Subject Name & Code:

BASIC ELECTRONICS ENGINEERING- BE01R00111

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SELF LEARNING ASSIGNMENT (SLA)

Assignment – 1

1. A silicon diode has a forward voltage drop of 0.7 V. Calculate the current through a series circuit with a 10 V source and a 1 kΩ resistor.

Solution:

- **Step 1:** Draw the circuit. It is a series circuit with a voltage source (V = 10 V), a resistor (R = 1 kΩ = 1000 Ω), and a silicon diode (V_f = 0.7 V).
- **Step 2:** Apply Kirchhoff's Voltage Law (KVL) to the loop. Starting from the source's negative terminal: $V - V_R - V_f = 0$
- **Step 3:** Substitute the known values. The voltage across the resistor is $V_R = I \times R$.
$$10\text{ V} - (I \times 1000\ \Omega) - 0.7\text{ V} = 0$$
- **Step 4:** Solve for the current, I.
$$10 - 0.7 = I \times 1000$$
$$9.3 = 1000I$$
$$I = \frac{9.3}{1000}$$
$$I = 0.0093\text{ A}$$
- **Step 5:** Convert to milliamperes (mA).
$$I = 9.3\text{ mA}$$

Final Answer: The current through the circuit is **9.3 mA**.

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2. For a Zener diode with $V_z = 5.1$ V and load resistance 1 kΩ, calculate the minimum series resistor required for a 12 V input to ensure regulation.

Solution:

- **Step 1:** Understand the circuit. The input voltage (V_in = 12 V) must be dropped across the series resistor (R_s) and the Zener diode, which maintains a constant voltage (V_z = 5.1 V) across the load resistor (R_L = 1 kΩ).
- **Step 2:** Calculate the load current, I_L.
$$I_L = \frac{V_z}{R_L} = \frac{5.1 \text{ V}}{1000 \, \Omega} = 0.0051 \text{ A} = 5.1 \text{ mA}$$
- **Step 3:** Apply KVL to find the voltage across the series resistor, V_Rs.
$$V_{in} = V_{Rs} + V_z$$
$$12 \text{ V} = V_{Rs} + 5.1 \text{ V}$$
$$V_{Rs} = 12 - 5.1 = 6.9 \text{ V}$$
- **Step 4:** The current through the series resistor (I_s) is the sum of the Zener current (I_z) and the load current (I_L). For the Zener to regulate, a minimum current, often approximated as I_z = 0, must flow through it. Thus, the minimum series current is I_s(min) ≈ I_L.
$$I_s \approx I_L = 5.1 \text{ mA}$$
- **Step 5:** Calculate the minimum series resistance, R_s(min), using Ohm's Law.
$$R_s(min) = \frac{V_{Rs}}{I_s} = \frac{6.9 \text{ V}}{0.0051 \text{ A}} = 1352.94 \, \Omega$$

Final Answer: The minimum series resistor required is approximately **1.35 kΩ**.

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3. A semiconductor diode has an internal resistance of 15 ohms. It is used as a half-wave rectifier. Apply voltage is 50sin314t and load resistance is 700 ohms. Calculate: (i) I_m, I_{dc}, I_{rms} (ii) a.c. input power (iii) d.c. output power (iv) peak inverse voltage (v) efficiency of rectification.

Solution:

- **Step 1:** Identify parameters from the applied voltage $V = 50\sin\ 314t$.
  Peak voltage, $V_m = 50 \text{ V}$
  Total resistance in the conducting path, $R_{total} = R_f + R_L = 15 \, \Omega + 700 \, \Omega = 715 \, \Omega$

- **Step 2:** Calculate currents.
  (i) Peak current, I_m:

$$I_m = \frac{V_m}{R_{total}} = \frac{50}{715} \approx 0.06993 \text{ A}$$
$$I_m \approx 69.93 \text{ mA}$$

(i) Average (DC) current, I_{dc}:
For a half-wave rectifier, $I_{dc} = \frac{I_m}{\pi}$

$$I_{dc} = \frac{0.06993}{\pi} \approx 0.02226 \text{ A}$$
$$I_{dc} \approx 22.26 \text{ mA}$$

(i) RMS current, I_{rms}:
For a half-wave rectifier, $I_{rms} = \frac{I_m}{2}$

$$I_{rms} = \frac{0.06993}{2} \approx 0.034965 \text{ A}$$
$$I_{rms} \approx 34.97 \text{ mA}$$

- **Step 3:** Calculate powers.
  (ii) AC Input Power, P_{ac}:

$$P_{ac} = I_{rms}^2 \times R_{total} = (0.034965)^2 \times 715$$
$$P_{ac} \approx 0.001222 \times 715 \approx 0.8737 \text{ W}$$

(iii) DC Output Power, P_{dc}:

$$P_{dc} = I_{dc}^2 \times R_L = (0.02226)^2 \times 700$$
$$P_{dc} \approx 0.0004957 \times 700 \approx 0.3470 \text{ W}$$

- **Step 4:** Calculate PIV and efficiency.
  (iv) Peak Inverse Voltage (PIV):
  For a half-wave rectifier, PIV = V_m

$$PIV = 50 \text{ V}$$

(v) Efficiency of Rectification, η:

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{0.3470}{0.8737} \times 100\% \approx 39.72\%$$

Final Answers:
(i) $I_m \approx 69.93$ mA, $I_{dc} \approx 22.26$ mA, $I_{rms} \approx 34.97$ mA
(ii) $P_{ac} \approx 0.874$ W
(iii) $P_{dc} \approx 0.347$ W
(iv) $PIV = 50$ V
(v) $\eta \approx 39.72\%$

4. An a.c. supply of 230V is applied to a full wave rectifier circuit through a transformer of a turn ratio 10:1. Determine (i) I_m, I_{dc}, I_{rms} (ii) a.c. input power (iii) d.c. output power (iv) peak inverse voltage (v) efficiency of rectification. Assume that the diode has forward resistance of 20 ohm and load resistance is 1kΩ.

Solution:

- **Step 1:** Find the transformer's secondary voltage.
  Turn ratio $n = N_p/N_s = 10/1$. Primary voltage $V_{rms} = 230$ V.
  Secondary voltage, $V_s(rms) = \frac{V_p(rms)}{n} = \frac{230}{10} = 23$ V
  Peak secondary voltage, $V_m = \sqrt{2} \times V_s(rms) = \sqrt{2} \times 23 \approx 32.53$ V
- **Step 2:** Circuit parameters.
  Total resistance, $R_{total} = R_f + R_L = 20\,\Omega + 1000\,\Omega = 1020\,\Omega$
- **Step 3:** Calculate currents.
  (i) Peak current, I_m:
  $$I_m = \frac{V_m}{R_{total}} = \frac{32.53}{1020} \approx 0.03189 \text{ A}$$

(i) Average (DC) current, I_{dc}:
For a full-wave rectifier, $I_{dc} = \frac{2I_m}{\pi}$
$$I_{dc} = \frac{2 \times 0.03189}{\pi} \approx 0.02030 \text{ A}$$

(i) RMS current, I_{rms}:
For a full-wave rectifier, $I_{rms} = \frac{I_m}{\sqrt{2}}$
$$I_{rms} = \frac{0.03189}{\sqrt{2}} \approx 0.02255 \text{ A}$$

- **Step 4:** Calculate powers.
  (ii) AC Input Power, P_{ac}:
  $$P_{ac} = I_{rms}^2 \times R_{total} = (0.02255)^2 \times 1020$$
  $$P_{ac} \approx 0.0005085 \times 1020 \approx 0.5187 \text{ W}$$

(iii) DC Output Power, P_{dc}:
$$P_{dc} = I_{dc}^2 \times R_L = (0.02030)^2 \times 1000$$
$$P_{dc} \approx 0.0004121 \times 1000 \approx 0.4121 \text{ W}$$

- **Step 5:** Calculate PIV and efficiency.
  (iv) Peak Inverse Voltage (PIV):
  For a center-tapped full-wave rectifier, PIV = $2V_m$
  $$PIV = 2 \times 32.53 \approx 65.06 \text{ V}$$

(v) Efficiency of Rectification, η:

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{0.4121}{0.5187} \times 100\% \approx 79.45\%$$

Final Answers:
(i) $I_m \approx 31.89$ mA, $I_{dc} \approx 20.30$ mA, $I_{rms} \approx 22.55$ mA
(ii) $P_{ac} \approx 0.519$ W
(iii) $P_{dc} \approx 0.412$ W
(iv) $PIV \approx 65.1$ V
(v) $\eta \approx 79.45\%$

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5. Full wave rectifier has two identical diodes, the internal resistance of each is 20Ω. The transformer has ratio of 5:1 and has a centre tap. The primary voltage is 230V, 50Hz. The load resistance is 980Ω. Calculate (a) Average load current (b) r.m.s. value of current(c) d.c. output voltage (d) peak inverse voltage (e) efficiency of rectification.

Solution:

- **Step 1:** Find the transformer's secondary voltage.
  $$V_s(rms) = \frac{V_p(rms)}{n} = \frac{230}{5} = 46 \text{ V}$$
  This 46V is across the entire secondary winding. For the center-tapped configuration, the voltage from center tap to one end is half.
  $$V_m(\text{half secondary}) = \sqrt{2} \times \frac{V_s}{2} = \sqrt{2} \times \frac{46}{2} = \sqrt{2} \times 23 \approx 32.53 \text{ V}$$

- **Step 2:** Circuit parameters.
  Total resistance, $R_{total} = R_f + R_L = 20\ \Omega + 980\ \Omega = 1000\ \Omega$

- **Step 3:** Calculate currents and voltages.
  Peak current, $I_m = \frac{V_m}{R_{total}} = \frac{32.53}{1000} = 0.03253$ A

(a) Average load current, I_{dc}:

$$I_{dc} = \frac{2I_m}{\pi} = \frac{2 \times 0.03253}{\pi} \approx 0.02071 \text{ A}$$

(b) RMS value of current, I_{rms}:

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.03253}{\sqrt{2}} \approx 0.02301 \text{ A}$$

(c) DC output voltage, V_{dc}:

$$V_{dc} = I_{dc} \times R_L = 0.02071 \times 980 \approx 20.30 \text{ V}$$

- **Step 4:** Calculate PIV and efficiency.
  (d) Peak Inverse Voltage (PIV):
  PIV = $2V_m = 2 \times 32.53 \approx 65.06$ V

(e) Efficiency of Rectification, η:

$$P_{ac} = I_{rms}^2 \times R_{total} = (0.02301)^2 \times 1000 \approx 0.5294 \text{ W}$$
$$P_{dc} = I_{dc}^2 \times R_L = (0.02071)^2 \times 980 \approx 0.4203 \text{ W}$$
$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{0.4203}{0.5294} \times 100\% \approx 79.39\%$$

Final Answers:
(a) $I_{dc} \approx 20.71$ mA
(b) $I_{rms} \approx 23.01$ mA
(c) $V_{dc} \approx 20.30$ V
(d) $PIV \approx 65.1$ V
(e) $\eta \approx 79.39\%$

6. Draw output of given circuit.

Solution:

The circuit is a **dual clipper** (or limiter). Its purpose is to "clip off" or limit parts of the input waveform that go above or below certain voltage levels.

- **Upper Clipping Level (+4V):** Diode **D1** is connected to a +4V supply. It will conduct **only when** the input voltage V_{IN} tries to rise **above +4V**. When D1 conducts, it clamps the output voltage V_{OUT} at **+4V**.
- **Lower Clipping Level (+6V):** Diode **D2** is connected to a +6V supply. It will conduct **only when** the input voltage V_{IN} tries to fall **below +6V**. When D2 conducts, it clamps the output voltage V_{OUT} at **+6V**.

Analyzing the Input Waveform:
The input is a sine wave with a peak of 20V. This means it swings from +20V to -20V.

- For the part of the cycle where V_{IN} is **above +4V**, D1 is ON, and the output is clipped at **+4V**.
- For the part of the cycle where V_{IN} is **below +6V**, D2 is ON, and the output is clipped at **+6V**.
- The input voltage **never exists between +4V and +6V** because it is instantly clipped at one of the two limits. The output will be a constant voltage, determined by which diode is forward-biased. In practice, for a standard dual clipper, the lower voltage source should be negative (e.g., -6V) to clip the negative part of the waveform.

Assignment – 2

1) An NPN BJT has emitter current $I_E = 5$ mA and collector current $I_C = 4.8$ mA. Find base current I_B, current gain β and α.

Solution:

- **Step 1:** Find the base current I_B.
  The fundamental current relationship in a BJT is: $I_E = I_C + I_B$
  $$I_B = I_E - I_C = 5 \text{ mA} - 4.8 \text{ mA} = 0.2 \text{ mA}$$
- **Step 2:** Find the common-base current gain α.
  $$\alpha = \frac{I_C}{I_E} = \frac{4.8 \text{ mA}}{5 \text{ mA}} = 0.96$$
- **Step 3:** Find the common-emitter current gain β.
  $$\beta = \frac{I_C}{I_B} = \frac{4.8 \text{ mA}}{0.2 \text{ mA}} = 24$$
  (Alternatively, $\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$*)*

Final Answer: $I_B = 0.2$ mA, $\beta = 24$, $\alpha = 0.96$

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2) In a silicon BJT, $V_{BE} = 0.7$ V. If base current is 2 mA, estimate percentage increase in I_C when V_{BE} increases to 0.75 V ($V_T = 25$ mV).

Solution:

- **Step 1:** Recall the exponential relationship between I_C and V_{BE}.
  $I_C = I_S e^{V_{BE}/V_T}$, where I_S is the saturation current.
- **Step 2:** Find the ratio of the new collector current to the original collector current.
  Let I_{C1} be the current at $V_{BE1} = 0.7$ V.
  Let I_{C2} be the current at $V_{BE2} = 0.75$ V.
  $$\frac{I_{C2}}{I_{C1}} = \frac{I_S e^{V_{BE2}/V_T}}{I_S e^{V_{BE1}/V_T}} = e^{(V_{BE} \; - V_{BE} \;)/V_T}$$
  $$\frac{I_{C2}}{I_{C1}} = e^{(0.75-0.7)/0.025} = e^{0.05/0.025} = e^2$$

- **Step 3:** Calculate the numerical value of the ratio.
  $$e^2 \approx 7.389$$
  This means $I_{C2} \approx 7.389 \times I_{C1}$
- **Step 4:** Calculate the percentage increase.
  Percentage Increase = $\frac{I_{C2}-I_{C1}}{I_{C1}} \times 100\% = (7.389 - 1) \times 100\% \approx 638.9\%$

Final Answer: The percentage increase in I_C is approximately **638.9%**.

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3) A transistor has $\beta = 60$ and base current pulse of 20 μA applied for 1 ms. Find maximum possible collector current and charge delivered to collector.

Solution:

- **Step 1:** Find the maximum possible collector current I_C.
  $$I_C = \beta I_B = 60 \times 20\,\mu\text{A} = 1200\,\mu\text{A} = 1.2\text{ mA}$$
- **Step 2:** Find the charge delivered to the collector.
  Charge Q = Current $\times$ Time
  $$Q = I_C \times t = (1.2 \times 10^{-3}\text{ A}) \times (1 \times 10^{-3}\text{ s})$$
  $$Q = 1.2 \times 10^{-6}\text{ Coulombs}$$

Final Answer: Maximum $I_C = 1.2$ mA, Charge delivered = **1.2 μC**.

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4) A fixed bias NPN transistor has $V_{CC} = 12$ V, $R_C = 2$ kΩ and $I_C =$ 4 mA. Find V_{CE} if emitter is grounded.

Solution:

- **Step 1:** Analyze the circuit. This is a common-emitter fixed bias configuration. The collector-emitter voltage V_{CE} is found using KVL in the collector-emitter loop.
- **Step 2:** Apply KVL: $V_{CC} - I_C R_C - V_{CE} = 0$
- **Step 3:** Substitute the values and solve for V_{CE}.
  $$12\text{ V} - (4 \times 10^{-3}\text{ A} \times 2 \times 10^3\ \Omega) - V_{CE} = 0$$
  $$12\text{ V} - 8\text{ V} - V_{CE} = 0$$
  $$V_{CE} = 4\text{ V}$$

Final Answer: $V_{CE} = 4\text{ V}$

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5) In a voltage-divider bias circuit, $V_{CC} = 15\text{ V}$, $R_1 = 150\text{ k}\Omega$, $R_2 = 33\text{ k}\Omega$, $R_C = 4.7\text{ k}\Omega$, $R_E = 1\text{ k}\Omega$, $\beta = 100$. Find I_C and V_{CE}.

Solution:

- **Step 1:** Find the base voltage V_B using the voltage divider rule (assuming I_B is negligible).
$$V_B \approx V_{CC} \times \frac{R_2}{R_1 + R_2} = 15 \times \frac{33\text{ k}\Omega}{150\text{ k}\Omega + 33\text{ k}\Omega} = 15 \times \frac{33}{183}$$
$$V_B \approx 2.705\text{ V}$$
- **Step 2:** Find the emitter voltage V_E.
$V_E = V_B - V_{BE}$. Assuming $V_{BE} = 0.7\text{ V}$ for silicon:
$$V_E = 2.705\text{ V} - 0.7\text{ V} = 2.005\text{ V}$$
- **Step 3:** Find the emitter current I_E, which is approximately equal to I_C.
$$I_E = \frac{V_E}{R_E} = \frac{2.005\text{ V}}{1\text{ k}\Omega} = 2.005\text{ mA}$$
$$I_C \approx I_E = 2.005\text{ mA}$$
- **Step 4:** Find the collector voltage V_C.
$$V_C = V_{CC} - I_C R_C = 15\text{ V} - (2.005 \times 10^{-3}\text{ A} \times 4.7 \times 10^3\ \Omega)$$
$$V_C = 15\text{ V} - 9.4235\text{ V} = 5.5765\text{ V}$$
- **Step 5:** Find the collector-emitter voltage V_{CE}.
$$V_{CE} = V_C - V_E = 5.5765\text{ V} - 2.005\text{ V} = 3.5715\text{ V}$$

Final Answer: $I_C \approx 2.01\text{ mA}$, $V_{CE} \approx 3.57\text{ V}$

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6) For an NPN transistor with $\beta = 80$, $I_B = 50\ \mu\text{A}$, $V_{CC} = 20\text{ V}$, $R_C = 3.9\text{ k}\Omega$, $R_E = 1\text{ k}\Omega$, find I_E, I_C and V_{CE}.

Solution:

- **Step 1:** Find the collector current I_C.
$$I_C = \beta I_B = 80 \times 50\ \mu\text{A} = 4000\ \mu\text{A} = 4\text{ mA}$$
- **Step 2:** Find the emitter current I_E.
$$I_E = I_C + I_B = 4\text{ mA} + 0.05\text{ mA} = 4.05\text{ mA}$$

- **Step 3:** Find the collector-emitter voltage V_{CE} using KVL around the C-E loop.
  $V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$
  $20 - (4 \times 10^{-3})(3.9 \times 10^3) - V_{CE} - (4.05 \times 10^{-3})(1 \times 10^3) = 0$
  $20 - 15.6 - V_{CE} - 4.05 = 0$
  $0.35 - V_{CE} = 0$
  $V_{CE} = 0.35\ \text{V}$

Final Answer: $I_E = 4.05\ \text{mA}$, $I_C = 4.00\ \text{mA}$, $V_{CE} = 0.35\ \text{V}$

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7) A transistor has $I_C = 2\ \text{mA}$, $R_C = 5\ \text{k}\Omega$, $V_{CC} = 10\ \text{V}$. Find V_{CE} if emitter is grounded.

Solution:

- **Step 1:** This is similar to question 4. Apply KVL in the collector-emitter loop.

$$V_{CC} - I_C R_C - V_{CE} = 0$$

- **Step 2:** Solve for V_{CE}.

$$10\ \text{V} - (2\ \text{mA} \times 5\ \text{k}\Omega) - V_{CE} = 0$$
$$10\ \text{V} - 10\ \text{V} - V_{CE} = 0$$
$$V_{CE} = 0\ \text{V}$$

Final Answer: $V_{CE} = 0\ \text{V}$

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8) For NPN transistor, $V_{BE} = 0.72\ \text{V}$, $V_{BC} = -0.1\ \text{V}$. Identify transistor operating region.

Solution:

- **Step 1:** Analyze the junction biases.
  - Base-Emitter (B-E) Junction: $V_{BE} = 0.72\ \text{V}$ -> **Forward Biased** (positive voltage).
  - Base-Collector (B-C) Junction: $V_{BC} = -0.1\ \text{V}$ -> **Reverse Biased** (negative voltage).
- **Step 2:** Correlate the biases with the operating regions of an NPN transistor.

- **Active Region:** B-E Junction Forward Biased, B-C Junction Reverse Biased.

Final Answer: The transistor is operating in the **Active Region**.

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9) For transistor with $h_{fe} = 100$, source resistance 10 kΩ, bias resistance 50 kΩ, estimate base current reduction due to source loading.

Solution:

- **Step 1:** Understand the scenario. The "bias resistance" likely refers to the equivalent resistance seen looking into the base of the transistor, $R_{in(base)}$. For a common-emitter amplifier, $R_{in(base)} \approx \beta R_E$. If R_E is not given, we assume the 50 kΩ is $R_{in(base)}$. The source resistance $R_s = 10\,\text{k}\Omega$ forms a voltage divider with $R_{in(base)}$.
- **Step 2:** Calculate the loading effect. The voltage at the base V_B is reduced from the open-circuit source voltage V_s due to this divider.
  Voltage Division Factor = $\frac{R_{in(base)}}{R_s+R_{in(base)}} = \frac{50\,\text{k}\Omega}{10\,\text{k}\Omega+50\,\text{k}\Omega} = \frac{50}{60} = \frac{5}{6}$
- **Step 3:** Relate this to base current. Since $I_B \propto V_B$, the base current is also reduced by the same factor compared to the case with no source loading ($R_s = 0$).
  Base Current Reduction Factor = $1 - \frac{5}{6} = \frac{1}{6}$
  Percentage Reduction = $\frac{1}{6} \times 100\% \approx 16.67\%$

Final Answer: The base current is reduced by approximately **16.67%** due to source loading.

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10) A CC amplifier (emitter follower) with $\beta = 80$ and $R_E = 2\,\text{k}\Omega$. If input changes by 1 V peak, estimate output amplitude and voltage gain.

Solution:

- **Step 1:** Find the input resistance at the base. For an emitter follower, $R_{in} \approx (\beta + 1)R_E$.
  $$R_{in} \approx (80 + 1) \times 2\,\text{k}\Omega = 81 \times 2\,\text{k}\Omega = 162\,\text{k}\Omega$$

- **Step 2:** Estimate the output amplitude. In an emitter follower, the output voltage at the emitter follows the input voltage at the base, minus a small drop across V_{BE}. The voltage gain is approximately 1.
  Therefore, if the input changes by 1 V, the output change will be very close to 1 V.
  Output Amplitude ≈ Input Amplitude ≈ 1 V
- **Step 3:** Calculate the voltage gain A_v. The exact formula is $A_v = \frac{R_E}{R_E + r_e'}$, where r_e' is the small-signal emitter resistance. Since r_e' is typically small (a few ohms to tens of ohms) compared to R_E (2 kΩ), the gain is very close to 1.
  $$A_v \approx 1$$

Final Answer: Output Amplitude ≈ 1 V, Voltage Gain $A_v \approx 1$

Assignment – 3

1) A CE amplifier uses coupling capacitor $C_C = 10\ \mu F$ connected to input resistance 50 kΩ. Find the lower cutoff frequency due to this capacitor.

Solution:

- **Step 1:** Identify the formula for the lower cutoff frequency (f_L) of a high-pass RC circuit formed by the coupling capacitor and the input resistance.

$$f_L = \frac{1}{2\pi R C_C}$$

- **Step 2:** Substitute the given values into the formula.

$$R = 50\,\text{k}\Omega = 50 \times 10^3\ \Omega$$
$$C_C = 10\ \mu\text{F} = 10 \times 10^{-6}\ \text{F}$$
$$f_L = \frac{1}{2\pi(50 \times 10^3)(10 \times 10^{-6})}$$

- **Step 3:** Calculate the result.

$$f_L = \frac{1}{2\pi(0.5)} = \frac{1}{3.1416} \approx 0.318\ \text{Hz}$$

Final Answer: The lower cutoff frequency is approximately **0.32 Hz**.

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2) In an amplifier circuit, bypass capacitor $C_E = 100\ \mu F$ and emitter resistance $R_E = 1\ k\Omega$. Determine cutoff frequency below which gain reduces (use $f_L = 1/(2\pi R_E C_E)$).

Solution:

- **Step 1:** Use the provided formula for the lower cutoff frequency due to the emitter bypass capacitor.

$$f_L = \frac{1}{2\pi R_E C_E}$$

- **Step 2:** Substitute the given values.

$$R_E = 1\,\text{k}\Omega = 1 \times 10^3\ \Omega$$
$$C_E = 100\ \mu\text{F} = 100 \times 10^{-6}\ \text{F}$$
$$f_L = \frac{1}{2\pi(1 \times 10^3)(100 \times 10^{-6})}$$

- **Step 3:** Calculate the result.

$$f_L = \frac{1}{2\pi(0.1)} = \frac{1}{0.6283} \approx 1.59\ \text{Hz}$$

Final Answer: The cutoff frequency is approximately **1.59 Hz**.

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3) A transistor amplifier has $V_{CC} = 10\,V$, $R_C = 2\,k\Omega$, $R_L = 5\,k\Omega$. Find AC load line slope and end points.

Solution:

- **Step 1:** Find the AC load resistance R_{ac}.
  In a common-emitter amplifier, R_C and R_L are in parallel from the AC perspective.

$$R_{ac} = R_C \parallel R_L = \frac{R_C R_L}{R_C + R_L} = \frac{(2k)(5k)}{2k + 5k} = \frac{10k}{7k} \approx 1.429\ \text{k}\Omega$$

- **Step 2:** Find the slope of the AC load line.
  The slope of the AC load line is $-\frac{1}{R_{ac}}$.
  Slope $\approx -\frac{1}{1.429\ \text{k}\Omega} \approx -0.7\ \text{mA/V}$
- **Step 3:** Find the endpoints of the AC load line.
  The AC load line passes through the Q-point. However, without the Q-point given, we find the extreme points.
  - **Saturation Point (i_C max):** $i_{C(max)} = I_{CQ} + \frac{V_{CEQ}}{R_{ac}}$ (requires Q-point).
  - **Cutoff Point (v_CE max):** $v_{CE(max)} = V_{CEQ} + I_{CQ} R_{ac}$ (requires Q-point).
    Since Q-point is not provided, we state the general method: The AC load line has a slope of -1/R_ac and pivots around the Q-point (I_CQ, V_CEQ). Its x-intercept is at V_CEQ + I_CQ * R_ac and its y-intercept is at I_CQ + V_CEQ / R_ac.

Final Answer: AC load resistance $R_{ac} \approx 1.43\ \text{k}\Omega$. Slope of AC load line $\approx -0.7\ \text{mA/V}$. Endpoints require Q-point for precise calculation.

---

4) For a transistor with $I_C = 2\,mA$, find g_m and r_e' if $\beta = 100$.

Solution:

- **Step 1:** Calculate the transconductance g_m.
  $g_m = \frac{I_C}{V_T}$, where V_T is the thermal voltage (≈ 25 mV at room temperature).
  $$g_m = \frac{2\text{ mA}}{25\text{ mV}} = 0.08\text{ S} = 80\text{ mS}$$
- **Step 2:** Calculate the small-signal emitter resistance r_e'.
  $r_e' = \frac{V_T}{I_E} \approx \frac{V_T}{I_C}$ (since $I_C \approx I_E$)
  $$r_e' = \frac{25\text{ mV}}{2\text{ mA}} = 12.5\ \Omega$$

Final Answer: $g_m = 80$ mS, $r_e' = 12.5\ \Omega$

---

5) A CE amplifier has $R_C = 4.7\,k\Omega$, $r_e' = 25\ \Omega$, $\beta = 120$. Compute small-signal voltage gain

---

Solution:

- **Step 1:** Recall the formula for the voltage gain of a common-emitter amplifier with bypassed emitter resistor.
  $A_v = -\frac{R_C}{r_e'}$ (The negative sign indicates a 180° phase inversion).
- **Step 2:** Substitute the given values into the formula.
  $$A_v = -\frac{4.7\text{ k}\Omega}{25\ \Omega} = -\frac{4700\ \Omega}{25\ \Omega} = -188$$

Final Answer: The small-signal voltage gain is **-188**.

---

6) For CE amplifier with $R_C = 3.3\,k\Omega$, $R_E = 1\,k\Omega$, $\beta = 100$, $r_e' = 25\ \Omega$, compute voltage gain with emitter resistor unbypassed.

Solution:

- **Step 1:** Recall the formula for the voltage gain of a common-emitter amplifier with an unbypassed emitter resistor.

$$A_v = -\frac{R_C}{r_e' + R_E}$$

- **Step 2:** Substitute the given values into the formula.

$$A_v = -\frac{3.3\ \text{k}\Omega}{25\ \Omega + 1\ \text{k}\Omega} = -\frac{3300\ \Omega}{1025\ \Omega} \approx -3.22$$

Final Answer: The small-signal voltage gain is approximately **-3.22**.

Assignment – 4

1) A JFET has $I_{DSS} = 12$ mA and $V_P = -4$ V. Calculate the drain current for $V_{GS} = -2$ V using Shockley's equation.

Solution:

- **Step 1:** Write down Shockley's equation.
$$I_D = I_{DSS}(1 - \frac{V_{GS}}{V_P})^2$$
- **Step 2:** Substitute the given values into the equation.
$$I_D = 12 \times 10^{-3}(1 - \frac{-2}{-4})^2$$
- **Step 3:** Simplify and calculate the expression inside the parentheses.
$$1 - \frac{-2}{-4} = 1 - 0.5 = 0.5$$
- **Step 4:** Complete the calculation.
$$I_D = 12 \times 10^{-3} \times (0.5)^2 = 12 \times 10^{-3} \times 0.25 = 3 \times 10^{-3} \text{ A}$$

Final Answer: $I_D = 3$ mA

---

2) For a JFET, $I_{DSS} = 10$ mA, $V_P = -5$ V. Find V_{GS} when $I_D = 6$ mA.

Solution:

- **Step 1:** Write down Shockley's equation.
$$I_D = I_{DSS}(1 - \frac{V_{GS}}{V_P})^2$$
- **Step 2:** Substitute the known values.
$$6 \times 10^{-3} = 10 \times 10^{-3}(1 - \frac{V_{GS}}{-5})^2$$
- **Step 3:** Divide both sides by I_{DSS}.
$$0.6 = (1 - \frac{V_{GS}}{-5})^2$$
$$0.6 = (1 + \frac{V_{GS}}{5})^2$$
- **Step 4:** Take the square root of both sides.

$$\sqrt{0.6} = 1 + \frac{V_{GS}}{5}$$
$$0.7746 \approx 1 + \frac{V_{GS}}{5}$$

- **Step 5:** Solve for V_{GS}.

$$\frac{V_{GS}}{5} \approx 0.7746 - 1 = -0.2254$$
$$V_{GS} \approx -0.2254 \times 5 = -1.127 \text{ V}$$

Final Answer: $V_{GS} \approx -1.13 \text{ V}$

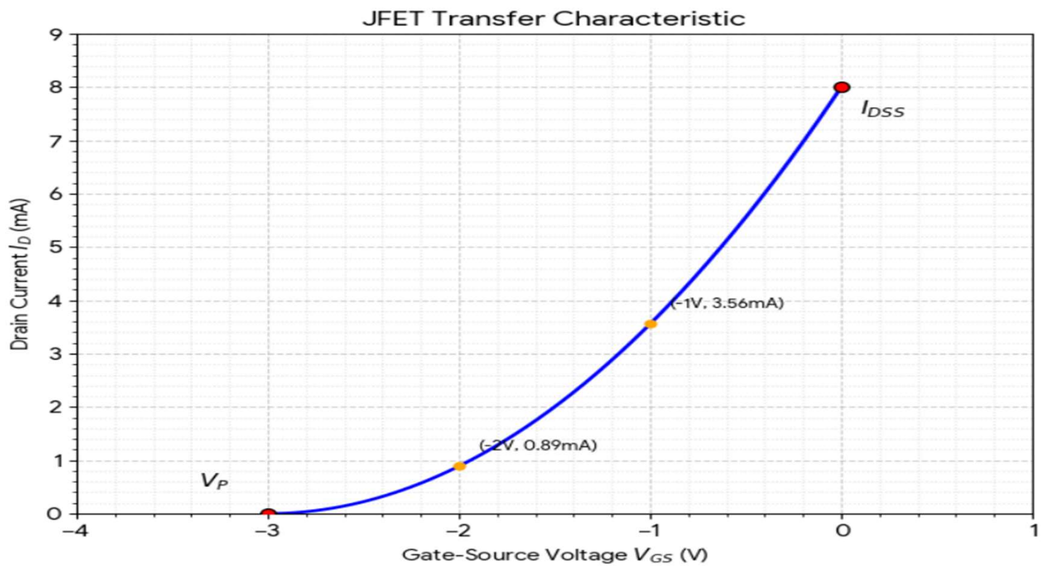
---

3) Sketch and calculate values for transfer and output characteristics of a JFET with $I_{DSS} = 8 \text{ mA}$ and $V_P = -3 \text{ V}$.

Solution:
This question asks for a sketch. I will provide the key calculation points for the sketch and a detailed AI prompt for the image.

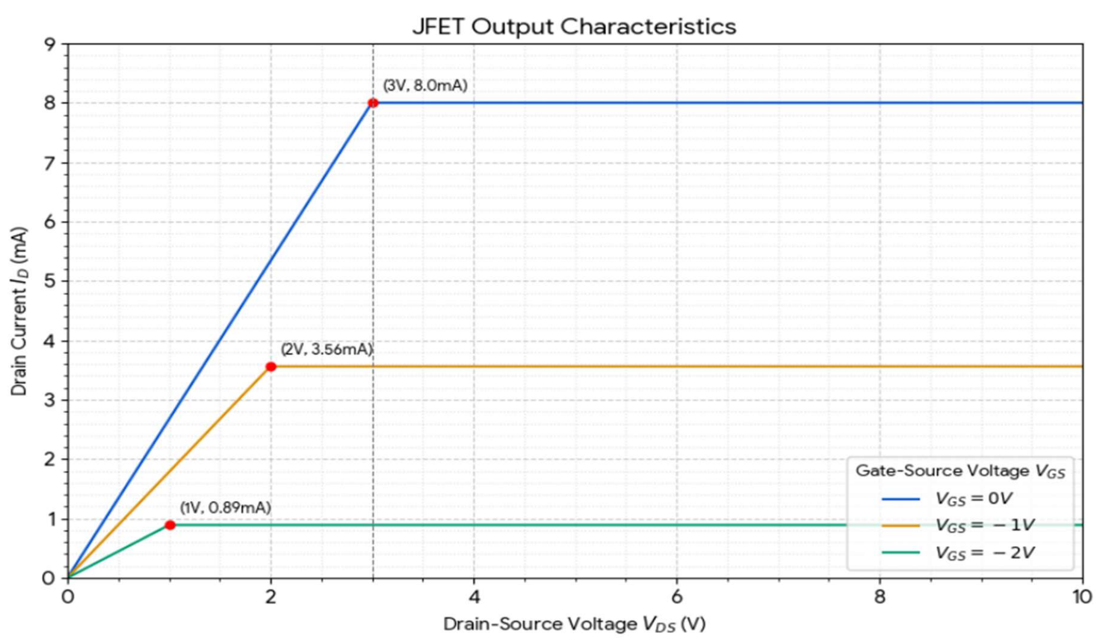
Calculation of Key Points for Transfer Characteristic (I_D vs V_{GS}):

- **Step 1:** Use Shockley's equation: $I_D = 8(1 - \frac{V_{GS}}{-3})^2 = 8(1 + \frac{V_{GS}}{3})^2$
- **Step 2:** Calculate I_D for specific V_{GS} values:
  - At $V_{GS} = 0 \text{ V}$: $I_D = 8(1 + 0)^2 = 8 \text{ mA}$
  - At $V_{GS} = -1 \text{ V}$: $I_D = 8(1 - 1/3)^2 = 8(2/3)^2 \approx 3.56 \text{ mA}$
  - At $V_{GS} = -2 \text{ V}$: $I_D = 8(1 - 2/3)^2 = 8(1/3)^2 \approx 0.89 \text{ mA}$
  - At $V_{GS} = -3 \text{ V}$: $I_D = 8(1 - 1)^2 = 0 \text{ Ma}$



Calculation for Output Characteristic (I_D vs V_{DS}):

- The output characteristics are a family of curves for different V_{GS}. In the saturation region, I_D is constant and given by Shockley's equation.
- The ohmic/triode region is defined by $V_{DS} < V_{GS} - V_P$. The boundary between ohmic and saturation is $V_{DS} = V_{GS} - V_P$.
  - For $V_{GS} = 0V$, boundary at $V_{DS} = 0 - (-3) = 3V$
  - For $V_{GS} = -1V$, boundary at $V_{DS} = -1 - (-3) = 2V$
  - For $V_{GS} = -2V$, boundary at $V_{DS} = -2 - (-3) = 1V$



4) For given $V_{GS} = -1.5$ V, find I_D and g_m using Shockley's equation. $I_{DSS} = 10$ mA, $V_P = -4$ V.

Solution:

- **Part A: Find I_D**
  - **Step 1:** Use Shockley's equation.
    $$I_D = I_{DSS}(1 - \frac{V_{GS}}{V_P})^2$$
  - **Step 2:** Substitute values.
    $$I_D = 10 \times 10^{-3}(1 - \frac{-1.5}{-4})^2 = 10 \times 10^{-3}(1 - 0.375)^2$$
  - **Step 3:** Calculate.
    $$I_D = 10 \times 10^{-3} \times (0.625)^2 = 10 \times 10^{-3} \times 0.390625$$
    $$= 3.906 \times 10^{-3} \text{ A}$$
- **Part B: Find g_m**
  - **Step 1:** Use the transconductance formula for a JFET.
    $g_m = g_{m0}(1 - \frac{V_{GS}}{V_P})$, where $g_{m0} = -\frac{2I_{DSS}}{V_P}$
  - **Step 2:** Calculate g_{m0}.
    $$g_{m0} = -\frac{2 \times 10 \times 10^{-3}}{-4} = \frac{0.02}{4} = 0.005 \text{ S} = 5 \text{ mS}$$
  - **Step 3:** Calculate g_m.
    $$g_m = 5 \times 10^{-3}(1 - \frac{-1.5}{-4}) = 5 \times 10^{-3}(1 - 0.375)$$
    $$= 5 \times 10^{-3} \times 0.625 = 3.125 \times 10^{-3} \text{ S}$$

Final Answer: $I_D \approx 3.91$ mA, $g_m \approx 3.13$ mS

5) An n-channel enhancement MOSFET has $k_n = 2\,\text{mA/V}^2$ and $V_{th} = 2\,\text{V}$. Find I_D for $V_{GS} = 5\,\text{V}$.

Solution:

- **Step 1:** Check the region of operation. Since $V_{GS} = 5V > V_{th} = 2V$, the MOSFET is on. We assume saturation ($V_{DS} > V_{GS} - V_{th}$) unless stated otherwise.
- **Step 2:** Use the saturation region current equation.
$$I_D = k_n(V_{GS} - V_{th})^2$$
- **Step 3:** Substitute the values.
$$I_D = (2 \times 10^{-3})(5-2)^2 = 0.002 \times (3)^2 = 0.002 \times 9 = 0.018\text{ A}$$

Final Answer: $I_D = 18\,\text{mA}$

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6) For a MOSFET with $V_{th} = 3\,\text{V}$, $k_n = 1.5\,\text{mA/V}^2$, calculate I_D for $V_{GS} = 6\,\text{V}$.

Solution:

- **Step 1:** Check the region of operation. $V_{GS} = 6V > V_{th} = 3V$, so the MOSFET is on. Assume saturation.
- **Step 2:** Use the saturation region current equation.
$$I_D = k_n(V_{GS} - V_{th})^2$$
- **Step 3:** Substitute the values.
$$I_D = (1.5 \times 10^{-3})(6-3)^2 = 0.0015 \times (3)^2 = 0.0015 \times 9 = 0.0135\text{ A}$$

Final Answer: $I_D = 13.5\,\text{mA}$

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7) A JFET amplifier has $V_{DD} = 15\,\text{V}$, $R_D = 3.3\,\text{k}\Omega$, and $R_S = 1\,\text{k}\Omega$. Find the DC load line and Q-point if $I_{DQ} = 3\,\text{mA}$.

Solution:

- **Step 1:** Find the equation for the DC load line using KVL around the drain-source loop.
$$V_{DD} = I_D R_D + V_{DS} + I_D R_S$$
$$V_{DD} = I_D(R_D + R_S) + V_{DS}$$

$$15 = I_D(3.3k + 1k) + V_{DS}$$
$$15 = I_D(4.3k) + V_{DS}$$

- **Step 2:** Find the endpoints of the DC load line.
  - When $I_D = 0$, $V_{DS} = V_{DD} = 15$ V (Cutoff)
  - When $V_{DS} = 0$, $I_D = \frac{V_{DD}}{R_D+R_S} = \frac{15}{4.3k} \approx 3.49$ mA (Saturation)
- **Step 3:** Find the Q-point. Given $I_{DQ} = 3$ mA.
  - Use the load line equation to find V_{DSQ}.
    $V_{DSQ} = V_{DD} - I_{DQ}(R_D + R_S) = 15 - (3 \times 10^{-3})(4.3 \times 10^3)$
    $V_{DSQ} = 15 - 12.9 = 2.1$ V
  - The Q-point is ($I_{DQ} = 3$ mA, $V_{DSQ} = 2.1$ V).

Final Answer: DC Load Line endpoints: ($V_{DS} = 15V, I_D = 0$) and ($V_{DS} = 0V, I_D = 3.49mA$). Q-point: (3 mA, 2.1 V).

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8) In a gate bias circuit with $V_{DD} = 15$ V, $R_D = 3.3$ kΩ, $R_G = 10$ MΩ, and $I_{DSS} = 12$ mA, $V_P = -4$ V, find V_{GSQ}.

Solution:

- **Step 1:** Analyze the gate bias circuit. In gate bias, V_{GS} is set directly by an external supply, often denoted as V_{GG}. The problem states "gate bias circuit" but only provides R_G. A common gate bias has V_{GS} fixed. If V_{GS} is not given, and only R_G is provided, it implies $V_{GS} = 0V$ because the gate resistor connects to ground, and $I_G = 0$.
- **Step 2:** Assume $V_{GSQ} = 0$ V for a simple gate bias configuration.

Final Answer: $V_{GSQ} = 0$ V

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9) A self-bias JFET circuit has $V_{DD} = 18$ V, $R_D = 2.2$ kΩ, $R_S = 1.5$ kΩ, $I_{DSS} = 10$ mA, $V_P = -4$ V. Determine Q-point.

Solution:

- **Step 1:** Write the equation for the self-bias line.

$$V_{GS} = -I_D R_S$$

- **Step 2:** Write the Shockley equation.

$$I_D = I_{DSS}(1 - \frac{V_{GS}}{V_P})^2$$

- **Step 3:** Substitute the bias line into Shockley's equation.

$$I_D = 10 \times 10^{-3}(1 - \frac{-I_D R_S}{-4})^2$$
$$I_D = 0.01(1 - \frac{1.5 \times 10^3 \cdot I_D}{4})^2$$

Let I_D be in mA: $I_D = 10(1 - \frac{1.5 I_D}{4})^2 = 10(1 - 0.375 I_D)^2$

- **Step 4:** Solve the quadratic equation.

$$I_D = 10(1 - 0.75 I_D + 0.140625 I_D^2)$$
$$I_D = 10 - 7.5 I_D + 1.40625 I_D^2$$
$$0 = 10 - 8.5 I_D + 1.40625 I_D^2$$

Rearranging: $1.40625 I_D^2 - 8.5 I_D + 10 = 0$

- **Step 5:** Use the quadratic formula.

$$I_D = \frac{8.5 \pm \sqrt{(-8.5)^2 - 4(1.40625)(10)}}{2(1.40625)} = \frac{8.5 \pm \sqrt{72.25 - 56.25}}{2.8125}$$
$$= \frac{8.5 \pm \sqrt{16}}{2.8125} = \frac{8.5 \pm 4}{2.8125}$$

This gives two solutions:

$$I_{D1} = \frac{12.5}{2.8125} \approx 4.44 \text{ mA}$$
$$I_{D2} = \frac{4.5}{2.8125} \approx 1.60 \text{ mA}$$

- **Step 6:** Choose the valid solution. I_D must be less than I_{DSS} (10 mA). Both are valid mathematically. The correct Q-point is usually the one where V_{DS} is positive and provides sufficient swing. We calculate V_{GS} for both.
  For $I_{D1} = 4.44$ mA: $V_{GS} = -I_D R_S = -4.44 \times 1.5 \approx -6.66$ V. But $V_P = -4V$, so $V_{GS} < V_P$ is not possible in the pinch-off region. Discard I_{D1}.
  For $I_{D2} = 1.60$ mA: $V_{GS} = -1.60 \times 1.5 = -2.4$ V. This is > V_P (-4V), so it's valid.

- **Step 7:** Find V_{DSQ} using KVL: $V_{DD} = I_D R_D + V_{DS} + I_D R_S$

$$V_{DSQ} = V_{DD} - I_{DQ}(R_D + R_S) = 18 - 1.60 \times 10^{-3}(2.2k + 1.5k)$$
$$V_{DSQ} = 18 - 1.60 \times 3.7 = 18 - 5.92 = 12.08 \text{ V}$$

Final Answer: Q-point: $I_{DQ} \approx 1.60$ mA, $V_{DSQ} \approx 12.1$ V, $V_{GSQ} = -2.4$ V

10) For a voltage divider bias circuit, $R_1 = 1\,\text{M}\Omega$, $R_2 = 330\,\text{k}\Omega$, $R_D = 3.3\,\text{k}\Omega$, $R_S = 1\,\text{k}\Omega$, $V_{DD} = 15\,\text{V}$, find gate voltage V_G and operating point.

(Note: JFET parameters I_{DSS} and V_P are missing from the problem. They are required to find the operating point. I will calculate V_G.)

Solution:

- **Step 1:** Find the gate voltage V_G using the voltage divider rule.

$$V_G = V_{DD} \times \frac{R_2}{R_1 + R_2} = 15 \times \frac{330\,\text{k}\Omega}{1000\,\text{k}\Omega + 330\,\text{k}\Omega} = 15 \times \frac{330}{1330}$$

$$V_G \approx 3.72\,\text{V}$$

Final Answer: Gate Voltage $V_G \approx 3.72\,\text{V}$. The operating point (I_D, V_{DS}) cannot be found without I_{DSS} and V_P.

Assignment – 5

1) An LED has a forward voltage of 2 V and is connected to a 5 V supply through a resistor. Find the required series resistor for 20 mA current, Determine power dissipated by LED.

Solution:

- **Step 1:** Calculate the voltage that must be dropped across the series resistor.
  The supply voltage is $V_{supply} = 5\text{ V}$.
  The LED forward voltage is $V_{LED} = 2\text{ V}$.
  Voltage across resistor, $V_R = V_{supply} - V_{LED} = 5\text{ V} - 2\text{ V} = 3\text{ V}$.
- **Step 2:** Use Ohm's Law to find the required series resistance R_s for a current $I = 20\text{ mA}$.
  $R_s = \frac{V_R}{I} = \frac{3\text{ V}}{20\times10^{-3}\text{ A}} = 150\ \Omega$.
- **Step 3:** Calculate the power dissipated by the LED.
  Power $P_{LED} = V_{LED} \times I = 2\text{ V} \times 20 \times 10^{-3}\text{ A} = 0.04\text{ W} = 40\text{ mW}$.

Final Answer: Required series resistor = **150 Ω**, Power dissipated by LED = **40 mW**.

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2) A photo diode generates a photo current of 30 µA at an illumination of 0.3 mW/cm². Find responsivity (A/W).

Solution:

- **Step 1:** Write the formula for responsivity R.
  $$R = \frac{\text{Output Photo Current (A)}}{\text{Input Optical Power (W)}}$$
- **Step 2:** Convert the given values to standard units.
  Photo current, $I_P = 30\ \mu\text{A} = 30 \times 10^{-6}\text{ A}$.
  Incident optical power, $P_{in} = 0.3\text{ mW/cm}^2$. *Note: Responsivity is typically calculated for the total power on the active area. Since area isn't specified, we assume the given power value is the incident power density relevant for the generated current.*
  $P_{in} = 0.3\text{ mW} = 0.3 \times 10^{-3}\text{ W}$.

- **Step 3:** Calculate the responsivity.
  $R = \frac{30\times10^{-6}\text{ A}}{0.3\times10^{-3}\text{ W}} = \frac{0.00003}{0.0003} = 0.1$ A/W.

Final Answer: Responsivity = **0.1 A/W**.

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3) A solar cell has open-circuit voltage $V_{OC} = 0.6$ V, short-circuit current $I_{SC} = 100$ mA, and fill factor $FF = 0.75$. Find maximum power output.

Solution:

- **Step 1:** Write the formula for the maximum power output P_{max} of a solar cell.

$$P_{max} = V_{OC} \times I_{SC} \times FF$$

- **Step 2:** Substitute the given values into the formula.

$$P_{max} = 0.6\text{ V} \times 100 \times 10^{-3}\text{ A} \times 0.75$$

- **Step 3:** Calculate the result.
  $P_{max} = 0.6 \times 0.1 \times 0.75 = 0.045\text{ W} = 45\text{ mW}$.

Final Answer: Maximum power output = **45 mW**.

---

4) A solar cell gives 4.5 V and 300 mA in full sunlight. Find total power and current for 6 cells connected in series-parallel ($2s \times 3p$).

Solution:

- **Step 1:** Analyze the configuration.
  - **Series Connection:** Voltages add up, current remains the same.
  - **Parallel Connection:** Currents add up, voltage remains the same.
  - Configuration: $2s \times 3p$ means 2 cells in series form a string, and 3 such identical strings are connected in parallel.
- **Step 2:** Calculate the voltage and current for one series string (2 cells).
  Voltage per string, $V_{string} = 2 \times 4.5\text{ V} = 9$ V.
  Current per string, $I_{string} = 300$ mA (same as a single cell in series).

- **Step 3:** Calculate the total voltage and current for the parallel combination (3 strings).
  Total Voltage, $V_{total} = V_{string} = 9$ V (voltage is the same in parallel).
  Total Current, $I_{total} = 3 \times I_{string} = 3 \times 300\,\text{mA} = 900\,\text{mA}$.
- **Step 4:** Calculate the total power output.
  Total Power, $P_{total} = V_{total} \times I_{total} = 9\text{ V} \times 900 \times 10^{-3}\text{ A} = 8.1\text{ W}$.

Final Answer: Total Power = **8.1 W**, Total Current = **900 mA**.

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5) For a seven-segment display, each segment draws 15 mA at 2 V. Find total current for displaying digit '8'.

Solution:

- **Step 1:** Identify which segments are lit to display the digit '8'.
  The digit '8' is displayed by illuminating all seven segments (a, b, c, d, e, f, g).
- **Step 2:** Calculate the total current.
  Since all 7 segments are ON, and each draws 15 mA, the total current is the sum of the currents through each segment.
  Total Current, $I_{total} = 7 \times 15\,\text{mA} = 105\,\text{mA}$.

Final Answer: Total current for displaying digit '8' = **105 mA**.

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