OFFLINE TEST SERIES

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ESE-2017 : Prelims Exam

UPSC Engineering Services Examination

E & T ENGINEERING

Answer Key & Solutions

Test 3: Part Syllabus Technical

Electronics Devices and Circuits

1.	(c)	16.	(d)	31.	(a)	46.	(a)	61.	(c)
2.	(c)	17.	(b)	32.	(d)	47.	(d)	62.	(a)
3.	(d)	18.	(d)	33.	(b)	48.	(a)	63.	(c)
4.	(d)	19.	(d)	34.	(c)	49.	(c)	64.	(c)
5.	(d)	20.	(b)	35.	(c)	50.	(c)	65.	(b)
6.	(c)	21.	(c)	36.	(a)	51.	(d)	66.	(a)
7.	(d)	22.	(c)	37.	(b)	52.	(b)	67.	(d)
8.	(d)	23.	(c)	38.	(a)	53.	(c)	68.	(a)
9.	(a)	24.	(b)	39.	(a)	54.	(c)	69.	(b)
10.	(b)	25.	(b)	40.	(d)	55.	(a)	70.	(d)
11.	(b)	26.	(c)	41.	(d)	56.	(b)	71.	(a)
12.	(d)	27.	(a)	42.	(c)	57.	(b)	72.	(a)
13.	(b)	28.	(d)	43.	(c)	58.	(b)	73.	(a)
14.	(a)	29.	(a)	44.	(c)	59.	(c)	74.	(a)
15.	(d)	30.	(c)	45.	(c)	60.	(c)	75.	(c)

DETAILED EXPLANATIONS

2. (c)

In a metal, all electrons are free electrons. Therefore, electron concentration remains same even if the temperature is raised. On increasing the temperature, the mobility of electrons decreases due to the more thermal agitation. Therefore, electrical conductivity of a metal has negative temperature coefficient.

3. (d)

Potential barrier now becomes $(V_0 + V_r)$ increase

where V_r is applied reverse bias voltage

space charge layer width $W \propto \sqrt{V_0 + V_r}$

so, increase electric field

$$E \propto x_{no} N_D$$

or

$$E \propto x_{po} N_A$$

where, x_{no} - part of depletion width on n-side increases as W increases with 'V_r'.

x_{po} - part of depletion width on p-side increases as W increases with 'V_r'.

so, electric field E increase.

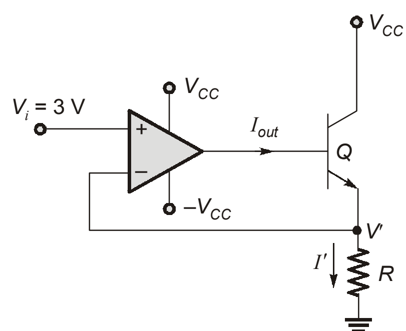
5. (d)

From the given diagram $V_{GS} = 0$

since $V_{GS} < V_T$, MOSFET will be in OFF state.

hence $V_D = 6$ V and $I_D = 0$

6. (c)



$$I_{out} = I_B$$

since op-amp draws no current, $V' = V_i = 3$ V

$$\therefore \quad \text{Current } I' = \frac{V'}{R} = \frac{3}{10} \text{ A}$$

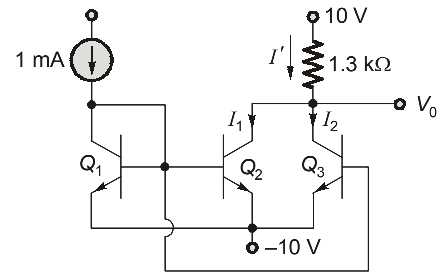
$$\therefore \quad I' = I_E = \frac{3}{10} \text{ A}$$

$$I_E = (1+99)I_B$$

$$\frac{3}{10} = 100\, I_B \quad \text{(or)} \quad \frac{3}{10} = 100\, I_{out}$$

$$\therefore \quad I_{out} = \frac{3}{1000} = 3 \text{ mA}$$

11. (b)



Assume current I' flows through the resistor 1.3 kΩ.
Also given Q_1, Q_2 and Q_3 are identical and β is large
From the given diagram, Q_1Q_2 is pair of transistors form current mirror circuit. Therefore the current I_1 = 1 mA
Similarly Q_1Q_3 pair of transistors also form current mirror circuit. Hence the current I_2 = 1 mA.
∴ The current $I' = I_1 + I_2 = 1 + 1 = 2$ mA

output voltage
$$V_0 = 10\text{ V} - 1.3\text{ k}\Omega \times (2\text{ mA})$$
$$= (10 - 1.3 \times 2)\text{ V}$$
$$= (10 - 2.6)\text{ V}$$
$$V_0 = 7.4\text{ V}$$

12. (d)
Given I_{DSS} = 10 mA, $V_P = -4$ V

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

by KVL in the input loop
$$-2.5 - V_{GS} = 0$$
⇒
$$V_{GS} = -2.5$$
$$I_D = 10 \times 10^{-3}\left[1 - \frac{2.5}{4}\right]^2 \text{ A}$$
$$I_D = 1.4\text{ mA}$$
$$15 - I_D \times 2\text{ k}\Omega - V_{DS} = 0$$
∴
$$V_{DS} = 15 - I_D \times 2\text{ k}\Omega = 15 - 2.8$$
$$V_{DS} = 12.2\text{ V}$$

13. (b)
We know that
$$I_{CEO} = (1 + \beta)I_{CBO}$$
$$= (49 + 1)20 \times 10^{-6}$$
$$I_{CEO} = 1\text{ mA}$$
Now, by applying KVL around the loop that includes V_{CC}, R_B and ground

$$I_{BQ} = \frac{V_{CC} - V_{BEQ}}{R_B} = \frac{10 - 0.7}{100\text{ k}\Omega} = 93\ \mu\text{A}$$

∴
$$I_{CQ} = \beta I_{BQ} + I_{CEO}$$
$$= 49 \times 93 \times 10^{-6} + 1 \times 10^{-3}\text{ A}$$
$$I_{CQ} = 5.557\text{ mA}$$

22. (c)

By voltage division rule at inverting terminal of op-amp

$$V_f = \frac{V_0 \cdot R_1}{R_1 + R_2}$$

$$\text{The feedback factor } \beta = \frac{R_1}{R_1 + R_2} = \frac{10}{11}$$

$$\text{closed loop gain } A_{CL} = \frac{A_{OL}}{1 + A_{OL}\beta} = \frac{10^4}{1 + 10^4 \times \frac{10}{11}}$$

$$\therefore \quad A_{CL} \approx 1.1$$

25. (b)

Here, $V_i = 2\text{V}$

$\therefore D_1 \rightarrow$ OFF and D_2, D_3, D_4 are ON

$$V_0 = 0.6 \times 3 = 1.8\text{ V}$$

$$I = \frac{10 - 1.8}{2\text{k}} = 4.1\text{mA}$$

27. (a)

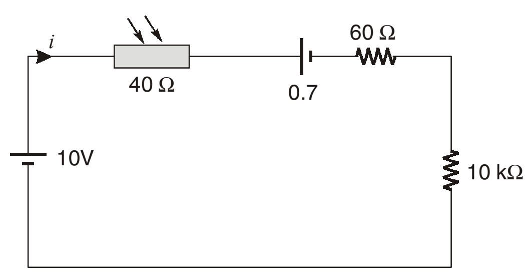
For four-point method

$$R = 4.53 \times \frac{V}{I} = 4.53 \times \frac{0.22}{10 \times 10^{-3}}\ \Omega/\text{square}$$

$$\therefore \quad R = 100\ \Omega/\text{square}$$

29. (a)

As LED is forward bias,



$$i = \frac{10 - 0.7}{(10\text{k} + 100)} = 9.2079 \times 10^{-4}\text{ A}$$

$$\therefore \quad V_{10\text{k}\Omega} = 10\text{k} \times 9.2079 \times 10^{-4} \approx 9.21\text{ V}$$

30. (c)

$$n = 1 \times \frac{10^{16}}{\text{m}^3} = 1 \times \frac{10^{16}}{10^6\text{cm}^3} = 1 \times \frac{10^{10}}{\text{cm}^3}$$

$$J_n = 50\text{ A/cm}^2$$

$$E = 15\text{ V/cm}$$

$$\mu_n = \frac{J_n}{neE} = \frac{50}{1 \times 10^{10} \times 1.6 \times 10^{-19} \times 15}$$

$$\mu_n = 2.083 \times 10^9\text{ cm}^2/\text{V-s}$$

34. (c)

During an electron transition across the energy gap in an indirect energy gap material, both momentum and energy of electron change.

38. (a)

$$V_z = V_{BE} + I \times 1.8\ \text{k}\Omega$$
$$6.2 = 0.7 + 1.8\ \text{k} \times I$$
$$I = \frac{6.2 - 0.7}{1.8}\ \text{mA} = 3.06\ \text{mA}$$

39. (a)

Given $\beta = 100$

Let the transistor be in active region

At the input loop

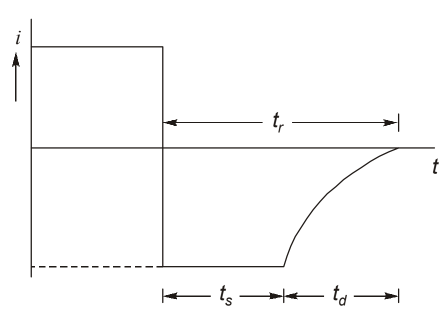
$$2.7 - 40 \times 10^3 I_B - 0.7 = 0$$
$$I_B = \frac{1}{20}\ \text{mA}$$
$$I_C = \beta I_B$$
$$= 5\ \text{mA}$$
$$V_{CE} = 10 - 2.5 \times 10^3 \times 5 \times 10^{-3}$$
$$V_{CE} = -2.5\ \text{V}$$

Transistor is in saturation region

42. (c)

Pinch off voltage in JFET depends on dimensions of device.

43. (c)

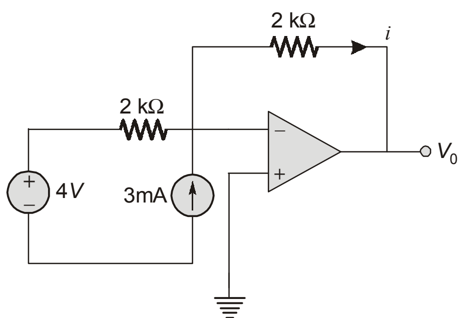


Reverse recovery time $t_r = t_s + t_d$

t_s = storage time (to remove stored minority carriers)

t_d = to bring the diode in reverse biased condition (i.e. $V_D = V_R$) and current $i = 0$.

44. (c)



$$i = 3\,mA + \frac{4}{2}\,mA = 5\,mA$$

$\therefore$ $$V_0 = -(2\text{ k}\Omega)(5\,mA) = -10\text{ volts}$$

45. (c)

$$V_0 = \left(1+\frac{20}{10}\right)6.3 = 18.9\text{ volts}$$

46. (a)

Variable capacitance diodes are used under reverse-bias condition.

47. (d)

In a MOSFET operating in the saturation region, the channel length modulation effect causes a decrease in the output resistance.

48. (a)

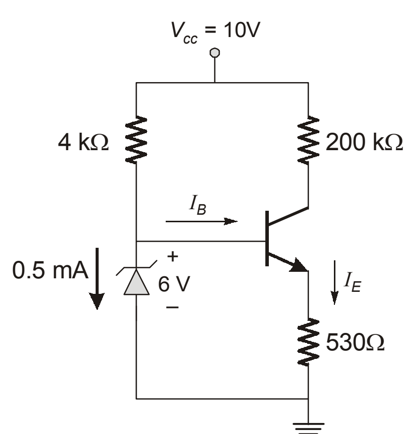
Oscillator is a feedback amplifier which satisfies the Barkhausen criterion given below:

(i) Loop gain Aβ must be slightly greater than 1.

(ii) Loop phase shift must be multiple of 360°.

Emitter follower is common-collector amplifier which has voltage series feedback.

49. (c)



From KVL, $$0.7 + 530\,I_E = 6$$

$\therefore$ $$I_E = \frac{5.30}{530} = 10\,\text{mA}$$

So, $$I_{4\,k\Omega} = \frac{10-6}{4\times10^3} = 1\text{mA}$$

$\therefore$ $$I_B = 0.5 \text{ mA}$$

Now, $$1+\beta = \frac{I_E}{I_B} = \frac{10}{0.5} = 20$$

$\therefore$ $$\beta = 19$$

52. (b)

We shall assume that both diodes are conducting. It follows that $V_B = 0$ and $V_0 = 0$. The current through D_2 can now be determined from

$$I_{D2} = \frac{10-0}{10\times10^3} = 1\,\text{mA}$$

Writing node equation at B,

$$I + (1\times10^{-3}) = \frac{0-(-10)}{5\times10^3}$$

$$I = 1 \text{ mA}$$

Thus D_1 and D_2 are conducting as originally assumed, and the final result is I = 1 mA and V_0 = 0 V.

54. (c)

Photodiode is always operated in reverse bias and when light is off current flowing through this diode is reverse saturation current as working as a normal diode when light is off.

56. (b)

$$I_0 = \frac{V_0 - V_S}{R_L} \qquad \text{where } V_0 = \left(1+\frac{R_L}{R_S}\right)V_S$$

57. (b)

An op-amp based non-inverting amplifier is voltage series feedback amplifier. Voltage series feedback is also known as series-shunt feedback.

59. (c)

$$\text{Generation rate} = \frac{\Delta n}{\tau_n} = \frac{\Delta p}{\tau_p}$$

Excess carrier concentration, $\Delta n = \Delta p$

$$\text{generation rate} = \frac{10^{15}}{10\times10^{-6}} = 10^{20}\text{ pair/cm}^3\text{/sec}$$

60. (c)

$$n_i^2 \propto T^3$$

$$\left(\frac{n_i}{2n_i}\right)^2 = \left(\frac{T_1}{T_2}\right)^3$$

$$T_2 = \sqrt[3]{4}\,T_1$$

$$T_2 = 1.587\,T_1$$

61. (c)

$$I_{D\,sat} = \frac{W\mu_n C_{ox}}{2L}(V_{GS} - V_T)^2$$

$$4 \times 10^{-3} = \left(\frac{W}{L}\right)25\times10^{-6}\,(4)^2$$

$$\frac{W}{L} = 10$$

$$W = 10L = 12.5\ \mu\text{m}$$

63. (c)

$$P_{D(\text{derate})} = P_{D(\text{max})} - [(\text{derating factor}) \times \Delta T]$$
$$= 400\text{ mW} - (3.2\text{ mW/°C})\,[90°\text{C} - 50°\text{C}]$$
$$= 400\text{ mW} - 128\text{ mW}$$
$$= 272\text{ mW}$$

$\therefore$ $P_{D(\text{derate})} = 272\text{ mW}$

64. (c)

Common base current gain

$$\alpha = \frac{\Delta I_C}{\Delta I_E} = \frac{0.995\times10^{-3}}{1.0\times10^{-3}} = 0.995$$

$\therefore$ Common emitter current gain is

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.995}{1-0.995} = 199$$

65. (b)

Given $I = 5$ mA, $T = 300$ k

forward resistance of a PN junction diode $r_f = \dfrac{\eta V_T}{I}$

$$V_T = \frac{T}{11600}$$

$$r_f = \frac{2\times\frac{T}{11600}}{5\times10^{-3}} = \frac{2\times300}{11600\times5\times10^{-3}}$$

$\therefore$ $r_f = 10.34\ \Omega$

73. (a)

A device can be used as oscillator if it exhibits negative resistance property and tunnel diode exhibited this property so, A and R both are true and R is correct explanation.

75. (c)

For the feedback amplifier to oscillate its loop gain is unity and phase shift is zero.

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