1. Thevenin Equivalent Source [20]

Find the $\underbrace{\text{Thevenin Equivalent Source}}_{V_{Th}.}$ with respect to the terminals a and b for the circuit shown below.

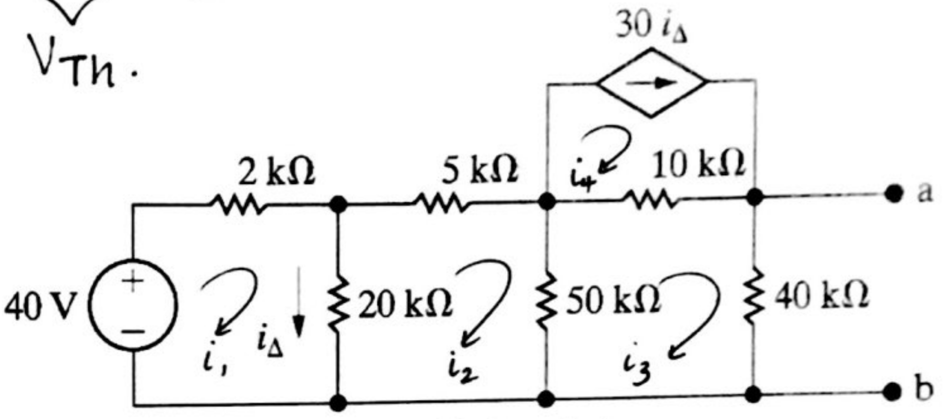


Fig. 1: Circuit with dependent source

- Using mesh analysis, since there is dependent current source between 2 nodes.

- Given: $30 i_\Delta = i_4$.

  and $i_\Delta = i_1 - i_2$

$\Rightarrow 30(i_1 - i_2) = i_4 \Rightarrow 30 i_1 - 30 i_2 - i_4 = 0$ —— ①

mesh 1 : $-40 + 2k \cdot i_1 + 20k(i_1 - i_2) = 0$.

$\Rightarrow 22k \cdot i_1 - 20k\, i_2 = 40$ —— ②

mesh 2 : $-20k \cdot i_1 + 75k\, i_2 - 50k\, i_3 = 0$ —— ③

mesh 3 : $-50k \cdot i_2 + 100k \cdot i_3 - 10k\, i_4 = 0$ —— ④

solving ①, ②, ③ & ④ $\longrightarrow$ $i_1 = 8\,mA$

$i_2 = 6.8\,mA$

$i_3 = 7\,mA$ $\qquad i_4 = 36\,mA$

- $V_{Th} = V_{ab} = V_{40k\Omega} = 40k \cdot i_3 = 280V$

FYI : $R_{Th} = 20k\Omega$ (use a test source between a & b)

2. Max Power Transfer [20]

For the circuit shown below,

(a) Find ***Ro*** that results in max power transfer [10]. *Hint: Use source transformation.*

(b) Find the maximum power delivered to ***Ro*** [10].

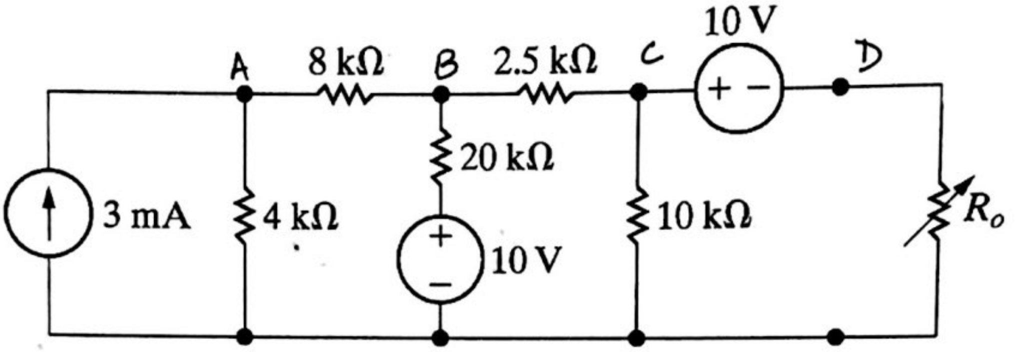
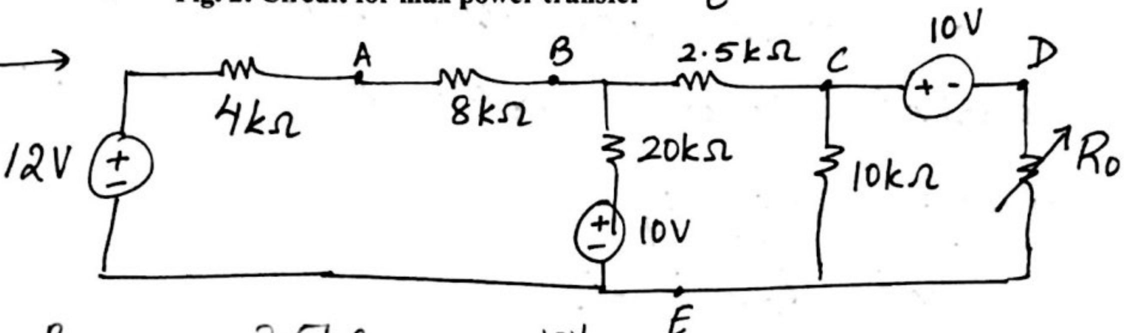
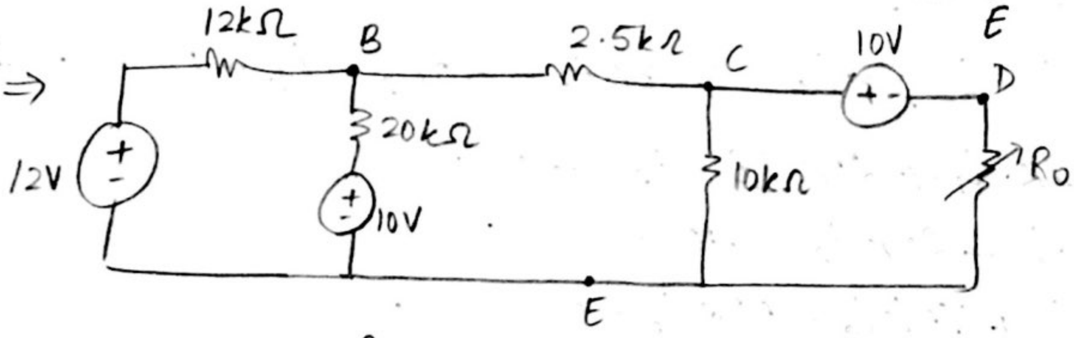


Fig. 2: Circuit for max power transfer

3mA || 4kΩ →



⇒



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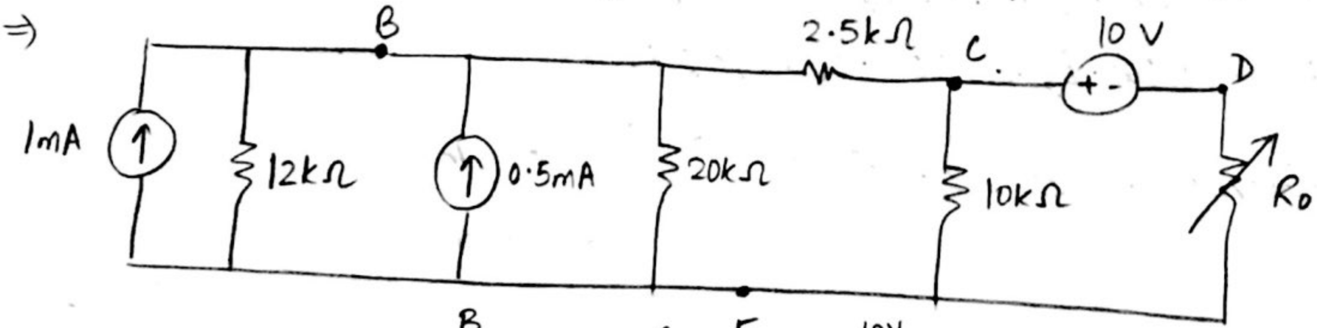
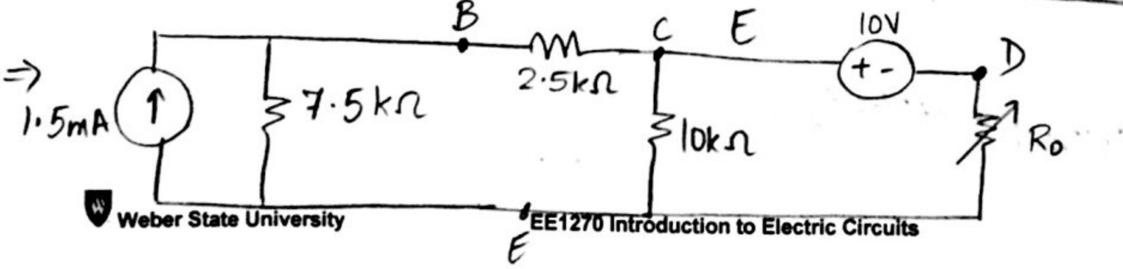
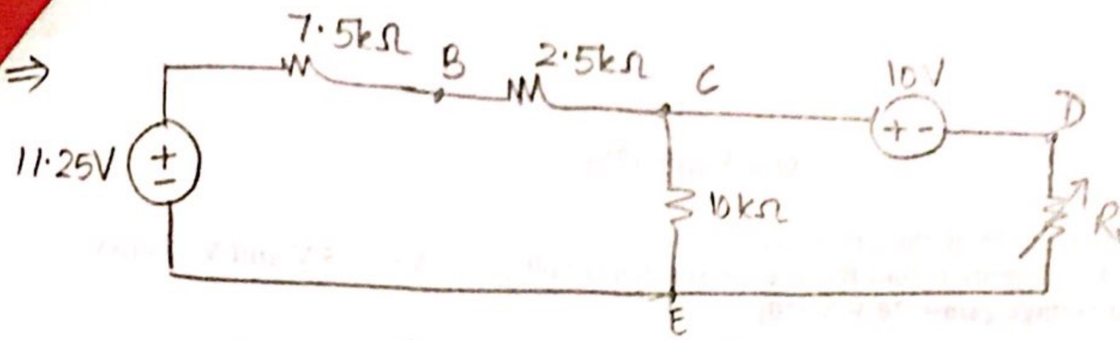
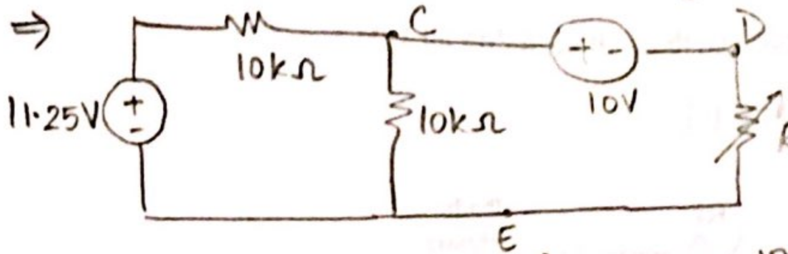
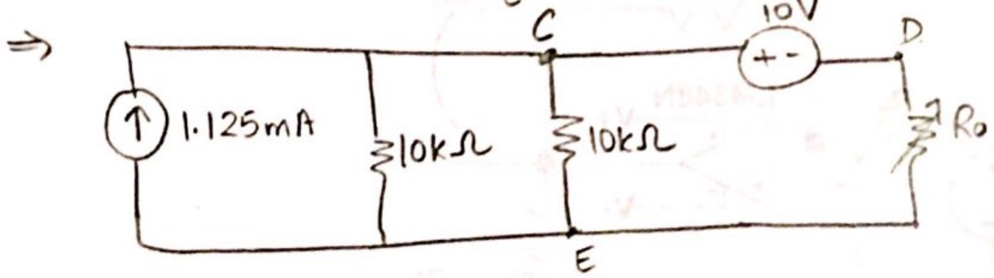


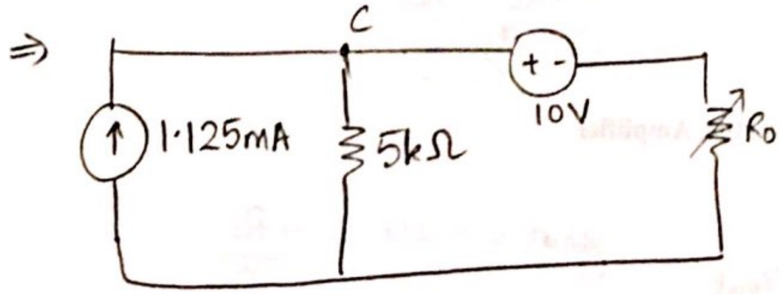
⇒

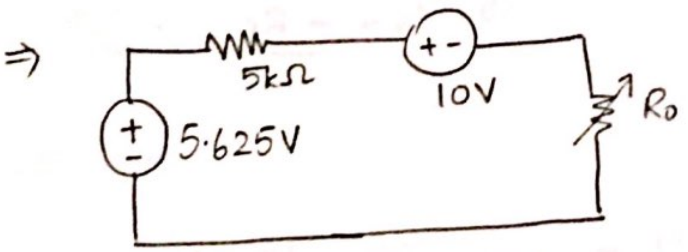


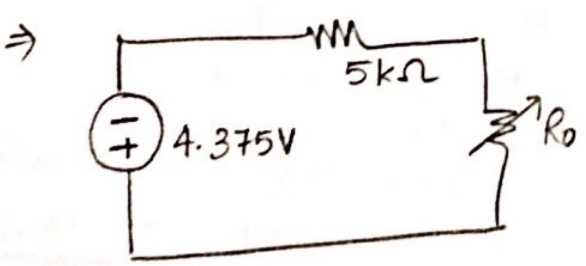












⇒ For max power transfer,

(a) $R_o = R_{Th} = \underline{\underline{5k\Omega}}$

(b) $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}} = \dfrac{(4.375V)^2}{4 \times 5k\Omega} = \underline{\underline{0.96mW}}$

3. Op-Amps [20]

The inverting op-amp is shown in the circuit below.
(1) Design the inverting amplifier (**find Rs**) with power supply voltages of **V+ = 15 V and V- = -15V**, **Rf=50 kΩ** such that **voltage gain= -20 V/V [10]**.

(2) Design the non-inverting amplifier (**find Rs**) such that **voltage gain= 30 V/V.**
Round the value of Rs to one decimal point [5].
Draw the schematic for the Non-inverting amplifier [5].

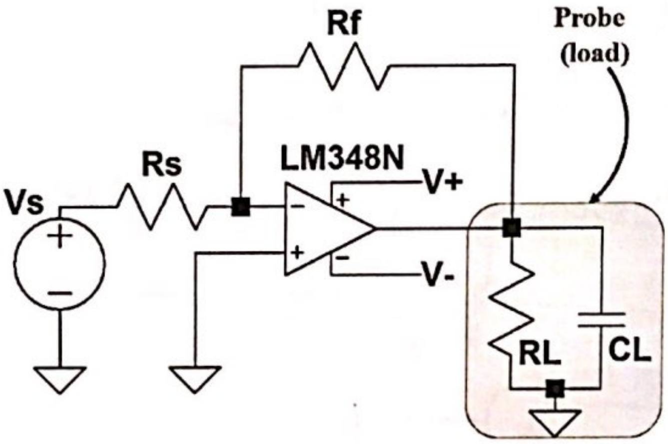
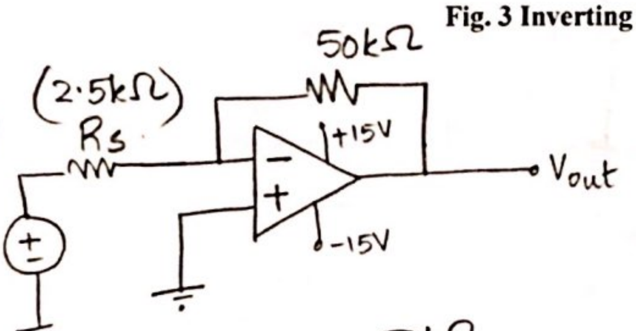


Fig. 3 Inverting Amplifier

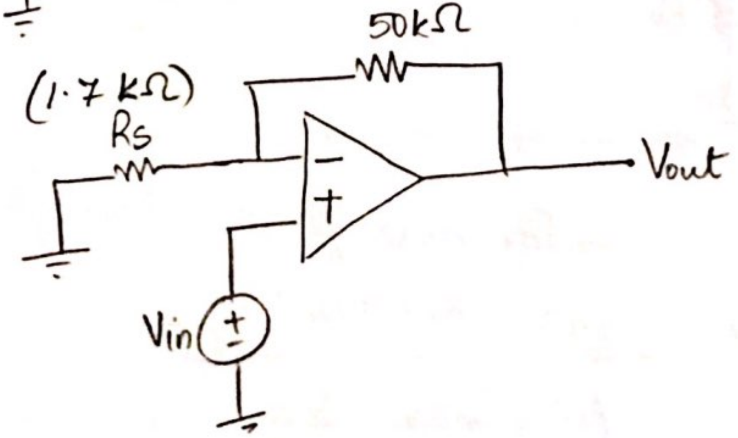
(1) (2.5kΩ)



$$\text{gain} = -20 = -\frac{R_f}{R_s}$$

$$\Rightarrow R_s = \frac{-R_f}{-20} = \frac{-50k}{-20} = \underline{2.5k\Omega}$$

(2) (1.7 kΩ)



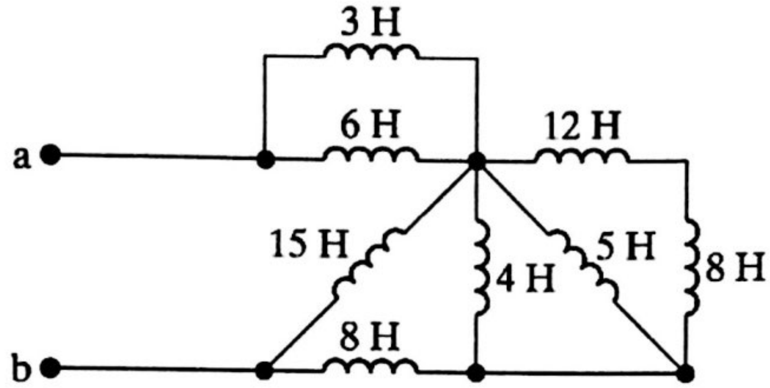
$$\text{gain} = 30 = \frac{R_f}{R_s} + 1$$

$$\Rightarrow \frac{R_f}{R_s} = 30 - 1$$

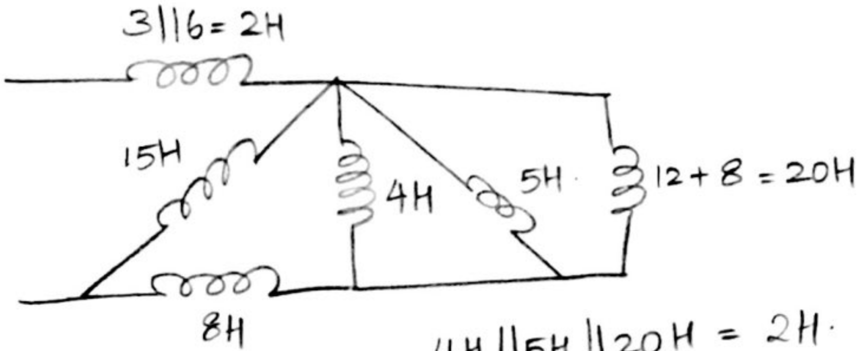
$$\Rightarrow R_s = \frac{50k\Omega}{29} = 1.72k\Omega \cong \underline{1.7k\Omega}.$$

4. Inductor and Capacitor [20]

(a) Find the equivalent inductance with respect to terminals a and b [10].

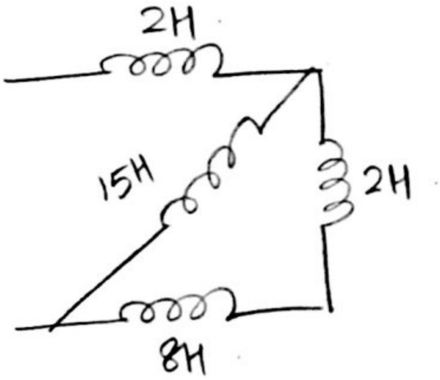


⇒



$4H \| 5H \| 20H = 2H.$

⇒



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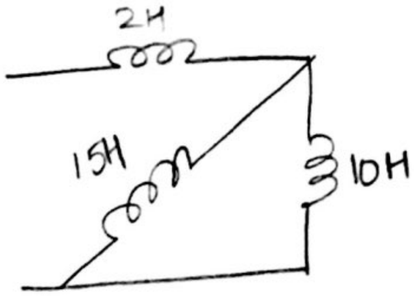

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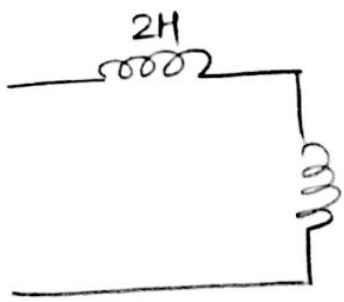
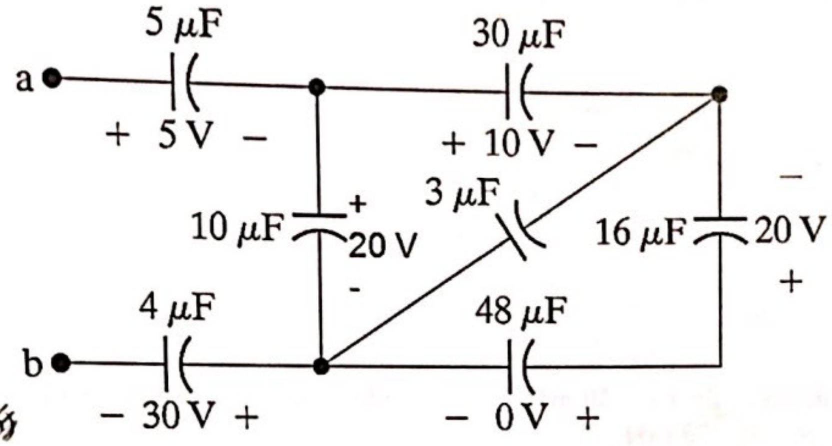
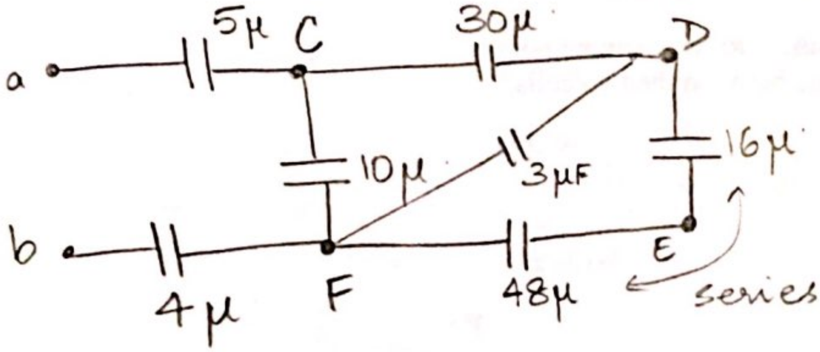


$15 \| 10 = 6H \Rightarrow L_{eq} = 2+6 = \underline{\underline{8H}}$

(b) Find the equivalent capacitance with respect to terminals a and b [10].

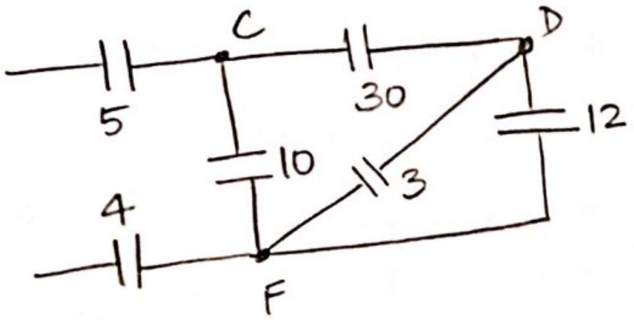




series $\Rightarrow \frac{1}{16} + \frac{1}{48} = \frac{1}{C_{DF}'}$

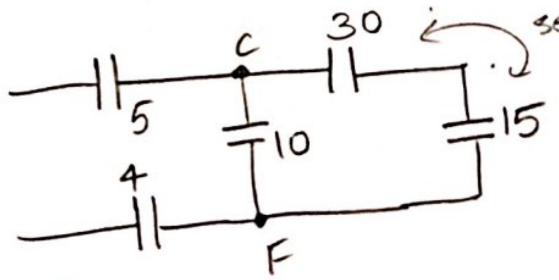
$\Rightarrow C_{DF}' = 12\mu F$

$\Rightarrow$



$12 \| 3 \Rightarrow C_{DF}'' = 12 + 3$
$= 15\mu F$

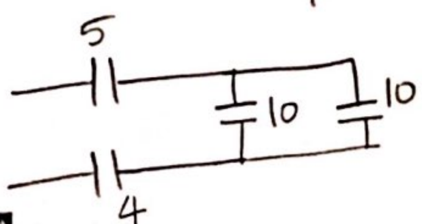
$\Rightarrow$



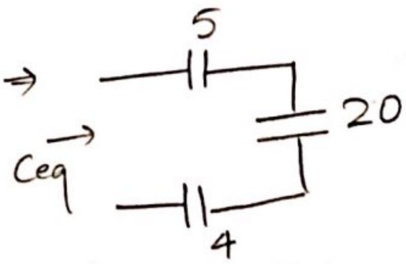
series $\Rightarrow \frac{1}{30} + \frac{1}{15} = \frac{1}{C_{CF}'}$

$\Rightarrow C_{CF}' = 10\mu F$.

$\rightarrow$



$\rightarrow$

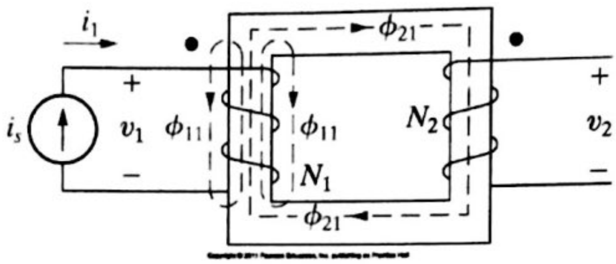


$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{5} + \frac{1}{20} + \frac{1}{4}$

$= \underline{\underline{2\mu F}}$

5. Transformer Design [20]

Suppose that you are going to design a step-up transformer to go from 10 V to 100 V. The key parameter is the ratio of the turns between the primary and secondary coil. Next, you must decide on the magnetic core (permeability constant).



Assume that the self-inductance of primary coil= L_1 = **20 mH**, the self-inductance of secondary coil = **L_2= 200 mH**, and the mutual inductance =**M= 50 mH**.

(a) Find the coupling coefficient, **k**.

(b) What is the turns ratio, **N_1/N_2**? Round it to two decimal points.

(c) How can you make a better coupling between the two coils?

(a) $M = k\sqrt{L_1 L_2} \Rightarrow k = \frac{M}{\sqrt{L_1 L_2}} = \frac{50\times10^{-3}}{\sqrt{20\times10^{-3}\times 200\times10^{-3}}}$

$= \underline{\underline{0.79}}$

(b) $\frac{N_2}{N_1} = \frac{100\,V}{10\,V} = 10:1$

(c) Using a core of higher permeability. OR putting the primary & secondary coils closer, so they have more coupling.