higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

CONTROL SYSTEMS N6

(8080016)

13 August 2021 (X-paper)
09:00–12:00

REQUIREMENTS: 3-cycle semi-logarithmic graph paper

This question paper consists of 7 pages, 1 Nichol's chart, 1 diagram sheet, a formula sheet of 2 pages, and a Laplace transform table of 3 pages.

305Q1G2113

Copyright reserved

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. Start each question on a new page.
5. Only use a black or blue pen.
6. On completion, insert the 3-cycle semi-logarithmic graph paper of the Bode plot into the ANSWER BOOK before handing it in.
7. Write neatly and legibly.

QUESTION 1

Give ONE term for each of the following control system statements by writing it next to the question number (1.1–1.10) in the ANSWER BOOK.

1.1 An arrangement of physical components connected in a circuit to manipulate, regulate, command or direct the system.

1.2 A function of time that has a value of zero up to time equal to zero, and for any time greater than zero, it has a constant value of one.

1.3 An undesired input signal which affects the value of the controlled output.

1.4 The sum of the transient response and the steady-state response in a linear constant differential equation.

1.5 The mathematical equation containing elements of a system to be transferred from the input to the output, assuming all initial conditions to be zero.

1.6 A function of time of which the amplitude is zero, where t = a, except where t = b.

1.7 The ratio of decibels between the controlled output and the reference input of a system.

1.8 The frequency produced when two complementary energy-storing components of a system produce an oscillation between them.

1.9 The ratio between the actual amount of damping and the critical amount of damping.

1.10 A slow variation of the output voltage or current of the amplifier when the input signal is maintained at a constant level.

(10 × 1) **[10]**

Copyright reserved

QUESTION 2

2.1 FIGURE 1(a) shows a first-order RC differentiator circuit diagram. FIGURE 1(b) shows the resulting block diagram for this system.

Find the transfer function for this system by using block diagram algebra reduction.

Let: $\tau = \mathbf{RC}$

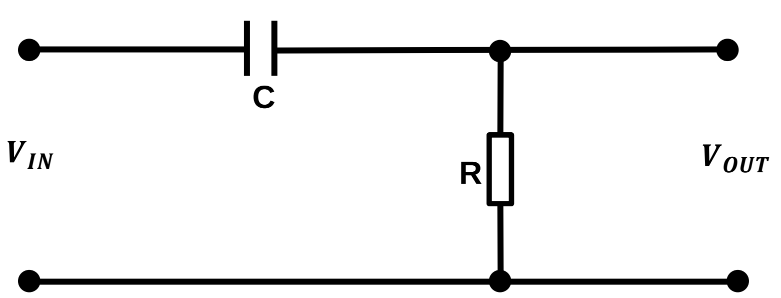


FIGURE 1(a)

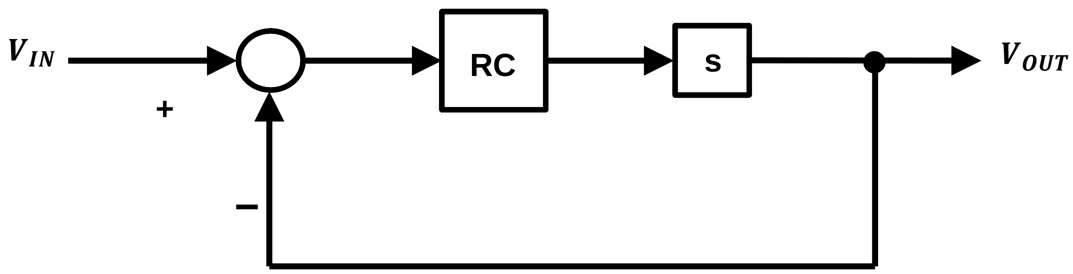


FIGURE 1(b) (5)

2.2 Express the given Laplace function in terms of the equivalent 's' domain:

$$\mathrm{F(t)} = 4\sin 3t$$ (2)

2.3 Express the given Laplace function in terms of the equivalent time function:

$$F(s) = \frac{32}{S(S+2)(S+4)}$$ (3)

[10]

QUESTION 3

3.1 Plot a point-by-point Bode diagram for the following data on the 3-cycle semi-logarithmic graph paper provided:

ω (rad/sec)	0,1	0,5	1	5	10	50	100
Gain (dB)	40	30	20	5	-4	-26	-35
Ø (Degrees)	-90°	-95°	-105°	-125°	-140°	-155°	-170°

(5)

3.2 Determine the following from the graph:

3.2.1 The phase crossover frequency

3.2.2 The gain crossover frequency

3.2.3 The frequency at the maximum peak value

3.2.4 The phase margin

3.2.5 The gain margin

(5 × 1) (5)
[10]

QUESTION 4

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

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 undamped 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 Is the system stable or unstable? (1)
[10]

Copyright reserved

QUESTION 5

DIAGRAM SHEET 1 (attached) illustrates a root locus plot of the closed-loop system as the amplifier gain varies from zero to infinity.

Use the root locus plot to determine the following:

5.1	The closed-loop poles	(2)
5.2	The gain constant (K_o) at point 'D'	(3)
5.3	The damped resonant frequency (ω_d)at point 'D'	(1)
5.4	The undamped resonant frequency (ω_n) at point 'D'	(1)
5.5	The damping factor (ζ) at point 'D'	(2)
5.6	The frequency at which the system becomes unstable	(1)
		[10]

QUESTION 6

6.1	State FIVE characteristics of an ideal operational amplifier.	(5)
6.2	State the function of a photoelectric transducer.	(2)
6.3	State the function of a tacho-generator in control systems.	(2)
6.4	What do tacho-generators measure?	(1)
		[10]

QUESTION 7

7.1	State TWO advantages of using rectified alternating current to control direct-current motor speed controllers.	(2)
7.2	Explain the operating principle of an electronic self-balancing potentiometer used to control a gun turret.	(6)
7.3	Name TWO types of photo-electric transducers.	(2)
		[10]

QUESTION 8

8.1	State SIX advantages of using fluid power.	(6)
8.2	Explain the operating principle of an external spur gear hydraulic pump.	(4)
		[10]

QUESTION 9

9.1 Name the THREE cascade-connected control terms of a pneumatic controller. (3)

9.2 Define the term *integral control action*. (2)

9.3 Name TWO disadvantages of using a proportional pneumatic controller. (2)

9.4 Explain the term *steady state* with regards to integral control. (3)
[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 on three forms.

Name the THREE forms. (3)

10.2 State the function of a pulse generator. (2)

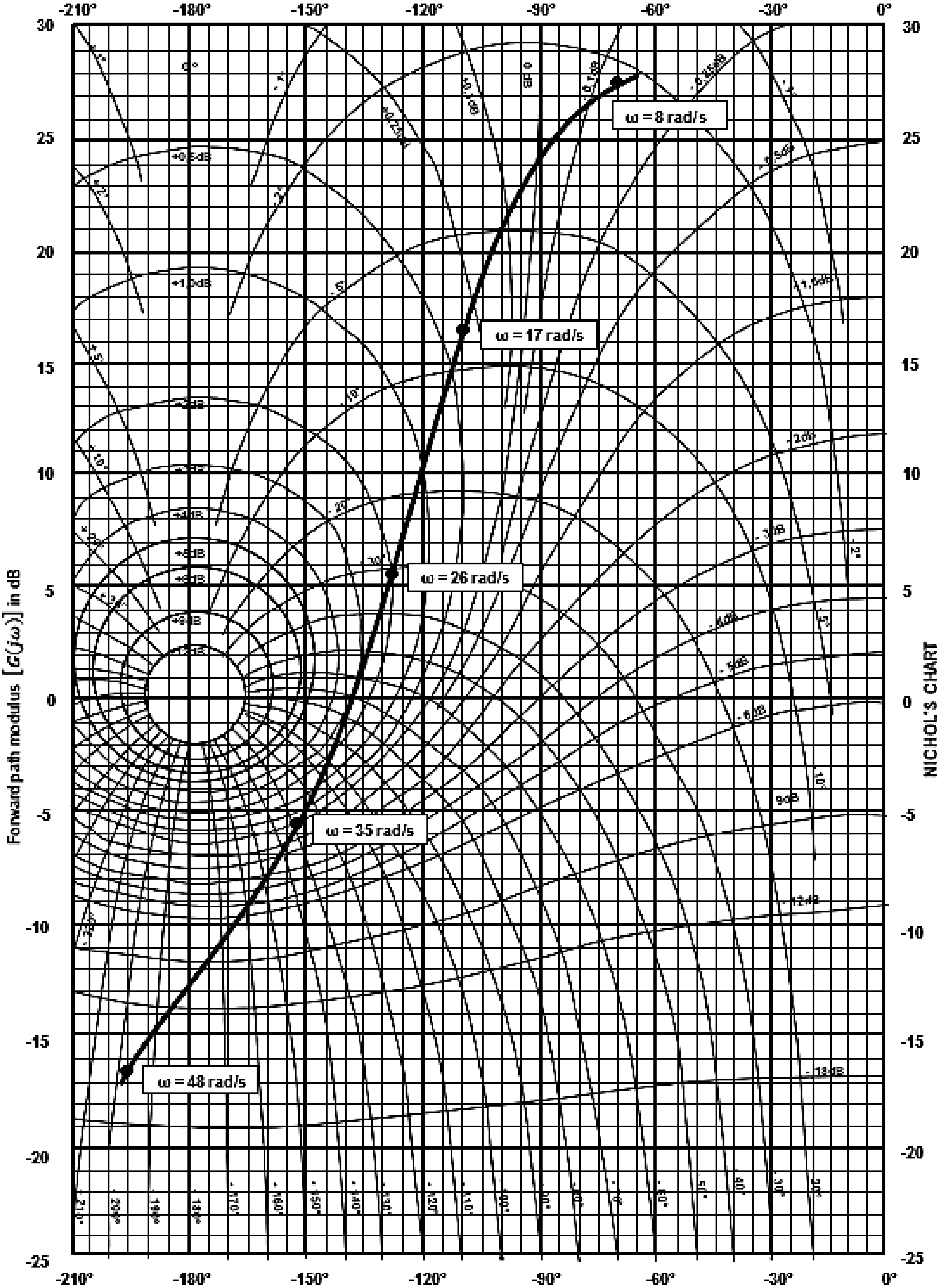
10.3 State THREE basic procedures to be followed when executing a system response test. (3)

10.4 Name the TWO groups into which analogue meters are classified. (2)
[10]

TOTAL: 100

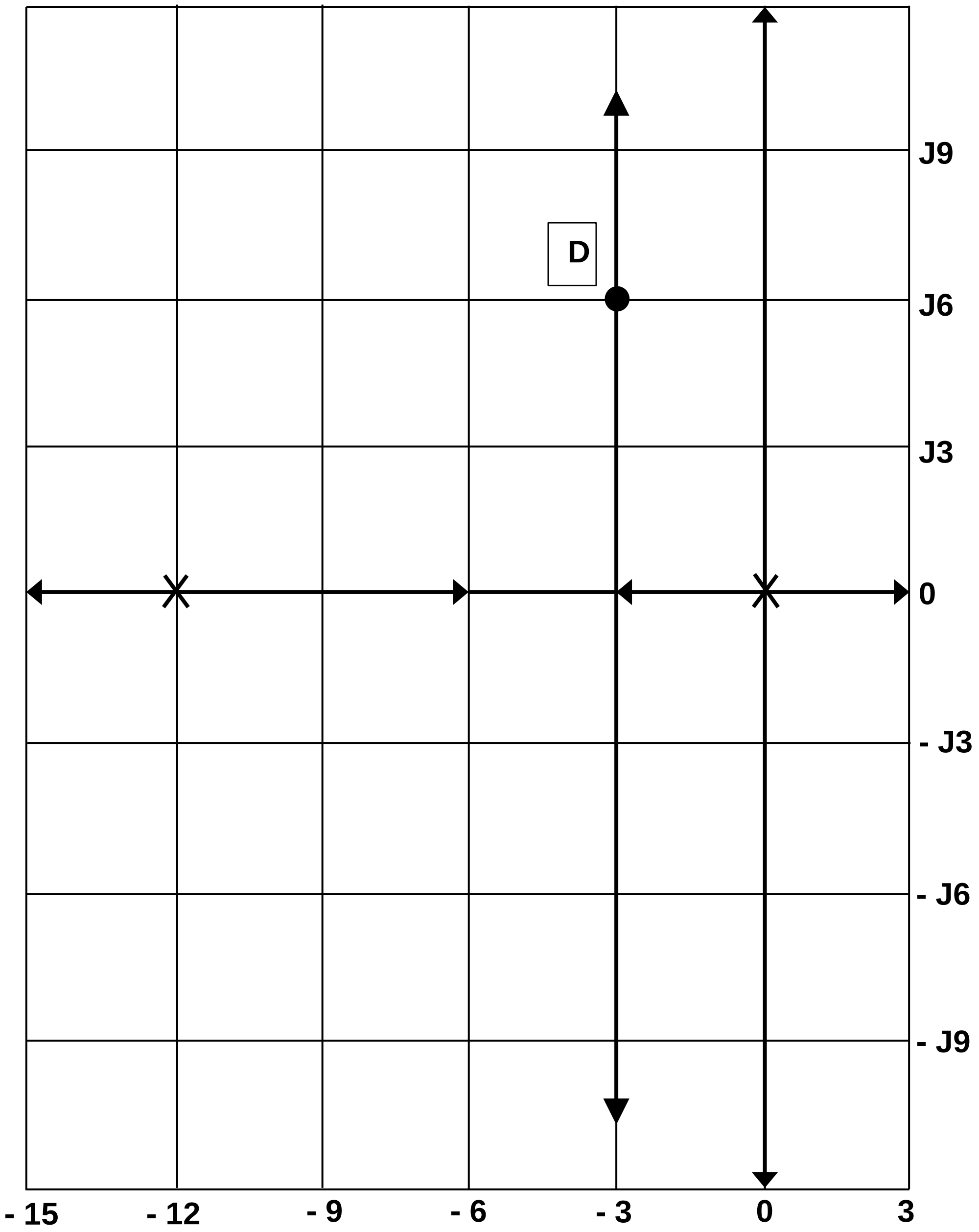
(8080016)

NICHOL'S CHART



Copyright reserved

DIAGRAM SHEET 1



Copyright reserved

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

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

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

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

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

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

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

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

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

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

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

Copyright reserved

AMPLIFIERS

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

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

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

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

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

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

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

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

BODE AND NICHOLS CHARTS

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

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

$$\tau = R.C$$

Copyright reserved

LAPLACE TRANSFORM TABLES

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).	$\frac{A}{s^2(s + a)}$	$\frac{A}{a^2}\ (e^{-at} +\ at - 1)$

Copyright reserved

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

Copyright reserved

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

Copyright reserved