higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

CONTROL SYSTEMS N6

(8080016)

27 November 2024 (X-paper)
09:00–12:00

REQUIREMENT: 3-cycle semi-logarithmic graph paper

This question paper consists of 8 pages, 1 diagram sheet of a Nichol's chart, a 2-page formula sheet and 3 pages of Laplace transforms.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
CONTROL SYSTEMS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. On completion, insert the 3-cycle semi-logarithmic graph paper of the Bode plot into the ANSWER BOOK before handing it in.
5. Use only a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1

Choose a term from COLUMN B that matches a description in COLUMN A. Write only the letter (A–J) next to the question number (1.1–1.10) in the ANSWER BOOK.

COLUMN A		COLUMN B	
1.1	A control system in which the control action is independent of the output	A	steady state response
1.2	An undesired input signal which affects the value of the controlled output	B	resonant frequency
1.3	Devices that monitor the output performance and convert the output energy to an appropriate signal so it can be compared to the reference input	C	silicon controlled rectifiers
1.4	That part of the total response that does not approach zero as time approaches infinity	D	damping factor
1.5	A term describing the value at which any external force input signal to the system causes a sustained oscillation between storing components of the system	E	disturbance
1.6	The ratio between the actual amount of damping and the critical amount of damping	F	open-loop control system
1.7	A function of time of which the amplitude is zero, where t = a, except where t = b	G	second-order system
1.8	A control system with two complementary energy storing elements	H	transducer elements
1.9	Power transmitted and controlled through the use of pressurized air	I	pneumatic system
1.10	Devices used in high power control for DC output drives or frequency control for AC output drives	J	impulse function

(10 × 1) **[10]**

QUESTION 2

2.1 Determine with the aid of block diagram algebra reduction, the total output of the block diagram in FIGURE 1.

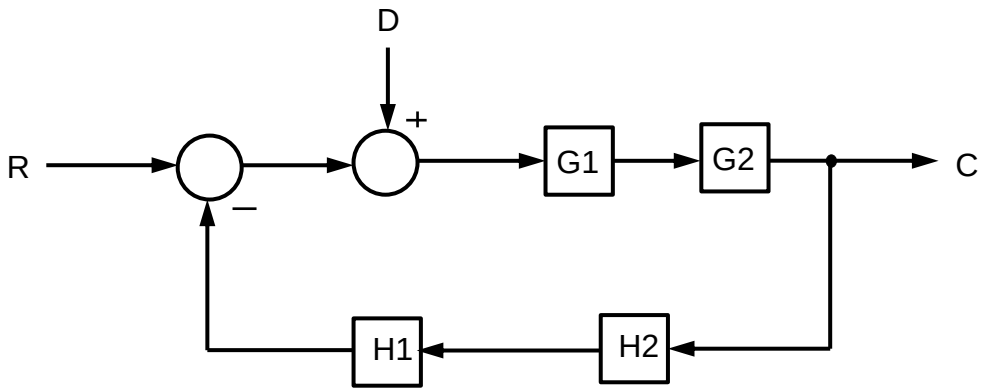


FIGURE 1 (7)

2.2 State the THREE effects of a disturbance on a control system. (3)
[10]

QUESTION 3

The transfer function of an open loop control system is given as:

$$G(s)H(s) = \frac{25}{s(1 + 0{,}25s)}$$

Use the following frequencies (ω = 0,1; 1; 10; 50; 100 rad/s) to do the following:

3.1 Calculate the log magnitude and phase values for the given frequencies in a table. (6)

3.2 Draw the Bode plot for the system on a 3-cycle semi-logarithmic graph paper. (4)
[10]

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QUESTION 4

The DIAGRAM SHEET (attached) illustrates a closed-loop gain versus phase plot on a Nichols chart.

4.1 Use the Nichols chart to determine the following:

4.1.1	The gain margin	(1)
4.1.2	The phase margin	(1)
4.1.3	The gain crossover frequency	(1)
4.1.4	The phase crossover frequency	(1)
4.1.5	The un-damped natural resonant frequency	(1)
4.1.6	The peak frequency response	(1)
4.1.7	The peak magnitude and phase	(2)
4.1.8	The closed-loop bandwidth	(1)

4.2 State if the system is stable or unstable. (1)

[10]

QUESTION 5

An open-loop transfer function for a root locus is given as:

$$G(s)H(s) = \frac{2K_o(S+2)}{S(S+1)(S+4)}$$

Use the given transfer function to determine the following:

5.1 The open-loop poles and the zeros

5.2 Do some of the loci break away? Explain.

5.3 The centre of asymptotes

5.4 The asymptotic angles

5.5 The stability of the system

(5 × 2) **[10]**

QUESTION 6

6.1 Express the given function in terms of the equivalent Laplace transformation:

$$f(t) = 6\,\frac{dx(t)}{dt} + 5x(t)$$ (3)

6.2 Using Laplace transforms, convert the following function to the 't' domain.

6.2.1 $$F(s) = \frac{23}{s-7}$$ (2)

6.2.2 $$F(s) = \frac{7\omega}{(s^2+\omega^2)(4s+2)}$$ (3)

6.3 Convert the given Laplace transform functions to a function of 's':

$$F(t) = e^{-at} + dt$$ (2)

[10]

QUESTION 7

7.1 Name the FOUR main groups of transducers. (4)

7.2 State the function of a tacho-generator in control systems. (2)

7.3 Give TWO advantages of using rectified alternating current to control direct current motor speed controllers. (2)

7.4 State the function of comparator elements used in closed-loop control systems. (2)

[10]

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QUESTION 8

8.1 Name TWO classes of piston-type pumps. (2)

8.2 FIGURE 2 shows a diagram of a certain type of pump. Study the diagram and answer the questions.

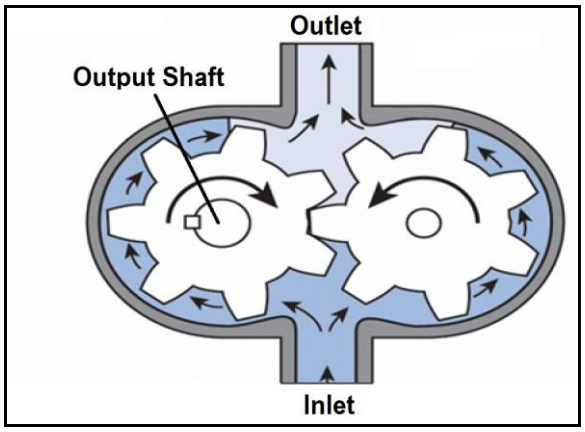


FIGURE 2

8.2.1 Name the pump in FIGURE 2. (1)

8.2.2 State the category under which this pump is classified. (1)

8.2.3 Explain the operating principle of the pump in FIGURE 2. (4)

8.3 Define the term *hydraulics.* (2)
[10]

QUESTION 9

9.1 Define the term *hunting* with regards to proportional control. (1)

9.2 State TWO disadvantages of using integral control in pneumatic systems. (2)

9.3 Explain why derivative control is very useful in pneumatics. (2)

9.4 Draw a neat labeled diagram of a capacitive pressure transducer. (5)
[10]

QUESTION 10

10.1 When using Lissajous figures to compare the phase difference between two sinusoidal signals, the resulting display on the screen of the oscilloscope could take three forms.

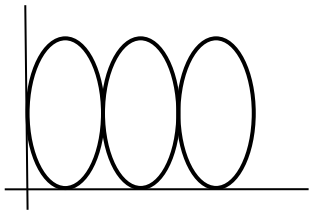
Name the THREE forms. (3)

10.2 List FOUR advantages of recording oscilloscope traces. (4)

10.3 Calculate the value of the unknown frequency (f_H) for the figure below.

HINT: $\frac{f_H}{f_V} = \frac{Number\ of\ vertical\ tangencies}{Number\ of\ horizontal\ tangencies}$

$f_V = 750\ H_z$.



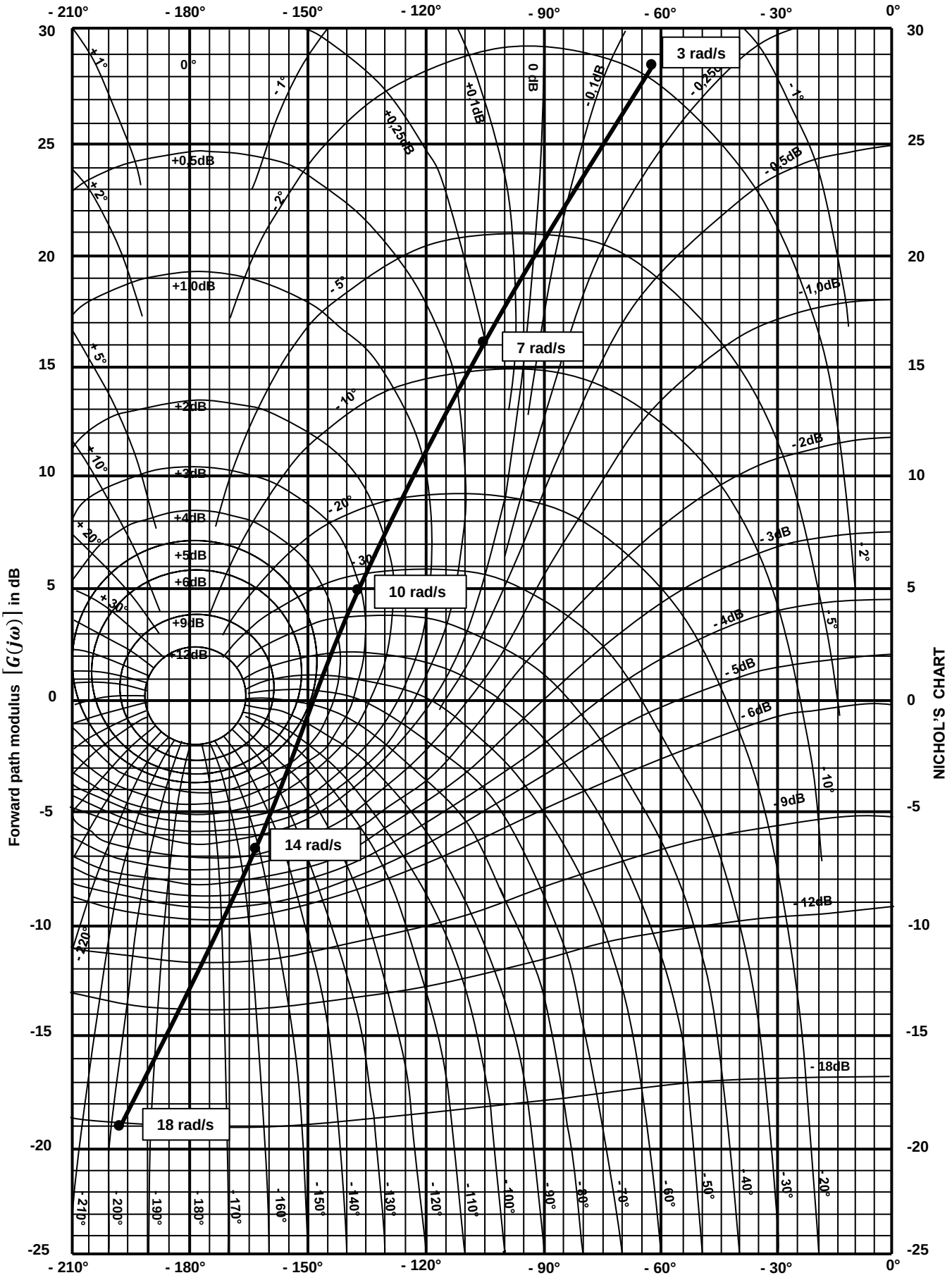
(3)
[10]

TOTAL: 100

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DIAGRAM SHEET



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FORMULA SHEET

$\omega_d = \omega_n\sqrt{1-\zeta^2} = 2\pi f$ $\qquad t_p = \frac{1}{f}$

Number of oscillations $\frac{t_s}{t_p}$ or / of $\frac{2\sqrt{1-\zeta^2}}{\pi.\zeta}$

Damping coefficient $(\alpha) = \zeta.\omega_n = \frac{1}{\pi}\tau$

Overshoot $= e^{\frac{-\zeta\pi N}{\sqrt{1-\zeta^2}}}$

$\Psi = tan^{-1}\left[\frac{\sqrt{1-\zeta^2}}{-\zeta}\right] + \pi\, rad$

Amplitude $= \varphi\left[1 + e^{\frac{-\zeta\pi N}{\sqrt{1-\zeta^2}}}\right]$

$\omega_n = \sqrt{\frac{Ko}{\tau}}$ $\qquad \tau + \frac{t_s}{4} = \frac{1}{\zeta.\omega_n}$

$\omega_p = \omega_n\sqrt{1-2\zeta^2}$

$\omega_b = \omega_n\sqrt{1-2\zeta^2+\sqrt{2-4\zeta^2+4\zeta^4}}$

$\frac{C}{R} = \frac{G}{1 \pm GH}$ $\qquad Sc = \frac{\sum P - \sum Z}{NP-NZ}$

$\zeta = COS\,\varphi$ $\qquad \Psi = \frac{(2Ko+1)180°}{NP-NZ}$

$Ko = \frac{\Delta P_1 . \Delta P_{2....}}{\Delta Z_1 . \Delta Z_{2....}}$

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AMPLIFIERS

BODE AND NICHOLS CHARTS

$$\mathrm{Vo} = -V_i \frac{\mathrm{R}_f}{\mathrm{R}_1} \qquad Gain = 20 \log \left[\frac{output}{input}\right] db$$

$$\mathrm{Vo} = -R_f \left[\frac{\mathrm{V}_1}{\mathrm{R}_1} + \frac{V_2}{R_2} + \cdots \frac{V_N}{R_N}\right] \qquad Phase = \mathrm{Sin}^{-1}\left[\frac{phase\ shift}{input}\right] - 180°$$

$$\mathrm{Vo} = \frac{R_f}{R_1}[V_2 - V_1]$$

$$\mathrm{Vo} = -RC \frac{dV_i(t)}{dt}$$

$$\mathrm{i}_e = \frac{V_e}{R_e}$$

$$R_c = \frac{V_c}{i_c}$$

$$\mathrm{gm}R_L = \frac{hfe}{hie}.R_L$$

$$\mathrm{t} = \frac{1}{f} \qquad \tau = R.C$$

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LAPLACE TRANSFORM TABLE

No	F(s)	f(t)
1.	1	$\delta(t)$
2.	$\frac{A}{s}$	$A(t)$ $\{0 \ \ t < 0\}$ $\{A \ \ t \geq 0\}$
3.	$\frac{1}{s}$	$U(t)$ $\{0 \ \ t < 0\}$ $\{1 \ \ t \geq 0\}$
4.	$\frac{A}{s^2}$	At
5.	$\frac{2A}{s^3}$	At^3
6.	$\frac{A_\omega}{s^2 + \omega^2}$	$A \sin \omega t$
7.	$\frac{A_s}{s^2 + \omega^2}$	$A \cos \omega t$
8(a).	$\frac{A}{\tau s + 1}$	$\frac{A}{\tau} e^{\frac{-t}{\tau}}$
8(b).	$\frac{A}{s + a}$	Ae^{-at}
9(a).	$\frac{A}{(\tau_1 s + 1)(\tau_2 s + 1)}$	$\frac{A}{\tau_1 - \tau_2} \left[e^{\frac{-t}{\tau_1}} - \frac{-t}{\tau_2}\right]$
9(b).	$\frac{A}{(s + a)(s + b)}$	$\frac{A}{(b - a)} [e^{-at} - e^{-bt}]$
10(a).	$\frac{A}{(\tau_s + 1)^2}$	$\frac{At}{\tau^2} \left[e^{\frac{-t}{\tau}}\right]$
10(b).	$\frac{A}{(s + a)^2}$	Ate^{-at}
11.	$\frac{A{\omega_n}^2}{s^2 + 2\zeta\omega_n s + {\omega_n}^2}$	$\frac{A\omega_n e^{-\zeta\omega_n t}}{\sqrt{1 - \zeta^2}} \sin(\omega_n \sqrt{1 - \zeta^2 t}$
12(a).	$\frac{A}{s(\tau s + 1)}$	$A(1 - e^{\frac{-t}{\tau}})$
12(b).	$\frac{A}{s(s + a)}$	$\frac{A}{a}(1 - e^{-at})$
13(a).	$\frac{A}{s^2(\tau s + 1)}$	$A\tau \left[e^{\frac{-t}{\tau}} + \frac{t}{\tau} - 1\right]$
13(b).	$\frac{A}{s^2(s + a)}$	$\frac{A}{a^2} (e^{-at} + at - 1)$

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14(a).	$\frac{A\omega}{(s^2+\omega^2)(\tau s+1)}$	$\frac{A\omega\tau}{1+\omega^2\tau^2}e^{\frac{-t}{\tau}}+\frac{A}{\sqrt{1+\omega^2\tau^2}}\sin(\omega t-\Psi)$ *where* $\Psi=\tan^{-1}\omega\tau\ (0<\Psi<\pi)$
14(b).	$\frac{A\omega}{(s^2+\omega^2)(s+a)}$	$\frac{A\omega e^{-at}}{(\omega^2+a^2)}+\frac{A}{\sqrt{\omega^2+a^2}}\sin(\omega t-\Psi)$ *where* $\Psi=\tan^{-1}\frac{\omega}{a}\ (0<\Psi<\pi)$
15(a).	$\frac{A}{s(\tau_1 s+a)(\tau_2 s+1)}$	$A\left[1+\frac{\tau_1 e^{\frac{-t}{\tau_1}}-\tau_2 e^{\frac{-t}{\tau_2}}}{\tau_1-\tau_2}\right]$
15(b).	$\frac{A}{s(s+a)(s+b)}$	$\frac{A}{ab}\left[1+\frac{ae^{-bt}-be^{-at}}{b-a}\right]$
16(a).	$\frac{A}{s(\tau+a)^2}$	$A\left[1-\frac{(\tau+t)}{\tau}e^{\frac{-t}{\tau}}\right]$
16(b).	$\frac{A}{s(s+1)^2}$	$\frac{A}{a^2}\left[1-(1+at)e^{-at}\right]$
17.	$\frac{A{\omega_n}^2}{s(s^2+2\zeta\omega_n s+{\omega_n}^2)}$	$A\left[1+\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin(\omega_n t\sqrt{1-\zeta^2}-\Psi\right]$ *where* $\Psi=tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta}\ (0<\Psi<\pi)$
18(a).	$\frac{A}{s^2(\tau_1 s+1)(\tau_2 s+1)}$	$A\left[t-\tau_1-\tau_2-\frac{{\tau_2}^2 e^{\frac{-t}{\tau_2}}-{\tau_1}^2 e^{\frac{-t}{\tau_1}}}{\tau_1-\tau_2}\right]$
18(b).	$\frac{A}{s^2(s+a)(s+b)}$	$\frac{A}{ab}\left[t-\frac{a+b}{ab}-\frac{\frac{b}{a}e^{-bt}-\frac{a}{b}e^{-at}}{b-a}\right]$
19(a).	$\frac{A}{s^2(\tau s+1)^2}$	$A\left[t-2\tau+(t+2\tau)e^{\frac{-t}{\tau}}\right]$
19(b).	$\frac{A}{s^2(s+a)^2}$	$\frac{A}{a^2}\left[t-\frac{2}{a}+\left(t+\frac{2}{a}\right)e^{-at}\right]$
20.	$\frac{A{\omega_n}^2}{s^2(s^2+2\zeta\omega_n s+{\omega_n}^2)}$	$A\left[\tau-\frac{2\zeta}{\omega_n}+\frac{e^{-\zeta\omega_n t}}{\omega_n\sqrt{1-\zeta^2}}\sin(\omega_n t\sqrt{1-\zeta^2}-\Psi\right]$ *where* $\Psi=2tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta}\ (0<\Psi<\pi)$

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21(a).	$\frac{A\omega}{(s^2+\omega^2)(\tau_1 s+1)(\tau_2 s+1)}$	$A\left[\frac{{\tau_1}^2\omega e^{\frac{-t}{\tau_1}}}{(\tau_1-\tau_2)(1+\omega^2{\tau_1}^2)}+\frac{{\tau_2}^2\omega e^{\frac{-t}{\tau_2}}}{(\tau_1-\tau_2)(1+\omega^2{\tau_2}^2)}+\frac{\sin(\omega t-\Psi)}{(1+\omega^2\tau^2)(1+\omega^2{\tau_2}^2)^{\frac{1}{2}}}\right]$ *where* $\Psi = tan^{-1}\,\omega\tau_1 + tan^{-1}\omega\tau_2$
21(b).	$\frac{A\omega}{(s^2+\omega^2)(s+a)(s+b)}$	$A\left[\frac{\omega e^{-at}}{(b-a)(\omega^2+a^2)}+\frac{\omega e^{-bt}}{(a-b)(\omega^2+b^2)}+\frac{\sin(\omega t-\Psi)}{(\omega^2+a^2)(\omega^2+b^2)^{\frac{1}{2}}}\right]$ *where* $\Psi = tan^{-1}\,\frac{\omega(a+b)}{ab-\omega^2}\ (0<\Psi<\pi)$
22(a).	$\frac{A\omega}{(s^2+\omega^2)(\tau s+1)^2}$	$\frac{A}{1+\omega^2\tau^2}\left[\frac{\omega t+2\omega\tau}{1+\omega^2\tau^2}\,e^{\frac{-t}{\tau}}+\sin(\omega t-\Psi\right]$ *where* $\Psi = 2tan^{-1}\,\omega\tau$
22(b).	$\frac{A\omega}{(s^2+\omega^2)(s+a)^2}$	$\frac{A}{\omega^2+a^2}\left[\frac{a\omega(at+2)e^{-at}}{\omega^2+a^2}+\sin(\omega t-\Psi\right]$
23.	$\frac{A\omega{\omega_n}^2}{(s^2+\omega^2)(s^2+2\zeta\omega_n s+{\omega_n}^2)}$	$\frac{A{\omega_n}^2}{[({\omega_n}^2-\omega^2)^2+4\zeta^2\omega^2{\omega_n}^2]^{\frac{1}{2}}}$ $\left[\sin(\omega t-\Psi)+\frac{\omega e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\Psi_2)}{\omega_n\sqrt{1-\zeta^2}}\right]$ *where* $\Psi_1 = tan^{-1}\left[\frac{2\zeta\omega\omega_n}{{\omega_n}^2+\omega^2}\right]\ (0<\Psi_1<\pi)$ and $\Psi_2 = tan^{-1}-\frac{2\zeta{\omega_n}^2\sqrt{1-\zeta^2}}{\omega^2-{\omega_n}^2(1-2\zeta^2)}\ (0<\Psi_2<\pi)$

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