2025 S4 Assignment 19B

Transformers - Answers

Note:
- State any formulae used.
- Upper case 'i' (e.g. current) to write as I
- Use suitable subscripts to differentiate between similar physical quantities in different parts of the power transmission circuit, e.g. V_p, V_s

---

1(a)   Mutual induction or Electromagnetic induction

 (b)   When the switch is closed, <u>current flows in coil P to produce a north pole on its right end</u>.

   By <u>Lenz's Law</u>, a momentary <u>current is induced in the coil Q to set up a north pole on its left end</u> to oppose the strengthening magnetic field set up by the coil P, when the switch is first closed.
   Using <u>right hand grip rule</u>, the current induced in Q will flow from left to right.

 (c)   The two coils have <u>north poles facing each other</u>.
   Since <u>like poles repel</u>, the coils <u>will move away from each other</u>.

 (d)   A momentary <u>deflection</u> is observed in the galvanometer <u>in a direction opposite to that in part (c)</u> when the switch is closed.
   The two coils will <u>move slightly towards</u> each other.

Note: *This because coil Q will have an induced e.m.f that sets up a magnetic field in the <u>same direction</u> to oppose the <u>decreasing</u> magnetic flux of coil P. Explanation not required.*

2(a) $\dfrac{N_s}{N_p} = \dfrac{V_s}{V_p}$ ⇒ 4000 : N_s = 240: 12 ⇒ N_s = 200 turns

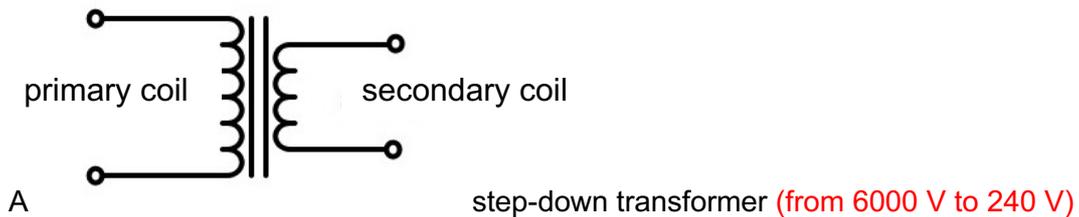Assume the transformer is ideal / 100% efficiency / has no power loss.
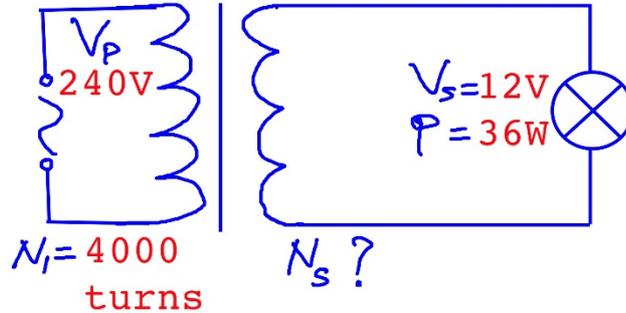
(b) $I_p V_p = I_s V_s$ ⇒ I_p x 240 V = 36 V ➔ I_p = 0.15 A

(c)   Energy = Pt   = 36 W x 300 s   = 10 800 J
                                      = 0.0030 kWh

3(a)   (i) Combined resistance = 5.00 km x (1000 m / 1.00 km) x 0.00120 Ω/m x 2 = 12.0 Ω

       (ii) Power loss   = I^2R = (40.0 A)^2 x 12.0 Ω   = 19 200 W

(b)

primary coil   secondary coil
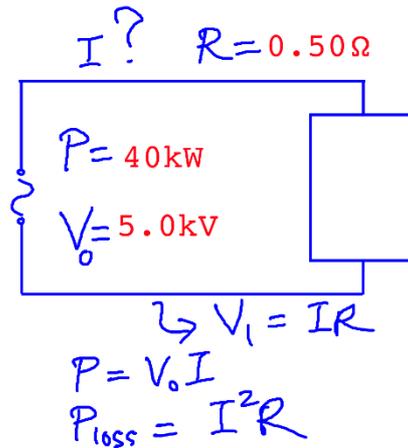
A   step-down transformer (from 6000 V to 240 V)

Note: Sketch a diagram of the circuit to help in understanding it.

4(a)(i) P=IV ➔ $I = P / V$ = 40 000 W / 5000 V = 8.0 A

Note: Sketch a diagram of the circuit to help in understanding it.

I? $R = 0.50\,\Omega$

$P = 40\text{kW}$

$V_o = 5.0\text{kV}$

$\hookrightarrow V_1 = IR$

$P = V_o I$

$P_{loss} = I^2 R$

(ii)   voltage drop, V   = IR = 8.0 A x 0.50 Ω = 4.0 V

(iii)   Power loss in the cables, $P = I^2R$ = (8.0 A)^2 x 0.50 Ω = 32 W
         OR $P = IV$ = 8.0 A x 4.0 V = 32 W

(b)   The power loss is converted to thermal energy produced per unit time in the cables and lost
        to the surroundings.

(c)   Power loss, $P = I^2R$ = (20 x 8.0 A)^2 x (0.50 Ω) = 12 800 W

        (OR use $I = P / V$ = 40 000 W / 250 V = 160 A)

Note:

	High voltage transmission	**Low voltage transmission**
Voltage input to the cables, V_i where $P = V_i\, I$	*5000 V or 5.0 kV* *Higher voltage*	*250 V*
Current in the cables, I where $I = P/V_i$	*8.0 A* *Lower current*	*160 A*
Power loss in the cables where $P_{loss} = I^2R$	*32 W* *Much lower power loss*	*12 800 W*

- *(a)(iii) and (b) show that* <u>*power loss in the cables is much lower in a high voltage transmission*</u>*.*
- *Hence, voltage output at a power generator is usually stepped up to a high voltage before transmission into the power grid.*

- *If V_i is higher*   ➔   *$I = P/V_i$ is lower*
                            ➔   *$P_{loss} = I^2R$ is also lower*