higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T430(**E**)(A13)T

NATIONAL CERTIFICATE

CONTROL SYSTEMS N6

(8080016)

13 April 2018 (X-Paper)
09:00–12:00

REQUIREMENTS: **3-cycle semi-logarithmic graph paper**

This question paper consists of 8 pages, 1 diagram sheet, 2 formula sheets, a Laplace transform table of 3 pages and a Nichols chart.

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. Neat, labelled circuit diagrams must be used in the explanation of answers only where they are requested.
5. Use only BLUE or BLACK ink.
6. Make use of drawing equipment and pencil for ALL sketches and diagrams.
7. Write neatly and legibly.

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 using pressurised liquid to transmit and control power	A	overshoot
1.2	Converts one form of energy to another	B	electro-optical control system
1.3	A control system that will remain at rest unless excited by a changed manipulated variable	C	angular velocity
1.4	Used to meet performance specifications for feedback control systems	D	absolute control system
1.5	The maximum difference between the transient response and the steady-state solution	E	transducer
1.6	Response oscillations do not die out but remain at a constant level	F	hydraulic control system
1.7	A control system comprising electronic circuitry using at least one communication path as light rays	G	pneumatics
1.8	A control system operating within specific controlled limits	H	compensation networks
1.9	The rate at which an angle changes	I	relative stability
1.10	Power transmitted and controlled through the use of pressurised air	J	steady-state accurate system

(10 × 1) **[10]**

QUESTION 2

Determine, with the aid of block diagram algebra reduction, the control ratio for the block diagram in FIGURE 1 below.

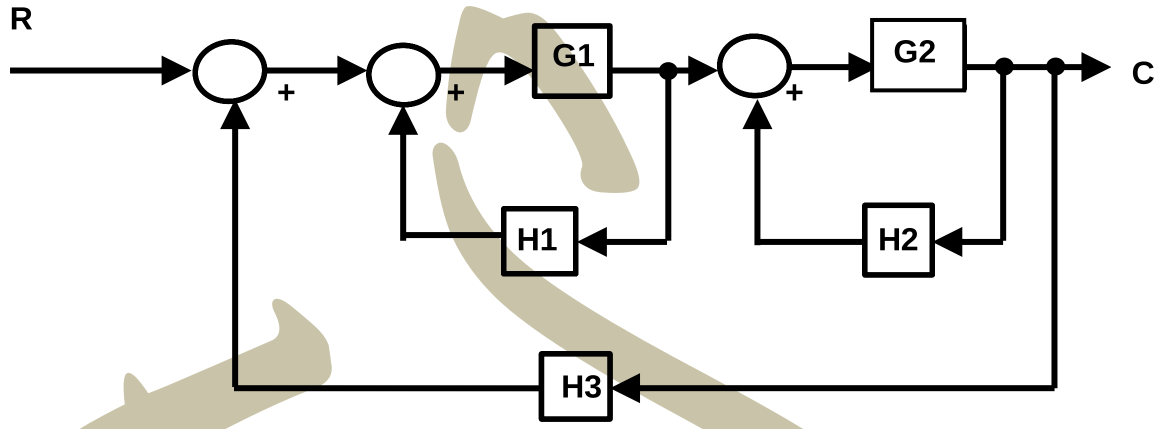


FIGURE 1

[10]

QUESTION 3

DIAGRAM SHEET 1 (attached), illustrates a point-by point bode diagram of the gain and phase values of a system as the frequency varies from 1 to 1 000 radians per second.

Determine the following from the graph:

3.1 The peak gain value (1)

3.2 The phase value at a frequency of 250 rad/s (1)

3.3 The frequency at the peak gain value (1)

3.4 The gain cut-off between 10 rad/s and 100 rad/s (1)

3.5 The gain crossover frequency (1)

3.6 The phase crossover frequency (1)

3.7 The gain margin (1)

3.8 The phase margin (1)

3.9 The stability of the system in terms of the gain and phase response (2)

[10]

QUESTION 4

4.1 Plot the gain and phase values for an open-loop control system onto a Nichols chart using the data in the table.

ω(rad/s)	Magnitude in dB	Phase in degrees
0,1	28,6	-96,5°
0,3	20,2	-103°
0,7	11,0	-124,4°
1,0	2,33	-149.4°
1,6	-2.56	-170,5°
2,3	-9,67	-184,7°
3,5	-18,46	-210°

(6)

4.2 Use the Nichols chart to determine the following:

4.2.1 The gain margin

4.2.2 The phase margin

(2 × 1) (2)

4.3 From the Nichols chart determine the additional gain in dB required, and by what factor the gain constant must be changed in order to give a gain margin of 10dB. (2)

[10]

QUESTION 5

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

$$G(s)H(s) = \frac{2K_o(S+4)}{S(S+2)(S+8)}$$

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 The transfer function of a control system is given as:

$$\frac{\omega_n^2}{s^2 + 4\,\zeta\omega_n s + \omega_n^2}$$

The input function is given as : $T_A = 10\sin 4t$

Using the Laplace transform tables:

6.1.1 Determine the Laplace transform of the input (T_A). (2)

6.1.2 Write an expression for the output response in terms of 's'. (3)

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

$$f(x) = 2\frac{dx}{dt} - 7x$$ (2)

6.3 Convert the given transform function to a function of time:

$$F(s) = \frac{100}{s(s+4)(s+5)}$$ (3)

[10]

QUESTION 7

7.1 State the main function of a transducer. (2)

7.2 Name TWO types of photo-electric transducers. (2)

7.3 State the TWO conditions a rectifier has to satisfy, in order to convert the A.C. signal into a D.C. signal. (2)

7.4 Name TWO disadvantages of potentiometers. (2)

7.5 Give TWO practical applications of an electronic self-balancing potentiometer. (2)

[10]

QUESTION 8

8.1 List the THREE main design considerations when designing a hydraulic system. (3)

8.2 FIGURE 2 below shows a diagram of a simple servo-mechanism with mechanical feedback. Study the diagram and identify the parts labelled A–G. Write only the answer next to the letter (A-G) in the ANSWER BOOK.

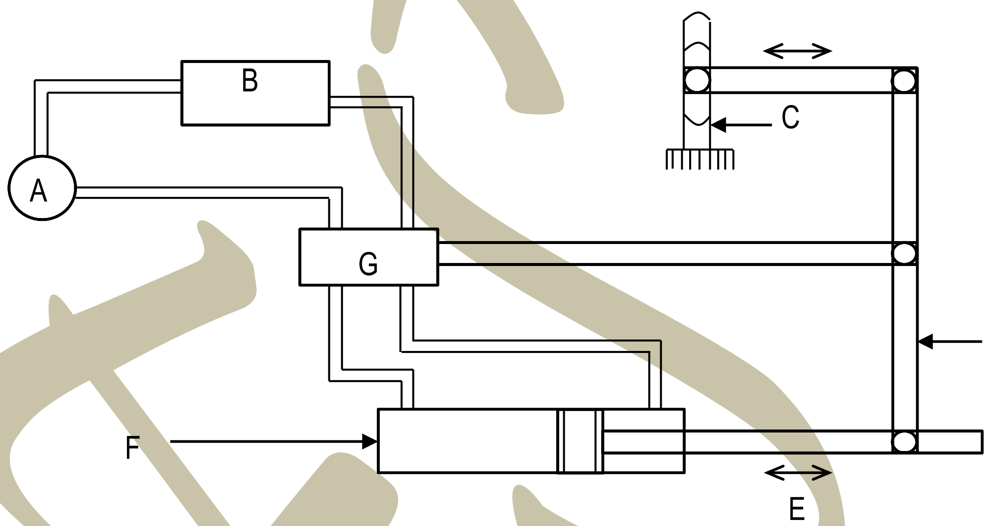


FIGURE 2

(7)
[10]

QUESTION 9

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

9.2 State FIVE advantages of using pneumatic systems. (5)

9.3 What is the purpose of introducing a derivative controller in a proportionally controlled pneumatic system? (2)

9.4 Explain the term *hunting* with regard to proportional control. (1)
[10]

QUESTION 10

10.1 The sine wave is one of the most commonly used waveforms in signal generation.

Name THREE other types of waveforms. (3)

10.2 State how the display of an analogue meter differs from that of a cathode ray oscilloscope. (2)

10.3 State THREE advantages of sine waves in signal generation. (3)

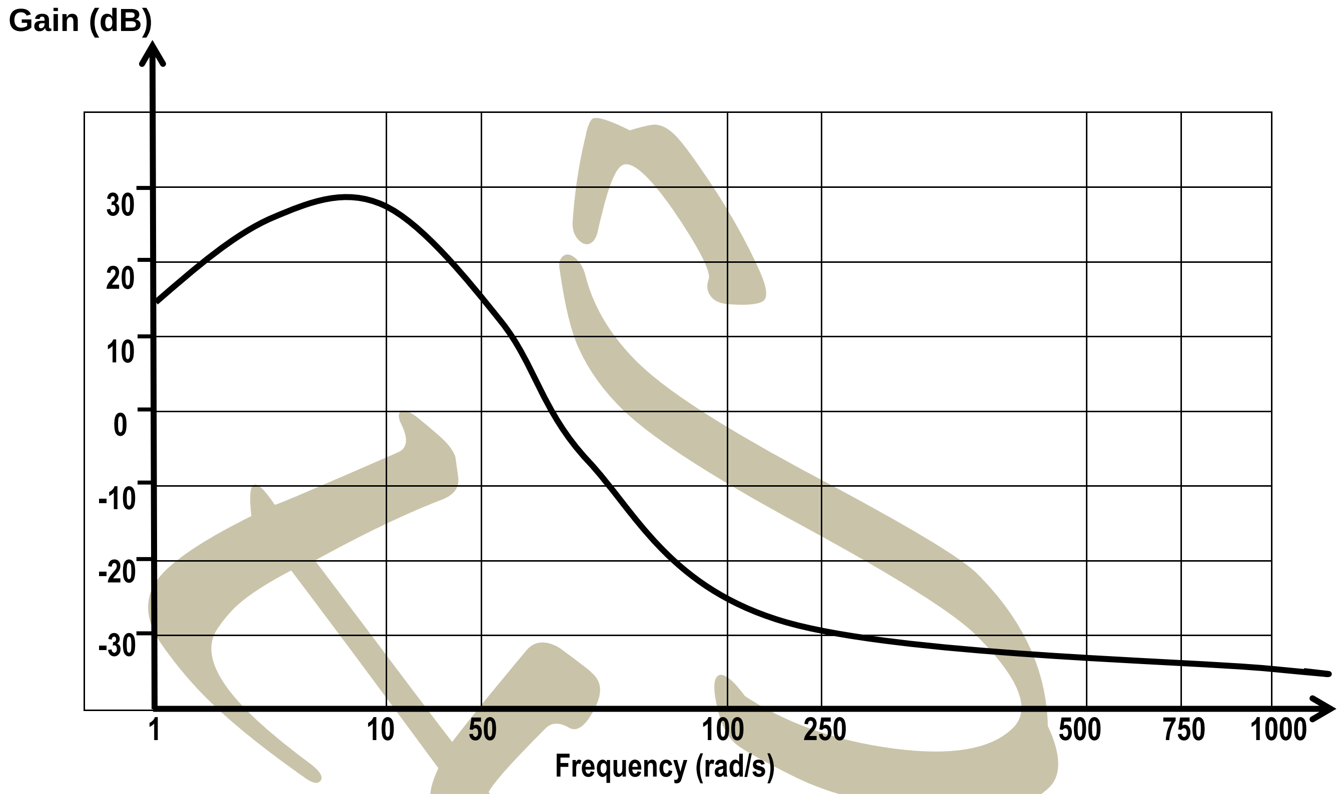
10.4 The saw-tooth wave is extensively used in electronics.

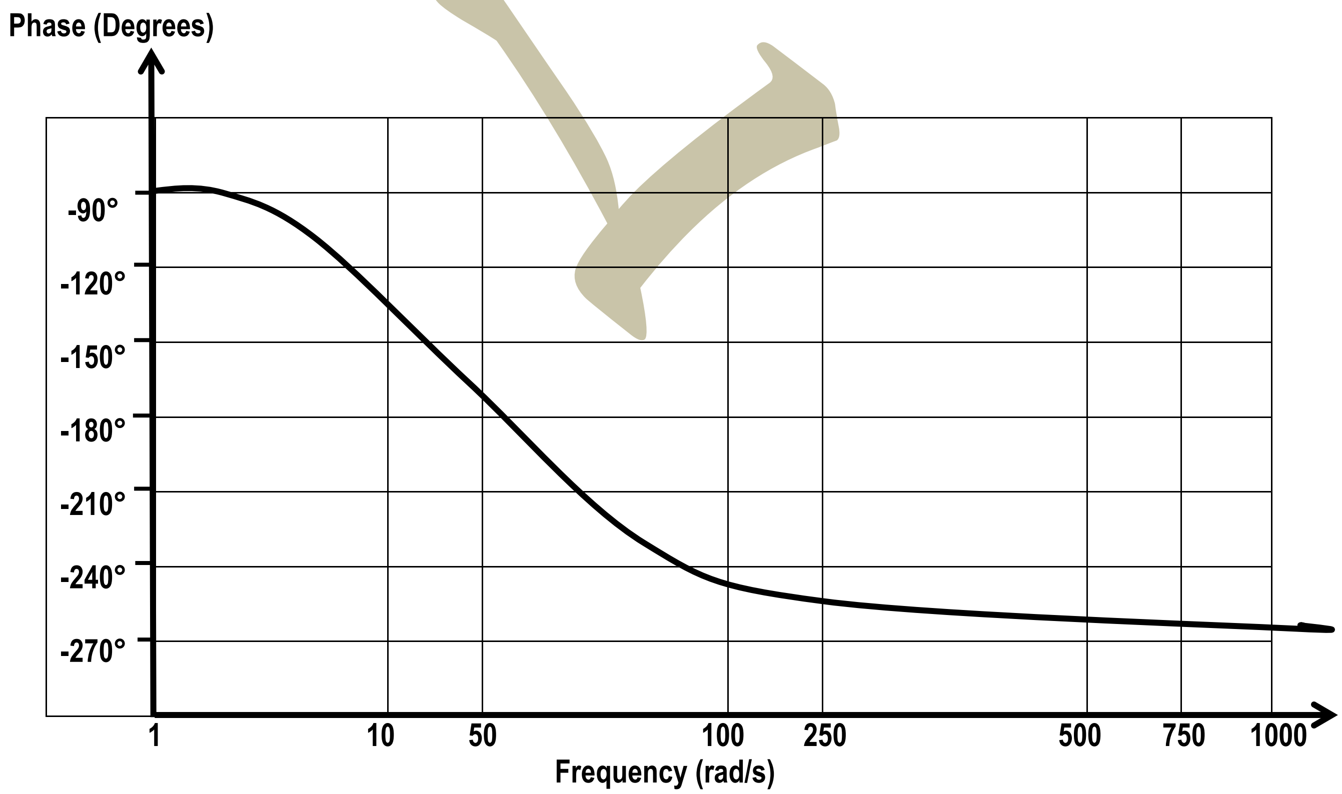
Give TWO applications of this type of waveform. (2)
[10]

TOTAL: 100

DIAGRAM SHEET 1

QUESTION 3





CONTROL SYSTEMS N6

FORMULA SHEET

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

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

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

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

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

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

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

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

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

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

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

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

AMPLIFIERS

$$\text{Vo} = -V_i \frac{\text{R}_f}{\text{R}_1}$$

$$\text{Vo} = V_i \left[\frac{\text{R}_f}{\text{R}_1}\right]$$

$$\text{Vo} = -R_f \left[\frac{\text{V}_1}{\text{R}_1} + \frac{V_2}{R_2} + \cdots \frac{V_N}{R_N}\right]$$

$$\text{Vo} = -\frac{1}{RC} \int V_i\,(t)dt + V_c$$

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

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

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

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

$$\text{t} = \frac{1}{f}$$

BODE AND NICHOLS CHARTS

$$Gain = 20\log\left[\frac{output}{input}\right]\ db$$

$$Phase = \text{Sin}^{-1}\left[\frac{phase\ shift}{input}\right] - 180°$$

$$\tau = R.C$$

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).	$\frac{A}{(s+a)(s+b)}$	$\frac{A}{(b-a)}\left[e^{-at} - e^{-bt}\right]$
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).	$\frac{A}{s^2(s+a)}$	$\frac{A}{a^2}(e^{-at} + at - 1)$

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).	$\frac{A}{s(s+1)^2}$	$\frac{A}{a^2}[1-(1+at)e^{-at}]$
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).	$\frac{A}{s^2(\tau_1 s+1)(\tau_2 s+1)}$	$A\left[t-\tau_1-\tau_2-\frac{\tau_2{}^2e^{\frac{-t}{\tau_2}}-\tau_1{}^2e^{\frac{-t}{\tau_1}}}{\tau_1-\tau_2}\right]$
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 $\Psi=2tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta}$ $(0<\Psi<\pi)$

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

NICHOLS CHART