Measure $V_s$ peak. Calculate $\frac{V_p}{V_s}$ and $\frac{N_p}{N_s}$ and compare their values.

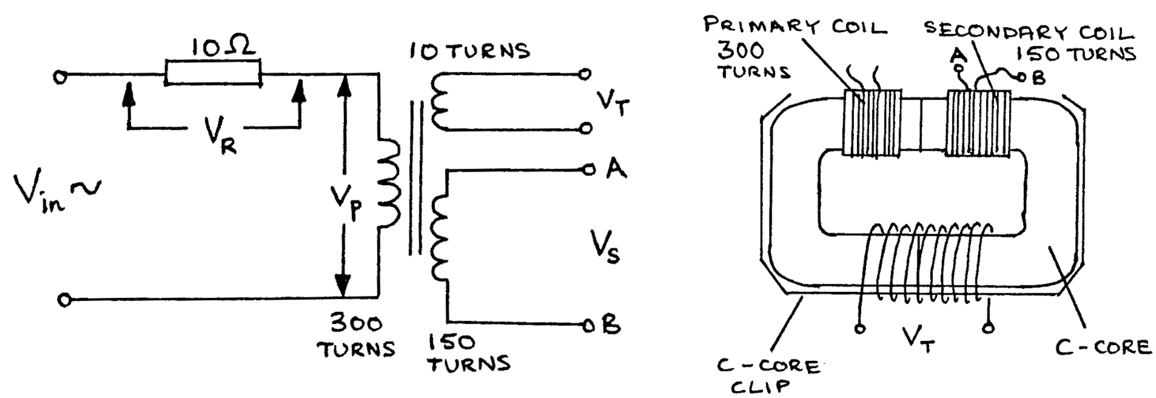
   b. Repeat a) with the following numbers of turns:

| $N_p$ | $N_s$ |
|---|---|
| 150 | 20 |
| 300 | 150 |
| 150 | 300 |

c. Keeping $N_p = 150$ turns and $N_s = 300$ turns, reduce $V_{in} = V_p$ to 2V peak. Measure $V_s$ peak, and calculate and compare $\frac{V_p}{V_s}$ and $\frac{N_p}{N_s}$.

d. Remove the clip from the iron cores, and remove one C-core. Place two coils, one on each arm of a single C-core. Again use $N_p = 150$ turns and $N_s = 300$ turns. Set $V_{in} = V_p = 4$V peak. Measure $V_s$.

2. Construct the following with $N_p = 300$ turns, $N_s = 150$ turns, and an extra test coil of 10 turns as shown:




a. Connect the CRO to measure $V_p$ peak, and set $V_{in}$ so that $V_p = 4$V peak.

b. Measure $V_R$ peak, and thus calculate $I_p$ peak, the current in the primary circuit.

c. Measure $V_T$ peak, across the 10 turn test coil.

d. Connect a 5Ω resistor between **A** and **B**, across the 150 turn secondary coil. Connect the CRO to measure $V_p$ and adjust $V_{in}$ so that $V_p = 4$V peak.

e. Measure $V_R$ peak, and thus calculate $I_p$ peak.

f. Measure $V_T$ peak again. This should be about the same size as the value measured in procedure 2 c) above.

# Theory

1. Flux Φ and induced emf $E$ are related by the following:

$$E_p = -N_p \frac{d\Phi_s}{dt} \quad \text{---- equation A}$$

$$E_s = -N_s \frac{d\Phi_p}{dt} \quad \text{---- equation B}$$

The unit of flux is the weber - Wb. When $\Phi_s$ (the flux through the secondary coil) $= \Phi_p$ (the flux through the primary coil), then:

$$\frac{d\Phi_s}{dt} = \frac{d\Phi_p}{dt}$$

therefore:

$$\frac{E_s}{N_s} = \frac{E_p}{N_p}$$

thus:

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

If the resistances of the primary coil and the secondary coil are both low and the currents flowing through them are not too large, then:

$$V_p \approx E_p \quad \text{and} \quad V_s \approx E_s$$

2. The 10 turn coil is used to detect if the flux $\Phi$ in the iron core changes in the experiment. If $\Phi = \Phi_{peak}\sin\omega t$, then equation 1B can be used to show that $V_T$ peak $\propto \Phi_{peak}$, provided that $\omega$ is constant.

# Analysis

1. Why, in experiment 1a) to 1c), are the two calculated ratios not exactly equal (hint: use the theory, and the fact that the primary coil has some resistance)?
2. Use the theory to explain the result of procedure 1 d).
3. According to Lenz's Law, the induced current in the secondary coil in the procedure 2 d) is in such a direction so as to **reduce** the flux in the core. However

procedure 2 f) shows that the flux remains approximately constant. How is this possible (hint: consider the primary coil)?

4. Give an explanation in terms of power flow for the change in $I_p$ produced as a result of connecting the 5Ω resistor to the secondary coil.

5. a. These coils are simple electrical transformers. What are the causes of power loss in a transformer, and how can they be minimised?

   b. All electricity supply companies use transformers in their power distribution systems. Explain, giving reasons, how they are used.