gradeup

GATE 2020
Electrical Engineering

Mega Mock Challenge
(02 Jan-03 Jan 2020)

Questions & Solutions

1. **Direction:** In the given question, four words are given of which two are most nearly the same or opposite in meaning. Find the two words and indicate your answer by marking the option which represents the correct combination.

A) Diligent B) Adorable
C) Meticulous D) Prominent

A. B-D B. A-C
C. A-B D. A-D
E. B-C

Ans. B

Sol. The meanings of the words are:

Diligent: having or showing care and conscientiousness in one's work or duties.

Adorable: inspiring great affection or delight.

Meticulous: showing great attention to detail; very careful and precise.

Prominent: important; famous.

Hence, **option B** is the correct answer.

2. **Direction:** A statement with one blank is given below. Choose the set of words from the given options which can be used to fill the given blank.

Despite almost ubiquitous scepticism, the electoral bonds have prevailed and, that too, almost solely ________ rhetorical claims of "transparency of political funding system," "clean money," and "donor's anonymity."

i. with the backing of the ruling government's

ii. based on the endorsement derived from the political party at power's

iii. backed by the political party at power's

A. Only i B. Only ii
C. Only iii D. Both i and ii
E. All of these

Ans. D

Sol. The given sentence talks about the prevailing nature of 'electoral bonds' in spite of concerns and doubts regarding the same. The sentence goes on to explain that this is occurring because of rhetorical claims by someone. From the options it is clear that the ruling part is responsible for these 'rhetorical claims'.

Option i – 'backing' means help or support and has been used in conjunction with the correct tense format of the sentence.

Option ii – 'endorsement' also means help or support and it tallies with the sentence structure.

Option iii – although 'backed' has been used it is in the incorrect tense form. This makes it incorrect.

Thus, option D is the correct answer.

3. Which letter—cluster will replace the question mark (?) in the following series?

HQCF, MVHK, JSEH, OXLM, ?

A. FTRD B. LUGJ
C. MKOP D. SWQ

Ans. B

Sol. Pattern is-

$$H \xrightarrow{+5} M \xrightarrow{-3} J \xrightarrow{+5} O \xrightarrow{-3} \boxed{L}$$

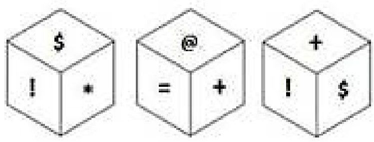
$$Q \xrightarrow{+5} V \xrightarrow{-3} S \xrightarrow{+5} X \xrightarrow{-3} \boxed{U}$$

$$C \xrightarrow{+5} H \xrightarrow{-3} E \xrightarrow{+5} J \xrightarrow{-3} \boxed{G}$$

$$F \xrightarrow{+5} K \xrightarrow{-3} H \xrightarrow{+5} M \xrightarrow{-3} \boxed{J}$$

Hence, the correct answer is option B.

4. Three different positions of the same dice are shown. Which symbol will be on the face opposite to the one having '*'?

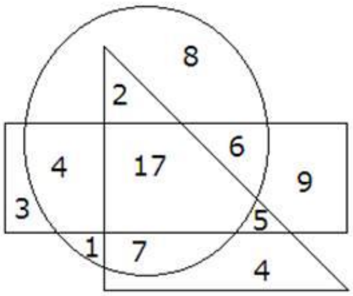


A. + B. !
C. $ D. @

Ans. A

Sol. Pick out the dices in which one symbol is common , after that arrange them in ACW or CW direction.
In II and III '+' is common
+ = @
* + ! $
Interchange the missing symbol '*' with repeated symbol '+'
Hence, option (A) is the correct answer.

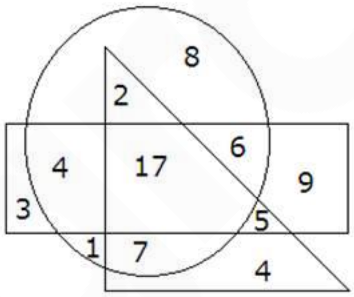
5. In the following diagram, the triangle represents 'Dentists', the circle represents 'Professors' and the rectangle represents 'Doctors'. The numbers in different segments show the number of persons.



How many professors are dentists but not doctors?
A. 17 B. 9
C. 15 D. 13

Ans. B

Sol. Given diagram is-



circle represents Professors
rectangle represents Doctors
triangle represents Dentists
No. of professors who are dentists but not doctors=2+7=9
Hence, the correct answer is option B.

6. In the following question, some statements followed by some conclusions are given. Taking the given statements to be true even if they seem to be at variance from commonly known facts, read all the conclusions and then decide which of the given conclusions logically follows the given statements.
Statement:
Parents must understand that their child cannot attain excellence on his own. He needs their support. They must thus be open to help him at various steps rather than merely setting high expectations.
Conclusion:
I. Ideal students are not born ideal or perfect. They are nurtured to become ideal by their educators. The environment at home has a great impact on the way a student performs in school.
II. The life of an ideal student may seem tough from a distance. However, it is actually much more sorted as compared to those who procrastinate and do not give complete attention to their studies.
A. If only conclusion I follows
B. If only conclusion II follows
C. If both I and II conclusion follow
D. If neither I nor II conclusion follows

Ans. A

Sol. Conclusion I follows, based on the given statement a major component in the making of an Ideal student is described that it takes efforts not only from the students but also from the educators(Teachers and Parents)
Conclusion II is a correct statement that is the hard work and struggle that it takes to become an ideal student but it cannot be the conclusion of the given statement.

7. **Direction:** Each question below is followed by two statements I and II. You have to determine whether the data given in the statement is sufficient for answering the question.

You should use the data and your knowledge of Mathematics to choose the best possible answer.

A man deposited Rs. 'x' in bank which gives simple interest at the rate of 8% p.a. Find the value of 'x'.

Statement I: After 3 years, amount received by him is Rs. (x + 672).

Statement II: Interest earned by him after 3 years is 24% of the amount deposited by him.

A. If the data in Statement I alone are sufficient to answer the question, while the data in Statement II alone are not sufficient to answer the question.

B. If the data in Statement II alone are sufficient to answer the question, while the data in Statement I alone are not sufficient to answer the question.

C. If the data either in Statement I or in Statement II alone are sufficient to answer the question.

D. If the data in both Statements I and II together are necessary to answer the question.

E. If the data even in both Statements I and II together are not sufficient to answer the question.

Ans. A

Sol. Statement I:

Simple interest earned by him

$= x + 672 - x = Rs.672$

So, $672 = \frac{x \times 8 \times 3}{100}$

$x = Rs.2800$

So, statement I alone is sufficient to answer the question.

Statement II:

We have to calculate principal(x) but we are not given interest since it is also in form of x. Hence, there are 2 unknowns.

Statement II alone is not sufficient to answer the question.

Thus, the data in Statement I alone are sufficient to answer the question, while the data in Statement II alone are not sufficient to answer the question.

So option (A) is the correct answer.

8. The given pie chart shows the breakup of total number of the employees of a company working in different offices (A, B, C, D and E). Total no. of employees = 2400

What is the number of offices in which the number of employees of the company is between 350 and 650?

A. 3 B. 4

C. 2 D. 1

Ans. A

Sol. Total no. of Employees (360°) = 2400

No. of employees in office A(126°)

$= \frac{2400}{360} \times 126 = 840$

No. of employees in office B(18°)

$= \frac{2400}{360} \times 18 = 120$

No. of employees in office C(54°)

$= \frac{2400}{360} \times 54 = 360$

No. of employees in office D(90°)

$= \frac{2400}{360} \times 90 = 600$

No. of employees in office E(72°)

$= \frac{2400}{360} \times 72 = 480$

Number of offices in which the number of employees of the company is between 350 and 650 = 3

9. Find the numbers a, b, c between 2 and 18 such that

I. their sum is 25,

II. the numbers 2, a, b are consecutive terms of an A.P. and

III. The numbers b, c, 18 are consecutive terms of a G.P.

A. a=5, b=8, c=12
B. a=7, b=8, c=12
C. a=5, b=9, c=11
D. a=7, b=5, c=11

Ans. A

Sol. We have a + b + c = 25 ...(i)

2, a, b are in A.P. ⇒ 2a = 2 + b ...(ii)

b, c, 18 are in G.P. ⇒ 18b = c2 ...(iii)

Substituting for a and b in (1), using relations (2) and (3), we get

$\Rightarrow 1 + \frac{b}{2} + \frac{c^2}{18} + c = 25$

$\Rightarrow c^2 + 12c - 288 = 0$

⇒ (c − 12) (c + 24) = 0

⇒ C= 12 or c= -24

Since the numbers lie between 2 & 18,

We take c=12

⇒ a + b = 13

⇒ a + 2a -2 = 13

⇒ b=8, a=5

10. **Statements:**

All lions are ducks.
No duck is a horse.
All horses are fruits.

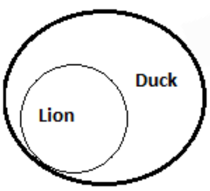
Conclusions:

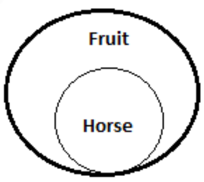
I. No lion is a horse.
II. Some fruits are horses.
III. Some ducks are lions.
IV. Some lions are horses.

A. Only either I or II and III & IV follow
B. Only either I or IV and both II and III follow
C. Only either I or IV and II follow
D. Only Conclusion I & II and III follow

Ans. D

Sol.



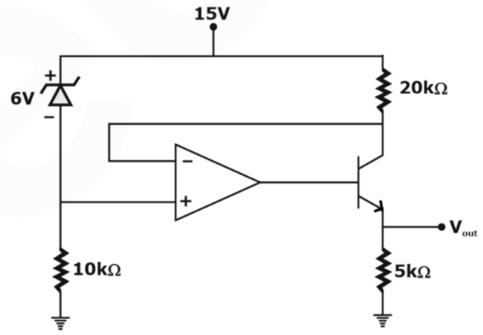


We use elimination to find an exception to the generality of the question. Thus we prove they are not implied. The diagram above satisfy all the above statement but contradict with the conclusion (iv). Since we found an exception, the conclusion is not true in every case. Thus it is not implied.

We can draw many scenarios that satisfy the statements using Venn diagram & check for the validity of the conclusions.

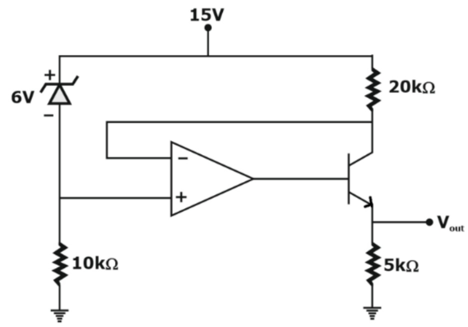
Conclusions (i), (ii), (iii) hold good for every case so they are implied.

11. For the transistor given in the circuit below, V_{BE} = 0.7 V, β = 50. Then the output voltage V_{out} is _____ V.



Sol. Given that:

V_{BE} = 0.7 V, β = 50



Applying KVL in the input side of the op-amp,

V^+ = 15 - 6 = 9 V

Using Virtual ground concept,

$V^+ = V^- = 9$ V

In BJT,

$$I_c = \frac{15-9}{20k} = \frac{6}{20k} = 0.3\ mA$$

$$I_c = \beta I_B$$

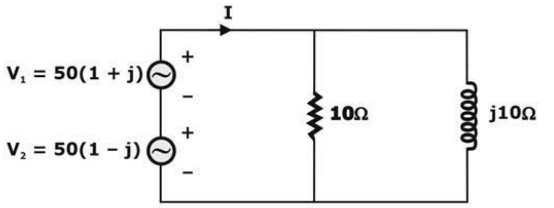
$$I_B = \frac{I_c}{\beta} = \frac{0.3}{50} = 0.006\ mA = 6\ \mu A$$

$$I_E = I_B + I_c$$

$$I_E = 0.006 + 0.3 = 0.306\ mA$$

$$V_{out} = I_E R_E = 0.306 \times 10^{-3} \times 5 \times 10^3 = 1.53\ V$$

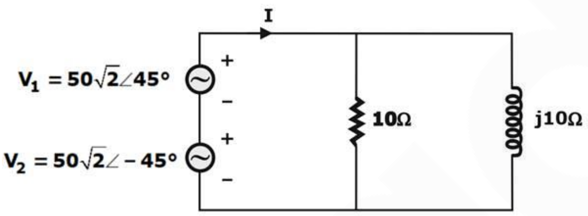
12. Calculate the phase difference between current I and the voltage V_1 in the circuit.

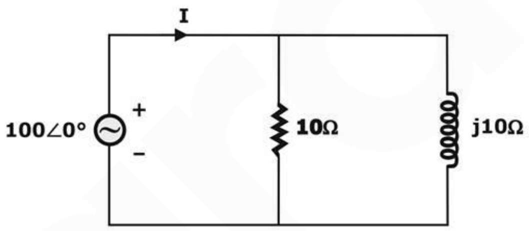


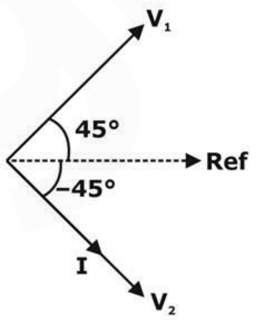
A. 45° B. −45°
C. −90° D. 90°

Ans. C

Sol.





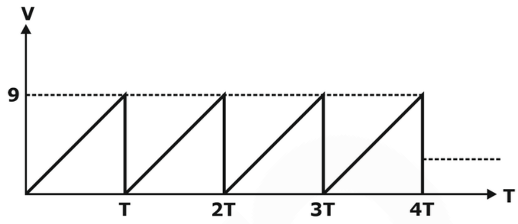


$$I = \frac{100\angle 0^\circ}{10} + \frac{100\angle 0^\circ}{10\angle 90^\circ}$$

I = $10\angle 0^\circ + 10\angle -90^\circ = 14.14\angle -45^\circ$

∴ Phase angle of current I with respect to voltage V_1 in the circuit is −90°.

13. Two voltmeters are connected to measure voltage of the following waveform using PMMC and Moving Iron Instrument.



Find the ratio:

$$\frac{\left(Reading\ of\ Moving\ Iron\ Instrument\right)^2}{Reading\ of\ PMMC\ Instrument} =$$

Sol. The above waveform given is standard sawtooth waveform, hence,

Rms value of waveform is $= \frac{A}{\sqrt{3}}$

Average value of waveform is A/2

Moving Iron Instrument measures AC quantity,
hence the reading of moving Iron Instrument is reading of Moving Iron Instrument = $\frac{9}{\sqrt{3}}$

PMMC type Instrument measures DC value,
hence the reading of PMMC Instrument is
Reading of PMMC Instrument = 9/2

$$Ratio\ of\ \frac{\left(Reading\ of\ Moving\ Iron\ Instrument\right)^2}{Reading\ of\ PMMC\ Instrument} :$$

$$= \frac{\left(9/\sqrt{3}\right)^2}{\left(9/2\right)} = \frac{81 \times 2}{3 \times 9} = 6$$

14. The magnetic field intensity in a region is $\vec{H} = 2x\hat{a}_x - 3y\hat{a}_y + 5z\hat{a}_z$, the current density in A/m² at a point (1, 2, 3) is

Sol. Given that:

$$\vec{H} = 2x\hat{a}_x - 3y\hat{a}_y + 5z\hat{a}_z$$

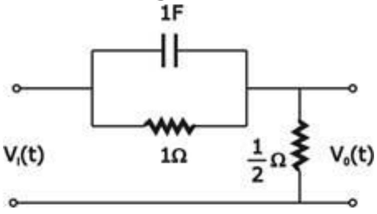
From Maxwell's equation,

$$\nabla \times \vec{H} = \vec{J}$$

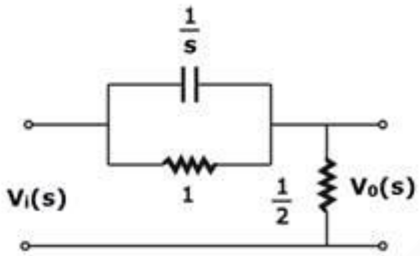
$$\vec{J} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2x & -3y & 5z \end{vmatrix} = a_x\left[\frac{\partial}{\partial y}(5z) - \frac{\partial}{\partial z}(-3y)\right] - a_y\left[\frac{\partial}{\partial x}(5z) - \frac{\partial}{\partial z}(2x)\right] + a_z\left[\frac{\partial}{\partial y}(-3y) - \frac{\partial}{\partial z}(2x)\right]$$

$$= a_x(0-0) - a_y(0-0) + a_z(0-0) = 0$$

15. For the given phase lead n/ω, then maximum possible phase read is _______ in degrees.



Sol.



$$T.F. = \frac{V_o(s)}{V_i(s)} = \frac{\frac{1}{2}}{\frac{1}{2} + \frac{\frac{1}{s}\cdot 1}{\frac{1}{s}+1}} = \frac{1+s}{3+s} = \frac{1+s}{3\left(1+\frac{s}{3}\right)}$$

Comparing with $\frac{1+aT_s}{1+T_s}$. We get $T = \frac{1}{3}$ a = 3

Max phase lead,

$$\phi_{max} = \sin^{-1}\left(\frac{a-1}{a+1}\right)$$

$$= \sin^{-1}\left(\frac{1}{2}\right) = 30^\circ$$

16. If a second order control system has poles (−1 ± jπ), then the step response will exhibit its 1st undershoot at?

A. 2 sec B. 1 sec
C. 1.57 sec D. 3.14 sec

Ans. A

Sol. The poles location is given by $-\zeta\omega_n \pm j\omega_d$

Here ωd = π rad/sec

and $\zeta\omega_n = 1$

the peak time $= \frac{n\pi}{\omega_d}$

the 1st undershoot occurs at n=2

$$t_p = \frac{2\pi}{\omega_d} = 2\sec$$

17. The value of sequence components of currents during a fault are:

$I_{a1} = 10\angle 90^\circ$

$I_{a2} = 7\angle -90^\circ$

$I_{a0} = 3\angle -90^\circ$

Determine the type of fault.

A. Single line to ground
B. Double line to ground
C. Line to Line
D. Symmetrical three phase

Ans. B

Sol. Since the zero-sequence component is not zero, the fault involves ground. Also, the negative of the sum of negative sequence and zero sequence currents is equal to positive sequence current i.e. $I_{a1} = I_{a2} + I_{a0}$.

Hence the fault is double line to ground.

18. A 60 Hz, single phase full wave AC Voltage controller feeds an RL load. The load is having the R = 6 Ω and L = 16 mH. The output is fully controllable for the range of 'α' (firing angle) is

A. 50° ≤ α ≤ 180°
B. 45° ≤ α ≤ 90°
C. 50° ≤ α ≤ 90°
D. 45° ≤ α ≤ 180°

Ans. D

Sol. For this R-L load the output is fully controllable for the range of 'α',

φ ≤ α ≤ π

$\omega L = 2 \times \pi \times 60 \times 16 \times 10^{-3} = 6.032 \sim 6\ \Omega$

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right) = \tan^{-1}\left(\frac{6.03}{6}\right) = 45.14^\circ \simeq 45^\circ$$

19. A 300 V DC Shunt Motor with a back emf of 280 V running at a speed of ω_1 = 560 rad/sec and develops a torque of 20 N-m. The flux per pole is 0.02 Wb. Find the speed of motor ω_2 (rad/sec) when it develops a torque of 25 N-m. The armature resistance is 0.5 Ω.

Sol. For DC motor, the equation of the torque is given as

$$T = k\phi\omega \Rightarrow T \propto \omega \quad [\because \text{it is shunt motor}, \phi = \text{constant}]$$

$$\frac{T_1}{T_2} = \frac{k\omega_1}{k\omega_2} = \frac{\omega_1}{\omega_2}$$

$$\frac{20}{25} = \frac{560}{\omega_2}$$

$$\omega_2 = \frac{560 \times 25}{20} = 700 \text{ rad/sec}$$

20. All queens and kings are removed from a deck of playing cards. Ace will be considered as 1 and jack will be considered as 0. You took out 4 cards. The probability that all cards will be in order (order is – 1234,0123,2345,6789….) from the same deck is M. What is (M x 10^5)?

A. 0.982 B. 0.700

C. 0.643 D. 0.500

Ans. A

Sol. Total cards = 52 – 4 – 4 = 44 (cards)

→ You took out 4 cards

∴ (1) Let order be 0, 1, 2, 3

So, $P\ (\text{order - }0, 1, 2, 3) = \frac{4}{44} \times \frac{1}{43} \times \frac{1}{42} \times \frac{1}{41} = x$

∴ Lost possible set – (7, 8, 9, 10) – 8 such sets are possible

∴ P (Total) = 8 × P(order – 0, 1, 2, 3) = 8x

⇒ 8x × 10^5 = 0.982

21. The minimal expression of function f(A,B,C,D) is

AB \ CD	00	01	11	10
00		1	×	1
01	1	1	×	×
11		×	1	×
10			×	1

A. $\overline{A}D + \overline{A}B + C$

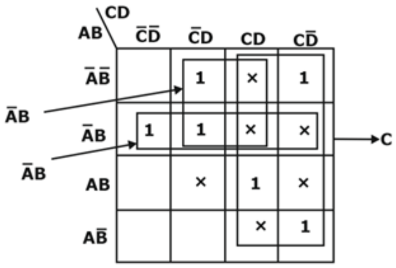
B. $\overline{A}B + AC + \overline{A}C + \overline{A}D$

C. $A + B + C + D$

D. $\overline{A} + \overline{B} + \overline{C} + \overline{D}$

Ans. A

Sol.



So, $f(A,B,C,D) = \overline{A}D + \overline{A}B + C$

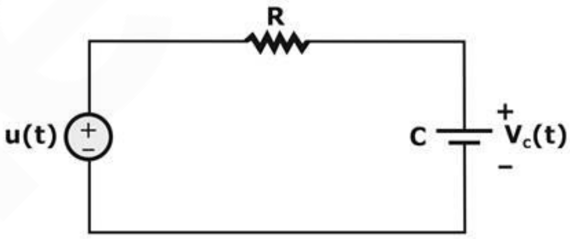
22. An RC series circuit, initially at rest has a step voltage signal. The response $V_C(t)$ across C is $V_C(t) = 2 - 2e^{-4t}$. If now, there is an initial voltage at C of 4 V, then the response $V_C(t)$ is given by

A. $2e^{-4t}$ V B. $2 + 2e^{-4t}$ V

C. 2 V D. $4 + 4e^{-4t}$ V

Ans. B

Sol.



$$V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]e^{-t/\tau}$$

From the given response, $V_C(t) = 2 - 2e^{-4t}$

$V_C(0)$ = initial voltage = 0 V

$V_C(\infty)$ = steady state voltage = 2 V

Time constant, $\tau = \frac{1}{4}$

But now there is initial voltage of 4 V

$V_C(0)$ = 4 V

Response is $V_C(t) = 2 + (4 - 2)\ e^{-4t}$

$V_C(t) = 2 + 2e^{-4t}$ V

23. A 3-φ full converter is fed from 3-φ, 400 V, 50 Hz source is connected to load, R = 10 Ω, E = 320 V and large inductance so that output current is ripple free. Find the power deliver to the battery (in kW) for a firing angle of 15°.

Sol. Since $\alpha = 15°$

$$V_o(\text{avg}) = \frac{3V_{ml}}{\pi}\cos\alpha$$

$$V_o(\text{avg}) = \frac{3 \times \sqrt{2} \times 400}{\pi}\cos(15°)$$

V_o(avg.) = 522.04 V

V_o(avg.) = I_o(avg.)R + E

$$I_o(\text{avg}) = \frac{522.04 - 320}{10}$$

I_o(avg.) = 20.20 A

So, the power deliver to the battery is

P = E. I_o = 320 × 20.20 = 6.46 kW

24. Find the value of $x(t)\ \delta(t - t_o)$ = ?, where t = time & t_o = positive shift

A. $x(t_o)\ \delta(t - t_o)$

B. $x(t - t_o)$

C. $x(t - t_o)\ \delta(t - t_o)$

D. No changes

Ans. A

Sol. Using the property of delta function,

$x(t)\ \delta(t - t_o) = x(t_o)\ \delta(t - t_o)$

25. If $(x)_r + (x^2)_{r+1} + (x^3)_{r+2} = (109)_{10}$,

where *x* represents the minimum number of NOR gates required to implement a half adder, then the positive value of radix '*r*' is ______.

Sol. Given that: $(x)_r + (x^2)_{r+1} + (x^3)_{r+2} = (109)_{10}$

Where x = Number of NOR Gates required to implement a half adder = 5

$$(5)_r + (5^2)_{r+1} + (5^3)_{r+2} = (109)_{10}$$

Decimal equivalent of each individual term is as follows:

$(5)_r = (r^0 \times 5)_{10} = 5$

$(25)_{r+1} = \left[2 \times (r+1)^1 + 5 \times (r+1)^0\right]_{10} = (2r+7)_{10}$

$(125)_{r+2} = \left[1 \times (r+2)^2 + 2 \times (r+2)^1 + 5 \times (r+2)^0\right]_{10} = (r^2 + 6r + 13)_{10}$

Substituting all decimal values in the above equation,

$5 + 2r + 7 + r^2 + 6r + 13 = 109$

$r^2 + 8r + 25 = 109$

$r^2 + 8r - 84 = 0$

$r^2 - 6r + 14r - 84 = 0$

$(r-6)(r+14) = 0$

$r = 6, -14$

Hence, the positive value of radix 'r' is 6.

26. Which of the following is not true about interpoles?

A. They improve commutation

B. They reduce armature reaction

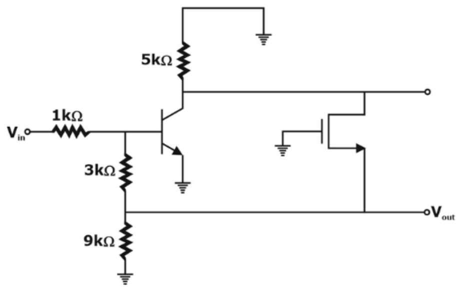
C. In generator, interpoles have the same polarity as that of the main pole behind looking forward in the direction of rotation.

D. They provide additional magnetic field in the air gap between the poles.

Ans. C

Sol. In generator, interpoles have the same polarity as that of the main pole ahead looking forward in the direction of rotation.

27. Determine the type of feedback topology is



A. series-series B. series-shunt

C. shunt-shunt D. shunt-series

Ans. C

Sol. **At output:**

By replacing output with short circuit, output voltage becomes zero hence it's voltage (shunt) sampling.

At input:

Feedback element is directly connected across it's base hence it's mixing shunt.

Therefore, the above configuration is shunt-shunt configuration.

28. The divergence of the vector field $\vec{V}=\left(x^2+y\right)\hat{i}+\left(z-2xy\right)\hat{j}+\left(xy\right)\hat{k}$ at (1,1,1) is

A. 1 B. -1

C. 0 D. 2

Ans. C

Sol.

$$\nabla\cdot\vec{V}=\frac{\partial}{\partial x}(x^2+y)+\frac{\partial}{\partial y}(z-2xy)+\frac{\partial}{\partial z}(xy)$$

$$=2x-2y$$

$$=0\ at\ (1,1,1)$$

29. In a series RLC circuit which is excited by a 40 V sinusoidal voltage source of variable frequency. The circuit exhibits resonance at 200 Hz and has a 3-dB bandwidth of 20 Hz. The magnitude of voltage across the capacitor at resonance is (in Volts)

Sol. At resonance condition, $V_L = jQV_{in}$

$V_C = -jQV_{in}$

i.e. $|V_L| = |V_C| = QV_{in}$

Where Q is quality factor

$$Q=\frac{f_0}{BW}=\frac{200}{20}=10$$

$V_C = 10 \times 40 = 400$ V

30. The Dirac function δ(t) is defined as

A. $\delta(t)=\begin{cases}1; & t=0\\ 0; & \text{otherwise}\end{cases}$

B. $\delta(t)=\begin{cases}\infty; & t=0\\ 0; & \text{otherwise}\end{cases}$

C. $\delta(t)=\begin{cases}1; & t=0\\ 0; & \text{otherwise}\end{cases}$

D. $\delta(t)=\begin{cases}\infty; & t=0\\ 0; & \text{otherwise}\end{cases}\ \&\ \int_{-\infty}^{\infty}\delta(t)dt=1$

Ans. D

Sol. Dirac delta function is defined as

$$\delta(t)=\begin{cases}\infty; & t=0\\ 0; & \text{otherwise}\end{cases}\ \&\ \int_{-\infty}^{\infty}\delta(t)dt=1$$

31. A 250 km, 3-phase, 50 Hz transmission line has the following ABCD parameters:

$$A=D=0.95\angle 1.5°$$

$$B=131.2\angle 71.5°$$

$$C=0.001\angle 90°$$

The sending end voltage is 230 kV. Find the maximum power (in MW) that can be transmitted to the receiving end at a voltage of 220 kV.

Sol. Power at receiving end,

$$P_r=\frac{V_sV_r}{B}\cos(\beta-\delta)-\frac{AV_r^2}{B}\cos(\beta-\alpha)$$

Maximum power is received when

$\beta=\delta$,

$$P_r=\frac{230\times 220}{131.2}-\frac{0.95\times(220)^2}{131.2}\cos(71.5°-1.5°)$$

$$=385.67-119.86$$

$$=265.81\ \text{MW}$$

32. Using trapezoidal rule for the table given below

x :	4	4.2	4.4	4.6	4.8	5.0	5.2
Ln x:	1.39	1.44	1.48	1.53	1.57	1.61	1.65

Find the value of Integral

$$I=\int_4^{5.2} \ln x.dx$$

A. 1.83 B. 1.93

C. 1.64 D. 0.98

Ans. A

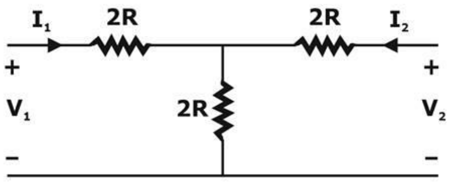
Sol. Width (h) =0.2

$$\int_4^{5.2} \ln x dx=\frac{h}{2}[(y_0+y_6)+2(y_1+y_2+y_3+y_4+y_5)]$$

$$\int_4^{5.2} \ln x dx=\frac{0.2}{2}[(1.39+1.65)+2(1.44+1.48+1.53+1.57+1.61)]$$

$$=1.83$$

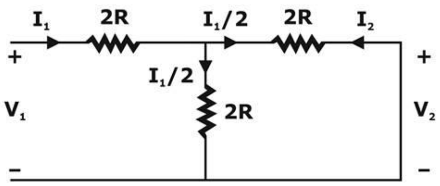
33. A two-port network is shown in figure. The parameter h_{21}, for this network can be given by



Sol. h – parameter equation to calculate h_{21}

$I_2 = h_{21} I_1 + h_{22}V_2$

$$h_{21}=\left.\frac{I_2}{I_1}\right|_{V_2=0}$$



The relevant circuit with $V_2 = 0$ is shown in above figure.
Using current division rule,

$$I_2 = \frac{-I_1}{2}$$

$$\therefore h_{21} = \frac{I_2}{I_1} = \frac{-1}{2}$$

34. A Single-phase Dual Converter is fed from 230 V, 50 Hz source. The load is R = 5 Ω and the current limiting reactor has L = 0.05 H. For $\alpha_1 = 35°$, Calculate the peak value of circulating current?

A. 3.5 A
B. 10.5 A
C. 7.5 A
D. 18.2 A

Ans. C

Sol. The peak value of circulating current in a 1 - φ Dual converter is

$$I_{c(peak)} = \frac{2V_m}{\omega L}(1 - \cos\alpha_1)$$

$$I_{c(peak)} = \frac{2 \times \sqrt{2} \times 230}{314 \times 0.05}(1 - \cos 35°)$$

$I_{C(peak)} = 7.49$ A

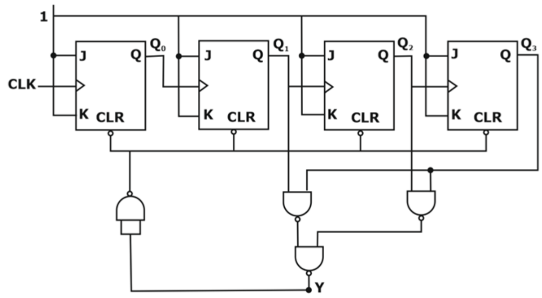
35. Which of the following is motors develops minimum torque and used in lower power applications?

A. DC series motor
B. Shaded pole induction motor
C. Capacitor start induction motor
D. Split phase induction motor

Ans. B

Sol. Shaded pole induction motors are used for low watt applications (up to 50W). They are very cheap motors and low maintenance having rotor same as squirrel cage induction motor.

36. Consider the counter circuit shown in figure below:



Then the modulus of the given counter is __________.(Assume Q_3 be MSB & Q_0 be LSB)

Sol. Let the initial contents of the flip-flops ($Q_3Q_2Q_1Q_0$) be 0000
To reset the counter, output Y must be equal to 1.
The expression for the output Y is given as

$$Y = \overline{\overline{Q_1Q_3} \cdot \overline{Q_2Q_3}}$$
$$= \overline{\overline{Q_1Q_3}} + \overline{\overline{Q_2Q_3}} = Q_1Q_3 + Q_2Q_3$$
$$= Q_3(Q_1 + Q_2)$$

So, from the table below,

S.No.	Q_3	Q_2	Q_1	Q_0	Y
0	0	0	0	0	0
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	0
4	0	1	0	0	0
5	0	1	0	1	0
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	0
10	**1**	**0**	**1**	**0**	**1**

Now, the output Y becomes 1, hence the combination ($Q_3Q_2Q_1Q_0$) becomes 1010.
The decimal equivalent of 1010 is 10.
Hence the modulus of the given counter is 10.

37. The solution curve of the differential equation $x\frac{dy}{dx} = y + 2x^3$ passes through the point (1,0). Then among the points given below, the curve also passes through:

A. (-1, 0)
B. (0, -1)
C. (2, 10)
D. (-2, 6)

Ans. A

Sol. The differential equation can be written as:

$$\frac{dy}{dx} = \frac{y}{x} + 2x^2$$

$$\frac{dy}{dx} - \frac{y}{x} = 2x^2$$

Which is a linear equation in 'y'

$$IF = e^{-\int \frac{1}{x}dx} = e^{-\log x} = -\frac{1}{x}$$

Thus, the solution of the equation will be:

$$y\, x\, IF = \int 2x^2 x\, IF\, dx$$

$$-\frac{y}{x} = -\int 2\,x\,dx$$

$$\frac{y}{x} = x^2 + C$$

Putting (1,0) we get C = −1

Thus,

$$\frac{y}{x} = x^2 - 1$$

Clearly only (-1,0) satisfies the above equation.

38. Let two fields be given as:

$$\vec{A} = \frac{5\sin^2(\theta)}{r^2}\hat{a}_r \text{ and } \vec{B}$$

$$= \left(\cos(x)\sin(y)\right)\hat{a}_x + \left(\cos(y)\sin(x)\right)\hat{a}_y$$

Which of the following statement is/are correct?

(P) A is solenoidal and B is irrotational.

(Q) A is irrotational and B is solenoidal.

(R) A and B both are solenoidal.

(S) A and B both are irrotational.

(T) A is solenoidal and rotational and B is not solenoidal.

(U) A and B are both neither solenoidal nor irrotational.

A. P and T B. P and Q

C. R and S D. only U

Ans. A

Sol. For a vector to be solenoidal,

$$\vec{\nabla}\cdot\vec{A} = 0$$

$$\vec{\nabla}\cdot\vec{A} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\cdot A_r\right) = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\cdot\frac{5\sin^2\theta}{r^2}\right) = 0$$

Hence, $\vec{A}$ is solenoidal.

For a vector to be irrotational,

$$\nabla\times\vec{A} = 0$$

$$\nabla\times\vec{A} = \frac{1}{r^2\sin\theta}\begin{vmatrix} \hat{a}_r & r\hat{a}_\theta & r\sin\theta\hat{a}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial\theta} & \frac{\partial}{\partial\phi} \\ \frac{5\sin^2\theta}{r^2} & 0 & 0 \end{vmatrix} \neq 0$$

Hence, $\vec{A}$ is not irrotational.

For a vector to be solenoidal,

$$\nabla\cdot\vec{B} = 0$$

$$\nabla\cdot\vec{B} = \frac{\partial}{\partial x}(A_x) + \frac{\partial}{\partial y}(A_y) + \frac{\partial}{\partial z}(A_z)$$

$$\nabla\cdot\vec{B} = \frac{\partial}{\partial x}(\cos x.\sin y) + \frac{\partial}{\partial y}(\sin x.\cos y)$$

$$= (-\sin x.\sin y) + (-\sin x.\sin y) = -2\sin x.\sin y \neq 0$$

Hence, $\vec{B}$ is not solenoidal.

For a vector to be irrotational,

$$\nabla\times\vec{B} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \cos x.\sin y & \sin x.\cos y & 0 \end{vmatrix} = \hat{a}_x[0-0] - \hat{a}_y[0-0]$$

$$+\hat{a}_z[\cos x.\cos y - \cos x.\cos y] = 0$$

Hence, $\vec{B}$ is irrotational.

39. A 230 V, single phase, energy meter has a constant load of 4 A passing through it for 6 hours at unity power factor. If the meter disc makes 2208 revolutions during this period. Calculate the power factor of the load if the number of revolutions made by the meter are 1472 when operating at 230 V and 5 A for 4 hours.

Sol. Given that,

V = 230 V, I = 4 A, t = 6 hrs, p.f. = 1

$$Energy\ consumed = (VI\cos\phi)\times t = 230\times4\times1\times6\times10^{-3} = 5.52\ kWhr$$

$$\therefore Meter\ constant,\ k = \frac{Number\ of\ revolutions\ made\ by\ meter}{Energy\ consumed}$$

$$= \frac{2208}{5.52} = 400\ rev/kWhr$$

when meter makes 1472 revolutions, then

Energy consumed by the meter is,

$$= \frac{1472}{400} = 3.68\ kWhr$$

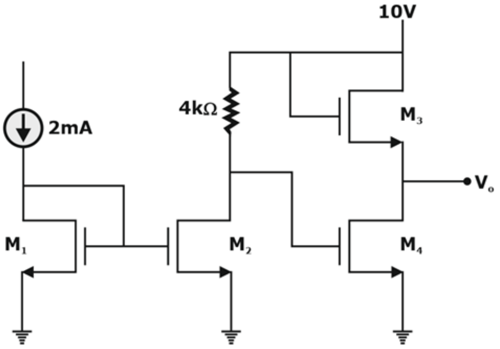
Now, the actual energy consumed by the meter is 3.68 kWh

$$VI\cos\phi\times t\times10^{-3} = 3.68$$

$$230\times5\times\cos\phi\times4\times10^{-3} = 3.68$$

$$\cos\phi = 0.8$$

40. In the circuit shown below, all transistors are n-channel enhancement type MOSFET's. They are identical and are biased to operate in saturation mode. Ignore channel length modulation, the output voltage V_o is ______ V.



Sol. According to the given circuit configuration, MOSFET M_1 and M_2 current mirror circuit.

$\therefore I_{D1} = I_{D2} = 2$ mA

Applying KVL,

$10 - (4 \times 10^3 \times 2 \times 10^{-3}) = V_{G4} = 2$ V

As all the transistors are identical and is operating in saturation mode.

Therefore, $I_g = 0$ A.

Hence, drain current is equals to source current, $I_D = I_S$

$I_{D3} = I_{D4} = I_{S3} = I_{S4}$

On comparing the drain current of M_3 and M_4,

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)\left(V_{gs4} - V_{t4}\right)^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)\left(V_{gs3} - V_{t3}\right)^2$$

$$\left(V_{gs4} - V_{t4}\right)^2 = \left(V_{gs3} - V_{t3}\right)^2$$

$$V_{gs4} = V_g - V_s = 2 - 0 = 2\ V$$

$$V_{gs3} = (10 - V_o)$$

$$V_{t4} = V_{t3} = V_t \quad [\because \text{Both are identical}]$$

$$(2 - V_t)^2 = (10 - V_o - V_t)^2$$

$$(2 - V_t) = (10 - V_o - V_t)$$

$$2 = 10 - V_o$$

$$V_o = 8\ V$$

41. Consider a state model of a system given by the equations

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 2 & 1 \\ 3 & 4 & -1 \\ -2 & -3 & -4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 2 \\ 3 \\ 4 \end{bmatrix}u \quad \text{and}$$

$$y = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 2 \end{bmatrix}u$$

Which of the following option is true.

A. System has '1' pole in the right half of s-plane

B. System has '0' pole in the right half of s-plane

C. System has '2' poles in the right half of s-plane

D. System has '3' poles in the right half of s-plane

Ans. A

Sol. Characteristics equation can be considered as $|SI - A| = 0$.

$$\begin{vmatrix} s & -2 & -1 \\ -3 & s-4 & 1 \\ 2 & 3 & s+4 \end{vmatrix} = 0$$

$$s\left[(s-4)(s+4) - 3\right] + 2\left[-3(s+4) - 2\right] - 1\left[-9 + 2(s-4)\right] = 0$$

$$s\left(s^2 - 16 - 3\right) + 2\left(-3s + (-12) - 2\right) - 1\left(-9 - 2s + 8\right) = 0$$

$$s^3 - 19s - 6s - 28 + 1 + 2s = 0$$

$$s^3 - 28s - 27 = 0$$

$$s = 5.3,\ -1.26,\ -4.039$$

It has one pole in the right half of s-plane

It also can be verified using Routh criteria.

42. A 3-φ semi-converter is connected to supply voltage of 230 V per phase & frequency of 50 Hz. The source inductance is 5 mH and the load current on DC side is constant at 18 A at 30° firing angle. The percentage voltage regulation due to source inductance is

A. 5.37 % B. 1.82 %

C. 3.51 % D. 2.46 %

Ans. A

Sol. Since firing angle α = 30°

For α ≤ 60°, the 3-φ semi-converter operates as a 6-pulse converter.

And the average voltage drop across the source inductance is given by,

$$= \frac{P\omega L_S}{2\pi} \times I_o$$

$$= \frac{6 \times 2\pi \times 50 \times 5 \times 10^{-3}}{2\pi} \times 18 = 27 \text{ V}$$

The No-load voltage of the 3-φ semi-converter is

$$V_o(\text{avg}) = \frac{3V_{ml}}{2\pi}(1 + \cos\alpha)$$

$$V_o(\text{avg}) = \frac{3 \times \sqrt{3} \times \sqrt{2} \times 230}{2\pi}(1 + \cos 30°)$$

V_o(avg.) = 502.2 V

The voltage regulation is given by

$$\%V.R. = \frac{27}{502.2} \times 100 = 5.37\%$$

43. An 8-pole separately excited DC generator has a lap wound armature containing 104 coils of 8 turns each. Resistance of each turn is 0.01 ohms. The flux per pole is 30 mWb and it is rotating at a speed of 500 rpm. If a load of 2000 Ω is connected across its terminals. The load current (in A) is

Sol. Given that:

100 coils with 8 turns

Hence, total number of conductors, Z = 104 x 8 x 2 = 1664

We know that back emf is given by

$$E = \frac{NP\phi Z}{60A}$$

$$E = \frac{500 \times 8 \times 0.03 \times 1664}{60 \times 8} = 416 \text{ V}$$

Now, the equivalent resistance of the winding:

Lap winding with 8 parallel paths, 13 coils per path.

Resistance of one path = 13 x 8 x 0.01 = 1.04 Ω

Total armature resistance = 1.04/8 = 0.13 Ω

Also, load resistance = 2000 Ω

Load current is given as

$$I_L = \frac{E}{(R_a + R_L)}$$

$$= \frac{416}{(0.13 + 2000)} = 0.2079 \text{ A}$$

44. Find the Laplace transform of the function f(t) given as

f(t) = $(t - 2)^2$

A. $\frac{4}{s} - \frac{4}{s^2} + \frac{2}{s^3}$, s>0

B. $\frac{4}{s} - \frac{4}{s^2} + \frac{4}{s^3}$, s>0

C. $\frac{4}{s} - \frac{2}{s^2} + \frac{2}{s^3}$, s>0

D. $\frac{2}{s} - \frac{4}{s^2} + \frac{2}{s^3}$, s>0

Ans. A

Sol. Given L $[(t-2)^2]$

$$= \lim_{T\to\infty} \int_0^T (t-2)^2 e^{-st}\,dt$$

Using integration by parts with u' = e^{-st} and V = $(t-2)^2$ we will find,

$$\int_0^T (t-2)^2 e^{-st}\,dt = -\left[\frac{(t-2)^2 e^{-st}}{s}\right]_0^T + \frac{2}{s}\int_0^T (t-2)e^{-st}\,dt$$

$$= \frac{4}{s} - \frac{(T-2)^2 e^{-sT}}{s} + \frac{2}{s}\int_0^T (t-2)e^{-st}\,dt$$

thus,

$$\lim_{T\to\infty}\int_0^T (t-2)^2 e^{-st}\,dt = \frac{4}{s} + \frac{2}{s}\lim_{T\to\infty}\int_0^T (t-2)e^{-st}\,dt$$

Using by parts with u' = e^{-st} and v =t-2 we find

$$\int_0^T (t-2)e^{-st}\,dt = \left[-\frac{(t-2)e^{-st}}{s} - \frac{1}{s^2}e^{-st}\right]_0^T$$

Let T $\to \infty$ in the above expression we will get

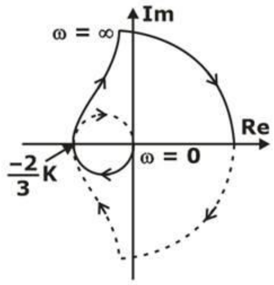
$$\lim_{T\to\infty}\int_0^T (t-2)e^{-st}\,dt = -\frac{2}{s} + \frac{1}{s^2}, s > 0$$

Hence,

$$F(s) = \frac{4}{s} + \frac{2}{s}\left(-\frac{2}{s} + \frac{1}{s^2}\right) = \frac{4}{s} - \frac{4}{s^2} + \frac{2}{s^3}$$

, s>0

45. The Nyquist plot for a stable open loop system is shown below:



For $K > \frac{3}{2}$, how many closed loop poles of a unity feedback system are in the right half of s-plane

Sol. Given that open loop system is stable, so we have no pole of open loop in right half of s-plane, i.e. P = 0

The intersection point of Nyquist plot with negative real axis is $\left(-\frac{2}{3}K, 0\right)$ and $K > \frac{3}{2}$

Now, for the given range,

$K > \frac{3}{2}$

Or $\frac{2}{3}K > 1$

Or $-\frac{2}{3}K > -1$

The intersection point will be in left of the critical point, so (−1 + j0) point will lie in the small loop in Nyquist plot. Therefore, the Nyquist plot encircles the critical point (−1 + j0) two times in clockwise direction, i.e. N = −2

So, we obtain the number of closed loop poles in right half plane as

N = P − Z

Or −2 = 0 − Z

Or Z = 2

Hence, the closed loop system has two poles in the right half of s-plane.

46. A single core cable has a conductor of 10 mm diameter and two layers of dielectric each of 10 mm thickness. The relative permittivity's are 3 and 2.5, determine the potential gradient (in kV/mm) at the surface of the conductor, when the potential difference between conductor and sheath is 60 kV.

Sol. Radius of conductor, r = 10/2 = 5 mm

Permittivity, $\varepsilon_1 = 3,\ \varepsilon_2 = 2.5$

R = 5 + 10 + 10 = 25 mm, & r_1 = 5 + 10 = 15 mm

Maximum potential gradient at surface of conductor,

$$g_{1(\max)} = \frac{Q}{2\pi\varepsilon_o\varepsilon_1 r} \quad \text{..........}(i)$$

$$g_{2(\max)} = \frac{Q}{2\pi\varepsilon_o\varepsilon_2 r_1} \quad \text{..........}(ii)$$

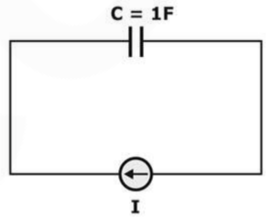
Potential difference between conductor and sheath is

60 = $V_1 + V_2$

$$60 = g_{1(\max)} \cdot r \cdot \ln\left(\frac{r_1}{r}\right) + g_{2(\max)} \cdot r_1 \cdot \ln\left(\frac{R}{r_1}\right)$$

Putting the values of r_1, R and $g_{2(max)}$ in above equation, we get, $g_{1(max)}$ = 7.01 kV/mm

47. Let the current flowing through the capacitor be u(t + 2) − u(t − 2), then Calculate the charge in capacitor at t = 0^+ and energy in capacitor at t = 4 sec respectively.

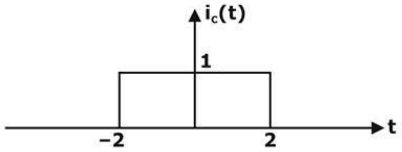


A. 2 C, 8 J
B. 2 C, 4 J
C. 4 C, 8 J
D. 8 C, 16 J

Ans. A

Sol. Current flowing through the capacitor is

$i_C(t)$ = u(t + 2) − u(t − 2)



Charge in the capacitor at t = 0^+ is

$$Q = \int_{-\infty}^{t} i_C(t)0^+ = \int_{-2}^{0} 1dt = 2C$$

Voltage across the capacitor at t = 4 sec

$$V_C = \frac{1}{C}\int_{-2}^{0} i_C(t)dt = \frac{1}{1}\int_{-2}^{2} 1dt = 4V$$

Energy stored in the capacitor is $\frac{1}{2}CV^2$

$$= \frac{1}{2} \times 1 \times 4^2 = 8 \text{ Joules}$$

48. In a 100-bus system, there are 70 load buses and 30 voltage-controlled buses. Under certain operating conditions the reactive power limit gets violated at 10 buses, find the difference of the order of the jacobian under these conditions and normal operating conditions.

Sol. Under normal conditions,
PQ buses = 70, PV buses = 29, Slack bus = 1
Order of jacobian = (2n – m – 2) x (2n – m – 2)
where n is total number of buses and m in number of PV buses.
= (2 x 100 – 29 – 2) x (2 x 100 – 29 – 2) = 169 x 169
Under given conditions,
PQ buses = 80, PV buses =19 , Slack bus = 1
Order of jacobian = (2 x 100 – 19 – 2) x (2 x 100 – 19 – 2) = 179 x 179
Difference = 179 – 169 = 10

49. Consider a continuous-time LTI system with frequency response $H(\omega)=\dfrac{1}{3+j\omega}$ and $y(t)=e^{-3t}u(t)-e^{-4t}u(t)$, Calculate x(t).

A. e^{-4t} u(t) B. e^{-3t} u(t)
C. $(e^{-4t} - e^{-3t})$ u(t) D. None of above

Ans. A

Sol. Since y(t) = x(t) × h(t)
y(ω) = x(ω) · H(ω)
y(t) = e^{-3t} u(t) – e^{-4t} u(t)

$$y(\omega)=\frac{1}{3+j\omega}-\frac{1}{4+j\omega}=\frac{1}{(3+j\omega)(4+j\omega)}$$

$$x(\omega)=\frac{y(\omega)}{H(\omega)}$$

$$x(\omega)=\frac{1}{(3+j\omega)(4+j\omega)}\cdot(3+j\omega)$$

$$\boxed{x(\omega)=\frac{1}{4+j\omega}}$$

So, $\boxed{x(t)=e^{-4t}u(t)}$

50. The characteristic equation of the system is
C.E = $s^5-2s^4-2s^3+4s^2+s-2=0$
The number of symmetric poles located in right half of s-plane is

Sol. C.E = $s^5 - 2s^4 - 2s^3 + 4s^2 + s - 2 = 0$

s^5	1	−2	1
s^4	−2	4	−2
s^3	0(−1)	0(1)	0
s^2	+2	−2	0
s^1	0(4)	0	0
s^0	−2		

$AE_1 = -2s^4 + 4s^2 - 2 = 0$

$\frac{d}{ds}AE_1 = -8s^3 + 8s \Rightarrow$ take 8 common $\Rightarrow -1, 1$

$AE_2 = 2s^2 - 2 = 0$

$\frac{d}{ds}AE_2 = 4s$

3 signs changes in the first columns

$\Rightarrow AE_1 = -2s^4 + 4s^2 - 2 = 0$

Or, $s^4 - 2s^2 + 1 = 0$

Or, $(s^2 - 1)^2 = 0$

∴ ⇒ There are two symmetric poles are located in RHP.
⇒ 1 non symmetric pole in RHP.
Total 3 poles in RHP.

51. Given $x(z)=\dfrac{z}{(z-a)^2}$ with |z| > a, the residue of x(z) z^{n-1} at z = a for n ≥ 0 will be

A. a^{n-1} B. a^n
C. na^n D. $n.a^{n-1}$

Ans. D

Sol. $X(z)=\dfrac{z}{(z-a)^2}$

$$z^{n-1}x(z)=\frac{z^n}{(z-a)^2}$$

Since z = a is a pole of second order therefore residue at z = a

$$\frac{1}{1!}\left[\frac{d}{dz}\{z-a\}^2\cdot\frac{z^n}{(z-a)^2}\right]_{at\ z=a}$$

$$\left[n\ z^{n-1}\right]_{z=a} = na^{n-1}$$

52. A synchronous generator is connected to an infinite bus at rated voltage and the synchronous impedance is (0 + j1.8) p.u. when supplying rated current at 0.8 p.f. lagging. Keeping the emf constant, Calculate the value of load current (in p.u.) at unity power factor. (Round off the answer up to 2 decimal places)

Sol. Given that:

Infinite bus voltage, $V = 1\angle 0°$ and current,

$$I_a = 1\angle -\cos^{-1}(0.8) = 1\angle -36.86°$$

Also,

$$E = V + I_a Z_s = V + jI_a X_s$$

$$= 1\angle 0° + (1\angle -36.86°)\times(1.8\angle 90°)$$

$$= 2.53\angle 34.7°$$

Now keeping value of excitation constant and current is at unity power factor.

So,

$$2.53\angle\theta° = 1\angle 0° + (I_a\angle 0°)\times(1.8\angle 90°)$$

$$2.53\cos\theta + j2.53\sin\theta = 1 + j1.8I_a$$

On comparing real and imaginary parts,

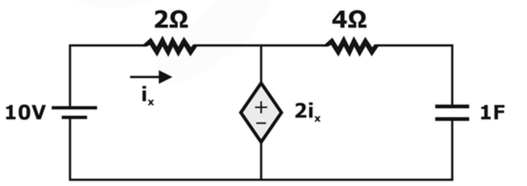
$$2.53\cos\theta = 1 \Rightarrow \theta = 66.72°$$

$$2.53\sin 66.72° = 1.8I_a$$

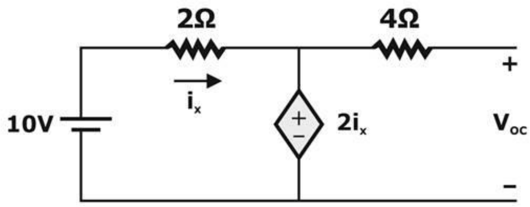
$$2.324 = 1.8I_a$$

$$I_a = 1.291 \text{ p.u.}$$

53. Calculate the time constant, τ (in sec) of the circuit shown below?



Sol. Calculation of open circuit voltage across capacitor,

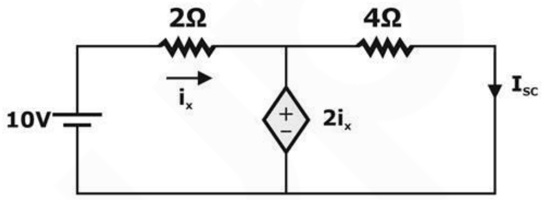


$$V_{OC} = 2i_x = 2\left(\frac{10-V_{OC}}{2}\right)$$

$2V_{OC} = 10$

$V_{OC} = 5$ V

Calculation of I_{SC}:



$$I_{SC} = \frac{2i_x}{4} = \frac{i_x}{2} \quad ...(1)$$

writing KVL in outer loop,

$10 - 2i_x - 4I_{SC} = 0$

By putting the value of i_x from equation (1)

$10 - 2 \times 2I_{SC} - 4I_{SC} = 0$

$$I_{SC} = \frac{10}{8} = 1.25$$

Resistance seen by capacitance is

$$R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{5}{1.25} = 4\,\Omega$$

Time constant, τ = R_{Th} × C = 4 × 1 = 4 sec

54. A 50 Hz, 4-pole, turbo-generator rated 100 MVA, 11 kV has an inertia constant of 9 MJ/MVA. Rotor accelerates when a mechanical input is suddenly raised to 70 MW for an electrical load of 40 MW. If the acceleration is maintained for 5 cycles, then what is the change in torque angle in electrical degrees.

Sol. From swing equation,

$$\frac{GH}{180f} \times \frac{d^2\delta}{dt^2} = P_m - P_e$$

$$\frac{100 \times 9}{180 \times 50} \times \frac{d^2\delta}{dt^2} = 70 - 40$$

$$0.1 \frac{d^2\delta}{dt^2} = 30$$

$$\frac{d^2\delta}{dt^2} = 300 \text{ elec.deg/sec}^2$$

Time in 1 cycle = $T = \frac{1}{f} = \frac{1}{50} = 0.02$ sec

Time in 5 cycles = 5 x 0.02 = 0.1 sec

Change in δ,

$$\delta = \frac{1}{2} \times 300 \times (0.1)^2$$

$$= 1.5 \text{ electrical-degree}$$

55. A 3-bus system has the following Y_{BUS} matrix:

$$Y_{BUS} = \begin{bmatrix} -j15 & j10 & j5 \\ j10 & -j20 & j10 \\ j5 & j10 & -j15 \end{bmatrix}$$

If the impedance of the line connecting bus 2 and 3 is halved and a capacitor is connected at bus 2 with capacitive reactance of -j0.5. What will be the Y_{22} element of modified Y_{BUS}?

A. -j28　　B. -j20

C. -j32　　D. -j30

Ans. A

Sol. Since, the impedance of line 2 - 3 is halved, its admittance got doubled.

Also, capacitive reactance of -j0.5 is added at bus 2.

Hence, its admittance will be 2j.

So, Y_{23} becomes 20j.

Also, Y_{22} becomes (-j20 - j10 + j2) = -j28

56. A 1-φ Voltage Source Inverter is controlled in a Single Pulse Width Modulation mode with a pulse width is 120° in each half cycle. The total harmonic distortion of output AC voltage waveform is ________%.

Sol. Given 2d = 120°

d = 60°

$$\% \text{ THD} = \sqrt{\frac{V_{o(rms)}^2 - V_{o1(rms)}^2}{V_{o1(rms)}^2}} \times 100$$

$$V_{o(rms)} = V_S \sqrt{\frac{2d}{\pi}}$$

$V_{o(rms)}$ = 0.816 V_s.

$$V_o = \sum_{i=1,3,5}^{\infty} \frac{4V_S}{n\pi} \text{Sin}\left(\frac{n\pi}{2}\right) \sin(nd)\sin(n\omega t)$$

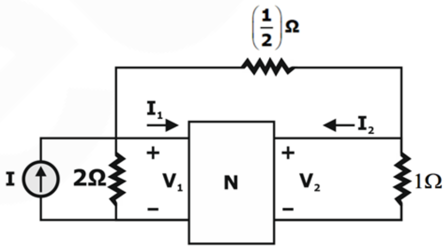
$$V_{o1(rms)} = \frac{4Vs}{\sqrt{2}\pi} \text{Sin}\left(\frac{\pi}{2}\right) \text{Sin}(60°) \quad [\because n = 1 \text{ for fundamental component}]$$

$V_{o1(rms)}$ = 0.78 V_s

$$\% \text{THD} = \sqrt{\frac{(0.816V_S)^2 - (0.780V_S)^2}{(0.780V_S)^2}} \times 100$$

% THD = 30.73 %

57. In the circuit shown below, N is a two-port network. If I = 1 A, then the values of V_1 and V_2 will be



Take the Y-parameter of two port network N, as $\begin{bmatrix} 2\mho & 1\mho \\ 2\mho & 2\mho \end{bmatrix}$

A. $V_1 = 0$ V and $V_2 = \frac{2}{9}$ V

B. $V_1 = \frac{2}{9}$ V and $V_2 = 0$ V

C. V_1 = 0 V and V_2 = 2 V

D. V_1 = 2 V and V_2 = 0 V

Ans. B

Sol. Applying KCL at input node, we get,

$$\frac{V_1}{2} + \frac{V_1 - V_2}{\left(\frac{1}{2}\right)} = -I_1 + I$$

$$\frac{5}{2}V_1 - 2V_2 = I - I_1 \quad \text{.............(1)}$$

Applying KCL at output node, we get,

$$\frac{V_2 - V_1}{\frac{1}{2}} + \frac{V_2}{1} + I_2 = 0$$

$$-2V_1 + 3V_2 + I_2 = 0 \quad \text{.........(2)}$$

As per the question, for network N, the y-parameters are

$$I_1 = y_{11}V_1 + y_{22}V_2 = 2V_1 + V_2$$

$$I_2 = y_{21}V_1 + y_{22}V_2 = 2V_1 + 2V_2$$

By substituting the values of I_1 and I_2 in equation (1) and (2), we get,

$$\frac{5}{2}V_1 - 2V_2 = 1 - (2V_1 + V_2)$$

$$\frac{5}{2}V_1 - 2V_2 = 1 - 2V_1 - V_2$$

$$\frac{9}{2}V_1 - V_2 = 1 \quad \ldots(3)$$

and, $-2V_1 + 3V_2 + 2V_1 + 2V_2 = 0$

$V_2 = 0$ …(4)

From equations (3) and (4)

$$V_1 = \frac{2}{9}\text{V and } V_2 = 0\text{ V}$$

58. A 20 KW, 500 V, three phase Induction motor is started using star-delta starter. The power factor at full load is 0.9 and efficiency at full load is 90%. The short circuit current at 150 V is 50 A. Find the ratio of starting to full load current.

Sol. Line current at full load is

$$I_L = \frac{\text{output power}}{\sqrt{3} \times \text{V} \times \cos\phi \times \text{efficiency}}$$

$$= \frac{20 \times 10^3}{\sqrt{3} \times 500 \times 0.9 \times 0.9} = 28.511\text{ A}$$

Line value of short circuit current for 150 V is 50 A

So, for 500 V,

$$I_{SC} = \frac{50 \times 500}{150} = 166.67\text{ A}$$

Phase value of short circuit current

$$= \frac{166.67}{\sqrt{3}}$$

Now in case of star delta starter, at starting in star connection, the per phase current taken by motor is $\frac{1}{\sqrt{3}}$ times the phase value of short circuit current, i.e.

$$= \frac{166.67}{\sqrt{3} \times \sqrt{3}} = 55.556\text{ A}$$

At starting motor is connected in star, hence Line current = Phase current = 55.556 A

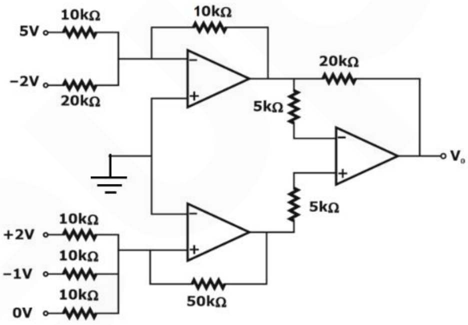
Line value of starting current = 55.556 A

Line value of full load current = 28.511 A

The ratio of starting current to the full load current is given as

$$\frac{I_{st}}{I_{fl}} = \frac{55.556}{28.511} = 1.948$$

59. Find the output voltage V_o (in V). [Assume that all the op-amps are ideal]



Sol. Applying KCL at node P,

$$\frac{0-5}{10k} + \frac{0-(-2)}{20k} + \frac{0-V_1}{10k} = 0$$

$$\frac{-5}{10k} + \frac{2}{20k} = \frac{V_1}{10k}$$

$$V_1 = 10k\left(\frac{-5}{10k} + \frac{2}{20k}\right)$$

$$V_1 = -4\ V$$

Applying KCL at node Q,

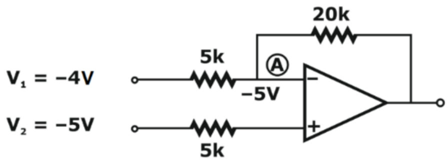
$$\frac{0-2}{10k} + \frac{0-(-1)}{10k} + \frac{0-0}{10k} + \frac{0-V_2}{50k} = 0$$

$$\frac{-2}{10k} + \frac{1}{10k} = \frac{V_2}{50k}$$

$$\frac{-1}{10k} - \frac{V_2}{50k}$$

$$\boxed{V_2 = -5V}$$

V+ = V– = –5 V



Applying KCL at node 'A'

$$\frac{-5-(-4)}{5k}+\frac{-5-V_o}{20k}=0$$

$$\frac{-5+4}{5k}-\frac{5+V_o}{20k}=0$$

$$\frac{-1}{5k}=\frac{5+V_o}{20k}$$

$$5+V_o=20k\times\frac{-1}{5k}=-4$$

$$V_o=-4-5=-9\ V$$

60. A 20 KVA, 2000/200 V transformer is reconnected as an autotransformer. What should be the minimum possible output rating of the transformer?

A. 220 kVA
B. 180 kVA
C. 22 kVA
D. 18 kVA

Ans. D

Sol. For minimum output the transformer windings should be connected with opposite polarity (subtractive polarity). Input applied across the two windings connected with opposite polarity in series and output across 200 V.

So voltage ratio is 1800/200 V.

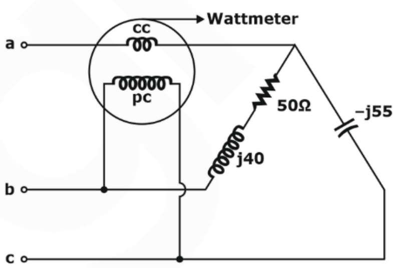
H.V. winding current = KVA/V_{rated} = 20000/2000 = 10 A

L.V. winding current = KVA/V_{rated} = 20000/200 = 100 A

Output current = 100 - 10 = 90 A

So, VA rating = 200 x 90 = 18000 VA = 18 KVA

61. Consider a circuit shown in figure below:



The load is connected across 3-phase, 400 V, 50 Hz supply with phase sequence abc. The reading of the wattmeter (in watts) is ___________. (round off to integer value)

Sol. The reading of the wattmeter is given as

W = voltage across pressure coil x current through current coil x Cosine of the angle between the voltage and current coils

$$V_{ab}=400\angle 0^\circ$$

$$V_{bc}=400\angle -120^\circ$$

$$V_{ca}=400\angle 120^\circ$$

current through current coil $I_C = I_1 + I_2$

$$=\frac{V_{ab}}{50+j40}+\frac{V_{ac}}{-j55}$$

$$=\frac{400\angle 0^\circ}{64.03\angle 38.65^\circ}+\frac{-400\angle 120^\circ}{-55\angle 90^\circ}$$

$$=6.24\angle -38.65^\circ+7.27\angle 30^\circ$$

$$=11.17\angle -1.34^\circ\ A$$

voltage across the potential coil

$$=V_{bc}=400\angle -120^\circ\ V$$

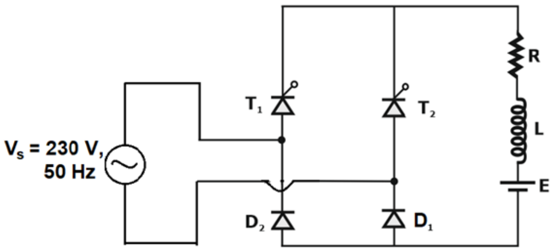
wattmeter reading is

$$W=V_{bc}I_c\cos(V_{bc}\ and\ I_c)$$

$$=400\times 11.17\times\cos(118.66^\circ)$$

$$=-2142.9\ W$$

62. A single-phase semi-converter shown in the figure below, is supplied from 230 V, 50 Hz source. The load consists of R = 10 Ω, E = 115 V and a large inductance so as to render the load current level. For firing advance angle of 140°, find the rms of source current is (in A).



Sol. Given that firing advanced angle = 140°

So, the firing angle = 180° – 140° = 40°

α = 40°

$$V_o(avg.) = \frac{V_m}{\pi}(1+\cos\alpha)$$

$$V_o(avg.) = \frac{\sqrt{2}\times 230}{3.14}(1+\cos 40°)$$

V_o(avg.) = 182.94 V

V_o(avg.) = I_o(avg.)R + E

$$I_o(avg.) = \frac{V_o(avg.) - E}{R} = 6.794\text{ A}$$

The rms value of source current for 1-φ Semi converter is given by

$$I_{sr} = I_o\sqrt{\left(\frac{\pi-\alpha}{\pi}\right)}$$

I_{sr} = 5.99 ≃ 6 A

63. A Buck regulator has an input voltage V_S = 15 V. The required output voltage V_0 = 5 V and the peak to peak output ripple voltage is 10 mV. The switching frequency is 20 kHz. The peak to peak ripple current in inductor is limited to 0.5 A. Determine the ratio of $\frac{L}{C}$, where L is filter inductance & C is filter capacitance.

Sol. In the Buck regulator,

V_S = 15 V V_o = 5 V f = 20 kHz

V_0 = DV_S

$$\text{Where, } D = \frac{1}{3}$$

During turn ON period,

$$(V_S - V_0) = L\frac{\Delta I}{T_{on}}$$

$$\frac{10\times 1}{3\times 20\times 10^3\times 0.5} = L$$

L = 0.33 mH

The ripple voltage is given by,

$$\Delta V_C = \frac{\Delta I}{8fC}$$

$$10\times 10^{-3} = \frac{0.5}{8\times 20\times 10^3 C}$$

$$C = \frac{0.5}{8\times 20\times 10^3\times 10\times 10^{-3}}$$

C = 0.312 mF

The required value of

$$\text{ratio} = \frac{L}{C} = \frac{0.33}{0.312} = 1.057$$

64. A 400 KVA, 2500/250 V, 50 Hz single phase transformer has maximum efficiency of 95% at 80% of full load and unity power factor. If transformer impedance is 10%, Calculate the voltage regulation at full load at 0.9 power factor lagging.

A. 5 % B. 6 %

C. 7 % D. 4 %

Ans. C

Sol.

$$\text{Efficiency, } \eta = \frac{\text{output power}}{\text{output power} + \text{Losses}}$$

At maximum efficiency, iron losses is equal to the copper losses.

$$P_i = P_{cu}$$

$$0.95 = \frac{0.8}{0.8 + 2P_i}$$

$P_i = 0.0210$ p.u. (i.e. 80% of full load copper losses)

$$P_i = x^2 P_{cufl}$$

$$P_{cufl} = \frac{P_i}{x^2} = \frac{0.021}{(0.8)^2} = 0.0328\text{ p.u.}$$

$$R_{p.u.} = 0.0328$$

$$Z_{p.u.} = 0.1$$

$$X_{p.u.} = \sqrt{Z_{p.u.}^2 - R_{p.u.}^2} = 0.944$$

$$\psi = \cos^{-1}\left(\frac{R_{p.u.}}{Z_{p.u.}}\right) = \cos^{-1}\left(\frac{0.0328}{0.1}\right) = 70.85°$$

$$\phi = \cos^{-1}(0.9) = 25.84°$$

$$\text{Voltage Regulation} = Z_{p.u.}\cos(\psi - \phi)$$

$$= 0.1\times\cos(70.85° - 25.84°)$$

$$= 0.1\times\cos(45.01°)$$

$$= 0.1\times 0.707$$

$$= 0.0707$$

$$= 7.07\%$$

65. Find the z-transform of the signal, obtain by sampling of x(t) = e^{-at}u(t)

A. $\frac{1}{1-(aT)e^{-z}}\ |z| > |e^{-aT}|$

B. $\frac{1}{1-e^{-aT}z^{-1}}\ |z| > |e^{-aT}|$

C. $\frac{1}{(1-e^{-aT})z^{-1}}\ |z| > |e^{-aT}|$

D. $\frac{1}{1-e^{-aT}}\ |z| > |e^{-aT}|$

Ans. B

Sol. Let sampling interval is T

$x(t)\big|_{t=nT} = x(nT) = e^{-anT}u(nT)$

$(e^{-aT})^n$ u(n) (from sampling condition)

x(n) = x(nT)

x(n) = $(e^{-aT})^n$ u(n)

Now Z-transform

$$x(z) = \sum_{n=-\infty}^{+\infty} x(n)z^{-n}$$

$$= \sum_{n=-\infty}^{+\infty} \left(e^{-aT}\right)^n u(n)z^{-n} = \sum_{n=0}^{\infty} \left(e^{-aT}z^{-1}\right)^n$$

$$= \frac{1}{\left(1-e^{-aT}z^{-1}\right)} |z| > \left|e^{-aT}\right|$$

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