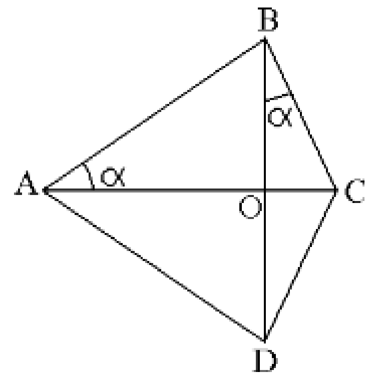
Solution Manual for Signals and Systems 1st Edition Mahmood Nahvi 0073380709 9780073380704

Chapter Problems

Problem [redacted] The four corners [redacted] quadrilateral [redacted] plane [redacted] labeled [redacted] clockwise direction [redacted] $ABCD$. ABC [redacted] ADC [redacted] right angles, [redacted] perpendicular [redacted] AC. The intersection [redacted] given that [redacted] = [redacted] the angle BAC called [redacted]. Show that [redacted] $= \sin^2$ [redacted] = [redacted] [redacted] labeled [redacted]



Solution.

[redacted] From [redacted] right triangle ABC [redacted] have [redacted] = [redacted]

[redacted] The angles $B\hat{A}C$ [redacted] $O\hat{B}C$ [redacted] equal [redacted] each other, therefore, $O\hat{B}C$ = [redacted]

[redacted] From [redacted] right triangle BOC [redacted] obtain

[redacted] $= \sin^2$ [redacted]

= [redacted] = [redacted]

[redacted] = = [redacted]

[redacted] $= 2OB$ =

Problem [redacted] The expression [redacted]$\cos(2\pi ft$ [redacted]) where [redacted] the magnitude, [redacted] the frequency (in Hz), [redacted] phase [redacted] radians, represents [redacted] sinusoidal signal [redacted] cosine form. Determine [redacted] amplitude, frequency, [redacted] phase [redacted] following signals when represented [redacted] above form.

[redacted] [redacted]$\cos(3t$ [redacted] $45^\circ)$ [redacted] [redacted]$\sin(\sqrt{2}t - 120^\circ)$ [redacted] − [redacted] [redacted] [redacted] $\pi(t - 0.5)$

[redacted] [redacted]$\cos(\pi t$ [redacted] $10^\circ)$ [redacted] $-\cos(2\pi t$ [redacted] $\pi/3)$ [redacted] − [redacted]$\sin(6.28t - 2\pi/3)$ [redacted] [redacted] $0.2(t -$ [redacted]

0.2251 150°

Solution.	signal	[redacted]	f	[redacted]
	[redacted] [redacted]$\cos(3t$ [redacted] $45^\circ)$	[redacted]	$\frac{3}{2\pi} = 0.4775$ $= 0.7958$	[redacted] 180°
	[redacted] [redacted]$\sin(\sqrt{2}t - 120^\circ) =$ [redacted]$\cos(\sqrt{2}t$ [redacted] $150^\circ)$	[redacted]	[redacted] $\frac{\sqrt{2}}{2\pi} =$	− [redacted]
	[redacted] − [redacted] = [redacted]$\cos(5t$ [redacted] $180^\circ)$	[redacted]	[redacted] $\frac{5}{2\pi}$ [redacted]	[redacted] -120°
	[redacted] [redacted] $\pi(t - 0.5) =$ [redacted]$\cos(\pi t - 90^\circ)$	[redacted]		
	[redacted] [redacted]$\cos(\pi t$ [redacted] $10^\circ)$	[redacted]		
	[redacted] $-\cos(2\pi t$ [redacted] $\pi/3) = \cos(2\pi t - 2\pi/3)$	[redacted]		

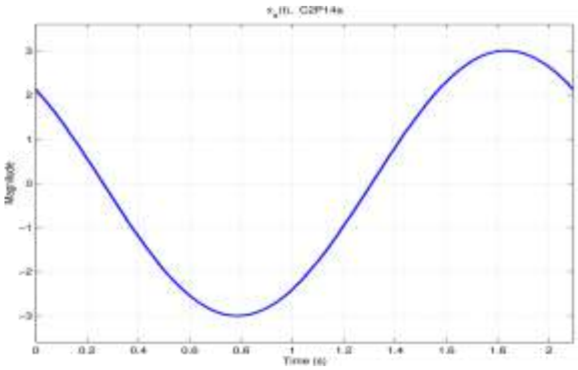
[redacted] $\cdot$ [redacted] $\sin(6.28t \cdot 2\pi/3) =$ [redacted] $\cos(6.28t \cdot \pi/6)$ [redacted]

[redacted] [redacted] $0.2(t \cdot$ [redacted] $=$ [redacted] $\cos(0.2t \cdot 11.46^\circ)$

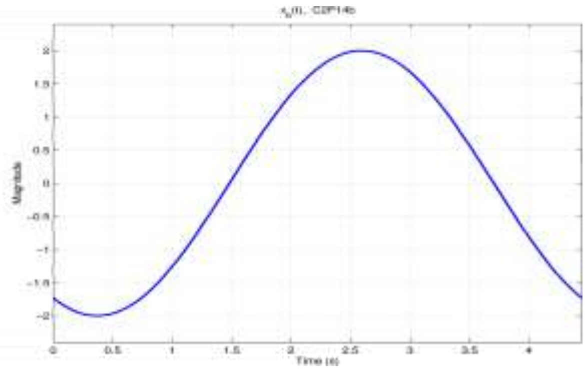
$$\frac{3.14}{\pi} = 0.9995 \quad \cdot$$ [redacted]

[redacted] $$\frac{1}{10\pi} = 0.0318 \quad \cdot \; 11.46^\circ$$

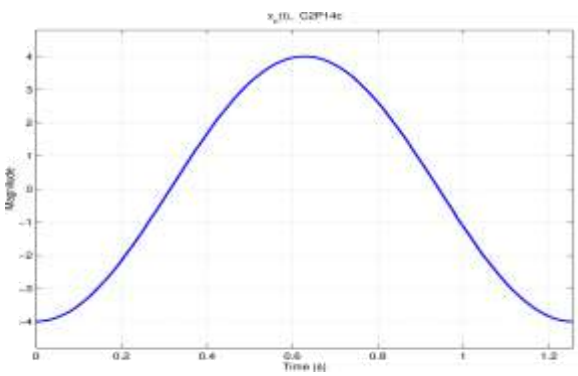
Problem [redacted] Sketch [redacted] label [redacted] signals given [redacted] Problem [redacted]



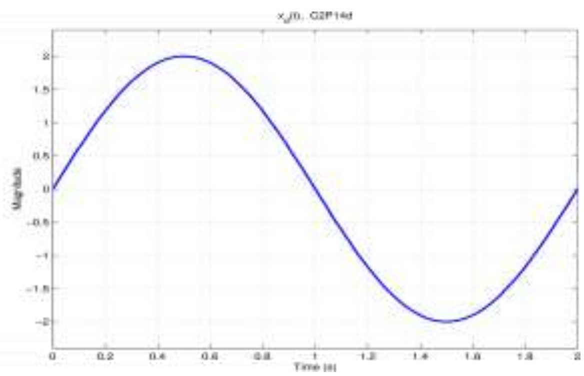
$x_a(t)$



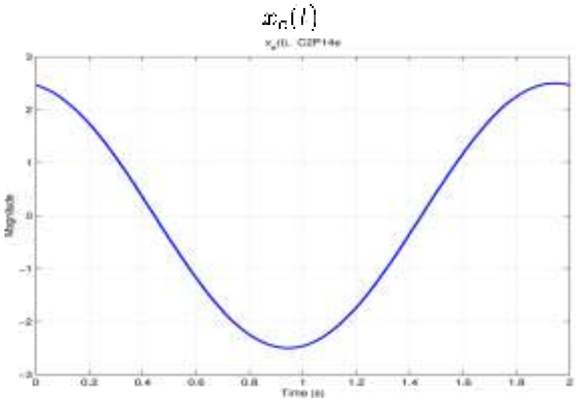
$x_b(t)$



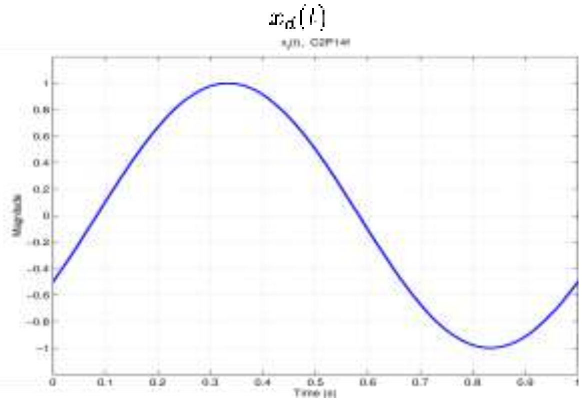
$x_c(t)$



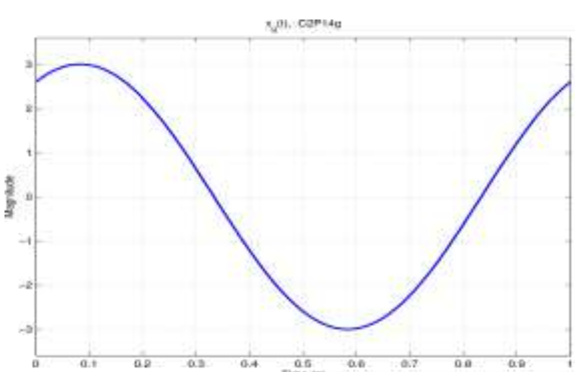
$x_d(t)$



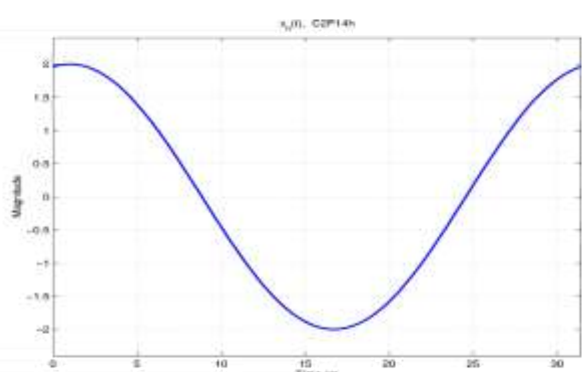
$x_e(t)$



[redacted]



$x_g(t)$



$x_h(t)$

Problems 16-21. Identify [illegible] correct frequency [illegible] given sinusoids.

Problem [illegible] The frequency [illegible] $10^6 \pi t$ [illegible]

[illegible] MHz

[illegible] MHz

[illegible] kHz

[illegible]

[illegible] kHz

[illegible] [illegible] above.

Problem [illegible] The frequency [illegible] $\sin(\pi t/6$ [illegible]

(a) 1/6 [illegible]

(b) 1/12 [illegible]

(c) 1/3 [illegible]

(d) $2/\pi$ [illegible]

(e) [illegible] above.

Problem 20 The frequency [illegible] $\cos(3000\pi t$ [illegible]

[illegible] kHz

[illegible] kHz

[illegible] kHz

[illegible]

[illegible] [illegible]

[illegible] [illegible] above.

Problem [illegible] The frequency [illegible] $10^6 t$ [illegible] most nearly

[illegible] kHz

[illegible] kHz

[illegible]

Problem [illegible] [illegible] above.

The frequency [illegible] $\sin(t/6)$ [illegible]

[illegible]

Problem [illegible] above.

(a) $\pi/3$ [illegible]

(b) $1/(12\pi)$ frequency [illegible] $10^3 t$ [illegible] most nearly

(c) 1/12 [illegible]

(d) $\pi/3$ [illegible]

(e) [illegible] above.

Problem [illegible] The

(a) [illegible] kHz

(b) [illegible]

(c) [illegible]

(d) [illegible]

(e) [illegible] above. [illegible] $10^6 t$ [illegible] most nearly

Problems 22-31. Identify correct period [illegible] given signals.

Problem [illegible] The period [illegible] $10^6 \pi t$ [illegible]

(a) [illegible]

(b) [illegible]

(c) [illegible]

(d) [illegible]

(e) [illegible] above.

Problem [illegible] The period [illegible] $\cos(2 \times 10^6 \pi t)$ [illegible]

[illegible]

(e) [illegible] above.

Problem [illegible] The period [illegible]

[illegible] s

Problem [illegible] The period [illegible]

[illegible]

(a) [illegible]

(b) [illegible]

(c) [illegible]

(d) [illegible]

(e) [illegible]

Problem [illegible] The period [illegible] $20\pi t$ [illegible]

(a) [illegible] s

(b) [illegible] [illegible] above.

(c) [illegible]

(d) [illegible]

(e) [illegible] above.

Problem [illegible] The period

(a) $3\pi/2$ s

(b) [illegible] s

(c) [illegible] s

(d) [illegible]

(e) [illegible]

a)

b)

c)

d)

e) above.

Problem The

period is

a)

b)

c) $(1/5 \quad 1/3)2\pi$

d) $3\pi/5$

e) above.

a)

b)

c) $\pi/2$

d) $\pi/3$

e)

The period

above.

Problem The period $\sin 200t + \sin 201t$

2.1π s

1.99π s

above.

Problem The period $\sin 200\pi t + \sin 201\pi t$

above.

Problems 32-37. Identify correct phase following sinusoids when expressed form $\cos(\omega t + \theta)$.

Problem The phase $\cos(\pi t + 30°)$

degrees

radians

radians

degrees

above.

Problem The phase $\sin(2\pi t - 30°)$

30 degrees

degrees

120 degrees

degrees

above.

Problem The phase $\cos(\pi t +$

degrees

radians

radian

degrees

above.

Problem The phase $\sin(\pi t +$ most nearly

radians

Problem The phase $\cos \pi(t - 0.5)$

degrees radians

$\pi/2$

radians

radians

above.

Problem $\cos 500\pi(t + 10^{-3})$

radians

degrees

radians

degrees

Problem The phase

degrees

radians

radians

radians

above.

Problems 38-45. Determine correct phase **relationship** between sinusoids given below.

Problem $= \cos(t + 10°)$, $= \cos(t - 30°)$

leads degrees

lags

leads degrees

degrees

lags degrees

above.

Problem $= \cos(t - 30°)$,

lags degrees

Problem $= \cos(t + 10°)$, $= \sin(t$

leads degrees

leads [illegible]

(a) [illegible]

(b) [illegible]

(c) lags degrees

(d) lags degrees

(e) above. degrees

Problem [illegible]

leads

(a) leads $= \cos(t \cdot$ [illegible] $ms)$

(b) degree

(c) lags $9/(10\pi)$ degrees

(d) radian

(e) almost [illegible] phase

above.

(a)

(b) lags

(c) lags

(d) leads

(e) above.

Problem [illegible]

(a) leads

(b) lags

(c) lags

(d) leads

(e) [illegible]

Problem [illegible]

(a) leads

(b) leads

(c) leads

(d) [illegible]

(e) [illegible]

$\cos(t$ [illegible] $55°)$

degrees

degrees

degrees

$\cos(t$ [illegible] $30°)$, $= \sin(t$ [illegible] $55°)$

degrees

degrees

degrees

degrees

above.

$= \cos(t \cdot$ [illegible]

degrees

radian

degrees

almost [illegible] phase

above.

Problem [redacted] [redacted] = [redacted] $10^4 t$, [redacted] = [redacted] $10^4(t - 10\mu s)$

[redacted] [redacted] lags [redacted] by [redacted] degrees

[redacted] [redacted] [redacted] [redacted] [redacted] almost [redacted] phase

[redacted] [redacted] leads [redacted] by [redacted] degrees

[redacted] [redacted] lags [redacted] by [redacted] degrees

[redacted] lags [redacted] by [redacted] radian.

Problem [redacted] [redacted] = [redacted] $10^6 t$, [redacted] = [redacted] [redacted] $1\mu s)$

[redacted] [redacted] leads [redacted] by [redacted] degrees

[redacted] [redacted] leads [redacted] by [redacted] radian

[redacted] [redacted] [redacted] [redacted] [redacted] almost [redacted] phase

[redacted] [redacted] lags [redacted] by [redacted] radian

[redacted] [redacted] [redacted] [redacted] above.

Problem [redacted] [redacted] phasors [redacted] convert each time function given below [redacted] [redacted] form [redacted] $\cos(2\pi f t$ [redacted] [redacted]

[redacted] [redacted] $\cos(3t$ [redacted] $45^\circ)$ [redacted] [redacted] $\sin(3t \quad 120^\circ)$

[redacted] $\cos(5t)$ [redacted] [redacted] $5(t \quad 0.5)$

[redacted] [redacted] $\cos(\pi t$ [redacted] $10^\circ) \quad \cos(\pi t$ [redacted] $\pi/3)$

[redacted] $\sin(6.28t \quad 2\pi/3)$ [redacted] [redacted] $6.28(t \quad 0.5)$

Solution. The answers [redacted]

[redacted] $3.1455\cos(3t$ [redacted] $82.89^\circ)$

[redacted] $5.7287\cos(5t \quad 167.93^\circ)$

[redacted] $2.0090\cos(\pi t \quad 12.41^\circ)$

[redacted] $1.6178\cos(6.28t \quad 68.26^\circ)$

The following Matlab code [redacted] executed [redacted] obtain [redacted] answers.

```
r1=3;  p1=45*pi/180;          v1=r1*exp(i*p1);
r2=2;  p2=-120*pi/180-pi/2;   v2=r2*exp(i*p2);
A1=abs(v1+v2)
P1=180*angle(v1+v2)/pi;
%
r1=-4;  p1=0;                 v1=r1*exp(i*p1);
r2=2;   p2=-2.5;              v2=r2*exp(i*p2);
A2=abs(v1+v2);
P2=180*angle(v1+v2)/pi;
%
r1=2.5;  p1=10*pi/180;        v1=r1*exp(i*p1)
r2=-1;   p2=pi/3;             v2=r2*exp(i*p2)
A3=abs(v1+v2)
P3=180*angle(v1+v2)/pi;
%
r1=-3;  p1=-2*pi/3-pi/2;      v1=r1*exp(i*p1);
r2=2;   p2=-3.[redacted]      v2=r2*exp(i*p2);
A4=abs(v1+v2)
P4=180*angle(v1+v2)/pi;
%
[redacted] [redacted] [redacted] [redacted] [redacted]; [redacted] [redacted] [redacted] [redacted] [redacted]; [redacted] [redacted]

[redacted]1455   [redacted]7287   [redacted] 0090   [redacted]6178
[redacted]8912  -167 9399  [redacted] 4147  [redacted] 3037
```

Problem [redacted] each time function given below determine [redacted] periodic [redacted] aperiodic, [redacted] specify [redacted] period [redacted] periodic.

[redacted]

[redacted] $\cos(\pi t$ [redacted] $10^\circ) - \cos(2\pi t$ [redacted] $\pi/3)$

[redacted] $\cos(3t$ [redacted]

[redacted] $3.141592t$

[redacted] $3.1416t$

[redacted] $\cos(5t)$ [redacted] $0.2(t -$ [redacted]

[redacted] $\sin(6.28t - 2\pi/3)$

[redacted]

[redacted] $\cos(1.14t$ [redacted] $3.141592t$

Solution. [redacted] $\frac{T_1}{T_2} = \frac{k_2}{k_1}$, where [redacted] integers, then [redacted] periodic with [redacted] $= k_1T_1 = k_2T_2$. **Equivalently,**

$$\frac{k_1}{k_2} = \frac{\omega_1}{\omega_2}, \quad \text{[redacted]} = \text{[redacted]}\frac{2\pi}{\omega_1} = \text{[redacted]}\frac{2\pi}{\omega_2}$$

	[redacted]	[redacted]	$\frac{\omega_1}{\omega_2}$ [redacted] $\frac{k_1}{k_2}$	Periodic?	[redacted] $=$ [redacted] $\frac{2\pi}{\omega_1} =$ [redacted] $\frac{2\pi}{\omega_2}$
[redacted]	[redacted]	[redacted]	$\frac{5}{\pi}$ [redacted] $\frac{k_1}{k_2}$	[redacted]	
[redacted]	[redacted]	3.1416,	$\frac{5}{3.1416} = \frac{6250}{3927} = \frac{k_1}{k_2}$,	[redacted]	[redacted] $= 6250\frac{2\pi}{5} = 3927\frac{2\pi}{3.1416} = 2500\pi$
[redacted]	[redacted]	[redacted]	$\frac{\pi}{2\pi} =$ [redacted] $= \frac{k_1}{k_2}$,	[redacted]	[redacted] $= \frac{2\pi}{\pi} =$ [redacted] $\frac{2\pi}{2\pi} =$ [redacted]
[redacted]	6.28,	0.2,	$\frac{6.28}{0.2} = \frac{157}{5} = \frac{k_1}{k_2}$,	[redacted]	[redacted] $= 157\frac{2\pi}{6.28} =$ [redacted] $\frac{2\pi}{0.2} =$ [redacted] $=$ [redacted]
[redacted]	[redacted]	[redacted]	[redacted] $= \frac{k_1}{k_2}$,	[redacted]	[redacted] $=$ [redacted] $\frac{2\pi}{5} =$ [redacted] $\frac{2\pi}{3}$
[redacted]	[redacted]	[redacted]	$\frac{1}{2\pi}$ [redacted] $\frac{k_1}{k_2}$,	[redacted]	
[redacted]	[redacted]	3.141592,	$\frac{\pi}{3.141592}$ [redacted] $\frac{k_1}{k_2}$,	[redacted]	[redacted] $= 142500\frac{2\pi}{1.14} = 392699\frac{2\pi}{3.141592} = 250{,}000\pi$
[redacted]	1.14,	3.141592,	$\frac{1.14}{3.141592} = \frac{142500}{392699} = \frac{k_1}{k_2}$,	[redacted]	

Problem 1.3 For each time function given below determine if it is periodic or aperiodic, and specify its period if periodic.

(a) $\cos 2\pi t + \cos 6.28t$

(b) $\cos 2\pi t + \cos 6.2816t$

(c) $\cos 2\pi t + \cos 6.28159t$

(d) $\cos 6.2816t + \cos 6.28159t$

(e) $\cos \sqrt{2}t + \cos 1.41t$

(f) $\cos 1.4142t + \cos 1.41t$

	ω_1	ω_2	$\frac{\omega_1}{\omega_2} \stackrel{?}{=} \frac{k_1}{k_2}$	Periodic?	$T = k_1\frac{2\pi}{\omega_1} = k_2\frac{2\pi}{\omega_2}$
(a)	2π,	6.28,	$\frac{2\pi}{6.28} \neq \frac{k_1}{k_2}$;	no	
(b)	2π,	6.2816,	$\frac{2\pi}{6.2816} \neq \frac{k_1}{k_2}$;	no	
(c)	2π,	6.28159,	$\frac{2\pi}{6.28159} \neq \frac{k_1}{k_2}$;	no	
(d)	6.2816,	6.28159,	$\frac{6.2816}{6.28159} = \frac{628160}{628159} = \frac{k_1}{k_2}$;	yes	$T = 628160\frac{2\pi}{6.2816} = 628159\frac{2\pi}{6.28159} = 2 \times 10^5\pi$
(e)	$\sqrt{2}$,	1.41,	$\frac{\sqrt{2}}{1.41} \neq \frac{k_1}{k_2}$;	no	
(f)	1.4142,	1.41,	$\frac{1.4142}{1.41} = \frac{2357}{2350} = \frac{k_1}{k_2}$;	yes	$T = 2357\frac{2\pi}{1.4142} = 2350\frac{2\pi}{1.41} = \frac{10^4\pi}{3}$

Problem [redacted] each time function given below determine [redacted] periodic, [redacted] aperiodic, [redacted] whether [redacted] information [redacted] needed. Specify [redacted] period [redacted] periodic.

[redacted] $3.14t$ [redacted]

[redacted] $3.14t$ [redacted] $3.1416t$

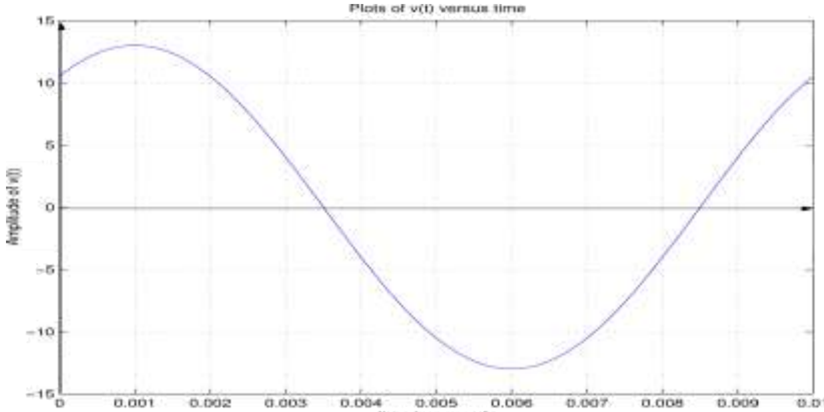
[redacted] $-\ \sin(100\pi t$ [redacted] $\pi/3)$

[redacted] $\sin(6.28t - \pi/3)$ [redacted] $\cos(t -$ [redacted]

	[redacted]	[redacted]	$\frac{\omega_1}{\omega_2}$ [redacted] $\frac{k_1}{k_2}$	Periodic?	$T =$ [redacted] $\frac{2\pi}{\omega_1} =$ [redacted] $\frac{2\pi}{\omega_2}$
[redacted]	3.14,	[redacted]	$\frac{3.14}{2\pi}$ [redacted] $\frac{k_1}{k_2}$;	[redacted]	
[redacted]	3.14,	3.1416,	$\frac{3.14}{3.1416} = \frac{3925}{3927} = \frac{k_1}{k_2}$,	[redacted]	$T = 3925\frac{2\pi}{3.14} = 3927\frac{2\pi}{3.1416} = 2500\pi$
[redacted]	[redacted]	100π,	$\frac{\pi}{100\pi} = \frac{1}{100} = \frac{k_1}{k_2}$;	[redacted]	$T =$ [redacted] $\frac{2\pi}{\pi} =$ [redacted] $\frac{2\pi}{100\pi} =$ [redacted]
[redacted]	6.28,	[redacted]	$\frac{6.28}{1} = \frac{157}{25} = \frac{k_1}{k_2}$,	[redacted]	$T = 157\frac{2\pi}{6.28} =$ [redacted] $\frac{2\pi}{1} =$ [redacted]

Problem [redacted] sinusoidal voltage $v(t)$ [redacted] frequency [redacted] Hz, [redacted] value, [redacted] peak value [redacted] which [redacted] reaches [redacted] ms. Write [redacted] equation [redacted] function [redacted] time [redacted] cosine form [redacted] plot [redacted]

Solution. $v(t) =$ [redacted] $[200\pi(t - 0.001)] =$ [redacted] $\cos(200\pi t - \pi/5)$.



$v(t) =$ [redacted] $\cos(200\pi t - \pi/5)$

Problems [redacted] following [redacted] determine [redacted] phase [redacted] with reference [redacted] (t).

[redacted] $= \cos(t$ [redacted] $30°)$ [redacted] $= \cos(t - 10°)$ [redacted] $= \sin(t$ [redacted] $30°)$ [redacted] $= \cos(t - 10°)$

[redacted] $= \cos(t$ [redacted] $= \sin(t - 10°)$ [redacted] $= \sin(t$ [redacted] $30°)$ [redacted] $= \sin(t - 10°)$

[redacted] lead), [redacted] $130°$, [redacted]

30°)

Solution. a 40°, b 50° (or

Problem [redacted] Consider [redacted] [redacted] [redacted] frequency [redacted] different phases $x(t) =$ [redacted] $+ \cos(\omega t$ [redacted] where [redacted] [redacted] expressed [redacted] $x(t) =$ [redacted] $\cos(\omega t$ [redacted] integer. Write [redacted] Matlab program [redacted] plot $x(t)$ [redacted] obtained [redacted] values [redacted] sinusoids having [redacted] following [redacted] conditions [redacted] above [redacted] phase. Problem

[redacted] values [redacted] As [redacted] Problem [redacted] consider

[redacted] value; [redacted]

Solution. The Matlab program [redacted] Problem [redacted] modified [redacted] used. integer

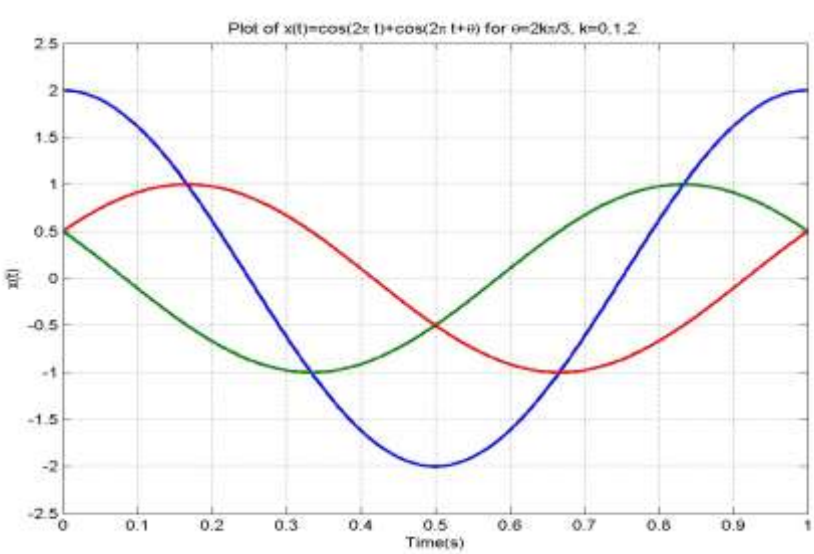
$$x(t) = \text{[redacted]} \cos(2\pi t \text{[redacted]}, \quad = \frac{2k\pi}{N},$$

result [redacted] identical numbers [redacted] plots [redacted] plots

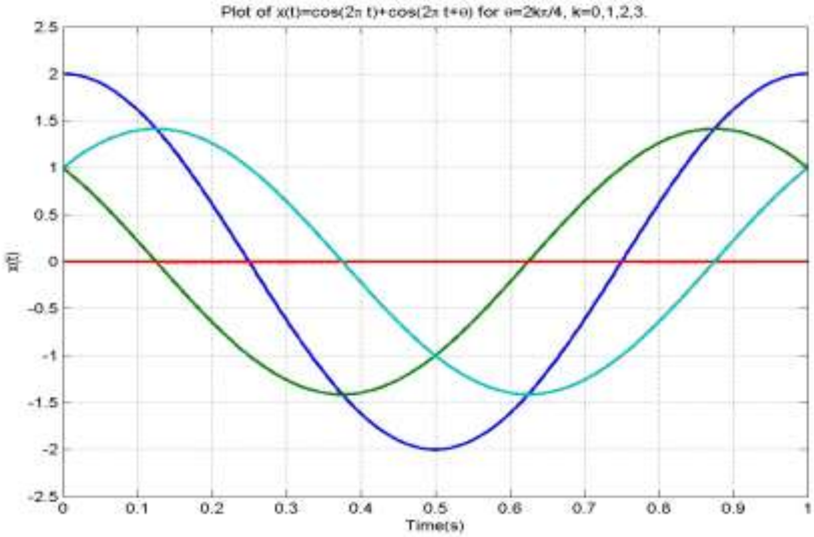
Representations suggested [redacted] and (b) appear analytically numerical values. The program shown below doesn't [redacted] $(N$ [redacted] them. Plots [redacted] shown below [redacted]

different from each other [redacted] models [redacted] (b). [redacted] generates

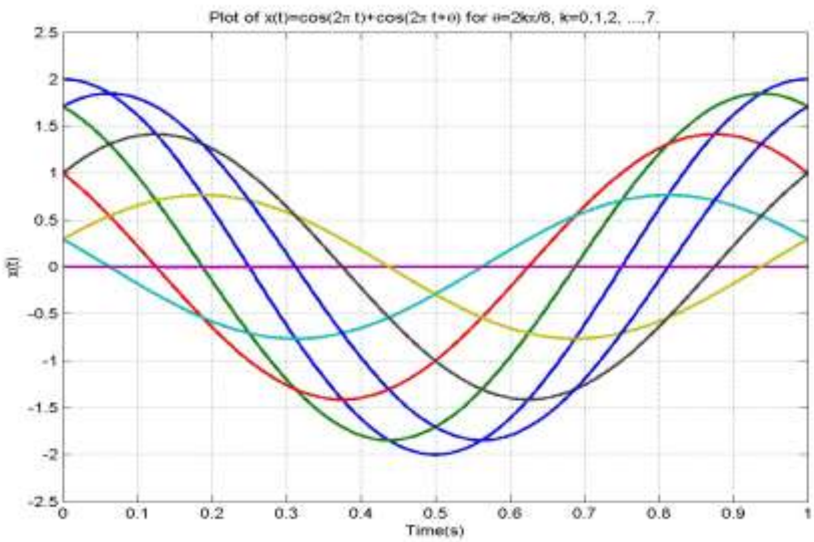
```
clear
[redacted]
theta=2*pi*k/N;
t=linspace[redacted]500);

for [redacted]
    for [redacted]
        x[redacted](2*pi*t[redacted](2*pi*t[redacted]+theta(j));

    end          'LineWidth'
end
for [redacted]
    plot[redacted]          ,[redacted]
    axis([redacted]
 end
```



Plots [illegible] problem [illegible] with [illegible] = [illegible]



Plots [redacted] problem [redacted] with [redacted] = [redacted]



Plots [redacted] problem [redacted] with [redacted] = [redacted]

Problem [redacted] [redacted] The following three measurements [redacted] made [redacted] [redacted] sinusoidal signal $x(t) =$ [redacted] $\cos(2\pi f t$ [redacted] [redacted] where [redacted] frequency [redacted] assumed [redacted] [redacted] MHz.

t	[redacted] [redacted]	[redacted] = [redacted] ms	[redacted] [redacted] ms
$x(t)$	[redacted] = 2.1213	[redacted] = 0.4693	[redacted] = 1.5020

[redacted] Verify [redacted] above frequency assumption. [redacted] Find [redacted] amplitude [redacted] phase [redacted] $x(t)$. [redacted] Knowing [redacted] frequency, what is [redacted] minimum number [redacted] samples from which [redacted] amplitude may [redacted] computed? Show how [redacted] minimum sample number [redacted] obtained.

Solution. [redacted] $x(t)$ = [redacted] $\cos(2\pi f_0 t$ [redacted] Then

From [redacted] obtains

From [redacted] obtains

From [redacted] obtains

From [redacted] obtains

Equate [redacted] to [redacted]

The result [redacted]

[redacted] = [redacted]

[redacted] $\cos(\alpha$ [redacted] $= A[\cos$ [redacted] $-$ [redacted] where [redacted] $10^{-7}\pi f_0$

[redacted] $\cos(2\alpha$ [redacted] $= A[\cos$ [redacted] $-$ [redacted]

[redacted] $= \frac{x_0}{A}$

[redacted] $= \frac{[redacted] \cos\alpha - [redacted]}{A \sin [redacted]}$

[redacted] $= \frac{1}{\sin [redacted]}\left(\cos [redacted] - \frac{x_1}{x_0}\right)$

[redacted] $= \frac{1}{\sin 2\alpha}\left(\cos [redacted] - \frac{x_2}{x_0}\right)$

[redacted] $\frac{1}{\sin [redacted]}\left(\cos [redacted] - \frac{x_1}{x_0}\right) = \frac{1}{\sin 2\alpha}\left(\cos [redacted] - \frac{x_2}{x_0}\right)$

[redacted] $= \cos^{-1}\left(\frac{x_0 + x_2}{2x_1}\right)$; [redacted] $= 10^{8}$ [redacted]

[redacted] From [redacted] and [redacted] we get

$$[redacted] \cos(\alpha [redacted] = A[\cos [redacted] - [redacted] = [redacted]$$

$$[redacted] = [redacted] - \frac{x_1}{\sin\alpha},$$

$$[redacted] = \frac{\sin\theta}{\cos\theta} = [redacted] - \frac{x_1}{[redacted]\sin [redacted]}$$

[redacted] = [redacted]

In the present [redacted] $= 0.2\pi$, [redacted] $= 2.1213$, [redacted] $= 0.4693$ which results in [redacted] $= \cot(0.2\pi) - \frac{0.4693}{2.1213 \sin 0.2\pi} =$ [redacted] $= 45°$,

The answer is $x(t) =$ [redacted] $\cos(2$ [redacted] $10^6\pi t$ [redacted] $45°)$.

The same answer will [redacted] from [redacted] and [redacted] needed to determine [redacted] and

[redacted] $\sin(\theta)$ obtained $2.1213\cot(0.4\pi)$ [redacted] $1.3620/\sin(0.4\pi) = 2.1213$,

[redacted] $= \left(\frac{2.1213}{2.1213}\right) =$ [redacted] $= 45°$, [redacted] signal [redacted] $x(t) =$ [redacted] $\cos(2\pi f t$ [redacted]

[redacted] Knowing the frequency, two samples [redacted] give enough information). that produce two independent equations [redacted] sinusoidal signals whose measure-
[redacted] (Samples that [redacted] degrees apart

Problem [redacted] For each set of measurements given in Table [redacted] model the sinusoid). (i.e., find the amplitude, frequency, and phase [redacted] $\cos(2\pi f t$ [redacted] the mathematical expression

Problem [redacted] Write the [redacted] and then sketch them.

ments are recorded in

Table [redacted] (Problem 54)

		[redacted]	[redacted] ms	[redacted] ms
	[redacted]	1.7321	1.8437	1.9263
[redacted]	[redacted]	1.7321	0.7615	0.1725
[redacted]	[redacted]	1.6209		0.1979
[redacted]	$x_3(t)$	0.1732	0.1889	
[redacted]	$x_4(t)$	1.4494	2.0148	2.5306
[redacted]	[redacted]	1.4330	1.3831	1.3201
[redacted]	$x_6(t)$	4.2092	4.9875	5.0184
			0.3516	
[redacted]	$x_7(t)$	0.2499		0.4500

Table [redacted] (Problem 55)

	signal	period	x_{max}	[redacted]	$x(0)$	slope [redacted]
[redacted]	[redacted]	[redacted] ms	[redacted]	[redacted]	2.7321	[redacted]
[redacted]	[redacted]	[redacted] ms	[redacted]	[redacted]	2.85	·
[redacted]	$x_3(t)$	[redacted] ms	[redacted]	[redacted]	0.3823	·
[redacted]		[redacted] ms	[redacted]	[redacted]	1.0511	[redacted]
	$x_4(t)$		[redacted]	[redacted]	2.366	[redacted]
[redacted]	[redacted]	[redacted] ms		7.5	3.1823	·
[redacted]	$x_6(t)$	[redacted] ms	2.5		1.0729	[redacted]
[redacted]	$x_7(t)$	[redacted] ms	[redacted]	[redacted]		

Problem [redacted]

Solution [redacted] Problem [redacted] Using [redacted] three sample values [redacted] [redacted] formulation developed [redacted] compute [redacted] [redacted] $x(t) = $ [redacted] $\cos(2\pi f t$ [redacted]. The following Matlab program [redacted] sample program.

```
fprintf([redacted]'Part [redacted]
t=linspace[redacted] 2*10^(-7), [redacted]
[redacted] [redacted]7321 [redacted]8437 [redacted]9263]
x0=1.7321; x1=1.8437; x2=1.9263;
[redacted] (2*pi)[redacted]*acos[redacted](x0+x2)[redacted](2*x1)[redacted]
alpha=2*10^(-7)*pi*f;
theta=atan(cot(alpha)-x1/(x0*sin(alpha)))
A=x0/cos(theta)

x=A*cos(2*pi*f*t+theta)
```

The results [redacted] given below.

```
Part [redacted]
   [redacted]7321    [redacted]8437    [redacted]9263
[redacted]
   [redacted]9974e+005
[redacted]
theta = [redacted]5238
[redacted] = [redacted] 0003
[redacted]

Part [redacted]
   [redacted]6209    [redacted]7615    [redacted]1725
[redacted]
   [redacted]0020e+005
[redacted]
theta= [redacted]9998
```

[illegible] = [illegible] 9990

[illegible]

Part [illegible]

[illegible] = [redacted] 1732 [redacted] 1889 [redacted] 1979

[illegible] = [illegible] 0018e+005

theta = [redacted] 5241

[illegible] = [redacted] 2001

Part [illegible]

= [redacted]4494 [redacted] 0148 [redacted] 5306

[illegible] = [redacted] 4997e-005

theta = [redacted]2001

[illegible] = [redacted]0005

Part [illegible]

= [redacted]4330 [redacted]3831 [redacted]3201

[illegible] = [redacted]5495e+005

theta = [redacted]3002

[illegible] = [redacted]5001

Part [illegible]

= [redacted]2092 [redacted]9875 [redacted]0184

[illegible] = [redacted]2002e+005

theta = [redacted]6000

[illegible] = [redacted]1000

Part [illegible]

= [redacted]2499 [redacted]3516

[illegible] = [redacted]5425e+005 [redacted]4500

theta = [redacted]9 [illegible] [redacted]

[illegible] = [redacted]0921

The answers rounded decimal given

Answers [illegible] Problem [redacted] points

= $\times 10^6 \pi t \cdot \pi/6)$

= [redacted]

[redacted] = [illegible] $\cos(4 \times 10^6 \pi t$

[redacted] = [illegible] $\cos(10^6 \pi t$

[redacted] = [redacted] $\cos(\times 10^6 \pi t \cdot \pi/6)$

[redacted] = [illegible] $\cos(5 \times 1.2)$

[redacted] = [redacted] $\cos(3.1 \; 10^6 \pi t \; 0.3)$

[redacted] = [redacted] $\cos(1.24 \times 10^6 \pi t \cdot 0.6)$

[redacted] = [redacted] $\cos(3.06 \times 10^6 \pi t \; 1.8)$

Problem [redacted] [illegible] sinusoidal

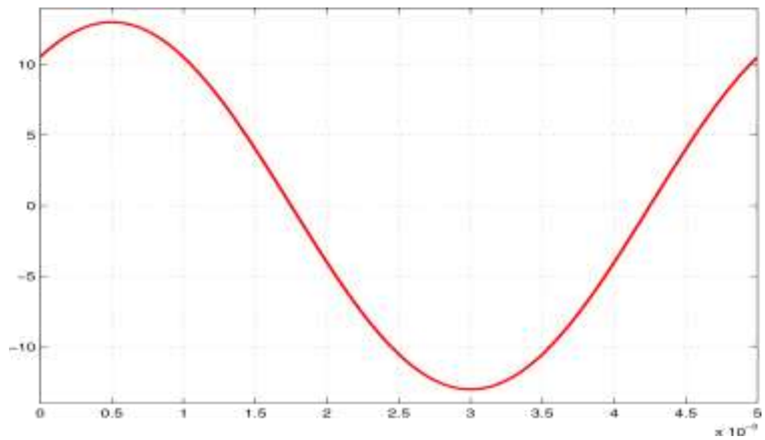
which [illegible] reaches

Ans. [redacted] below.

[redacted] [redacted] [redacted] $=$ [redacted] $\cos(400\pi t - 2\pi/5) -$ [redacted]

voltage $v(t)$ [redacted] [redacted] frequency [redacted] [redacted] Hz, [redacted] [redacted] [redacted] value, [redacted] [redacted] peak value [redacted] [redacted] [redacted] [redacted] t=0.5 [redacted] Write [redacted] equation [redacted] [redacted] function [redacted] time [redacted] [redacted] cosine form.

[redacted]



$v(t) =$ [redacted] $[400\pi(t - 0.0005)] =$ [redacted] $\cos(400\pi t$

$- \pi/5)$

Problem [illegible] low-frequency periodic signal $s(t)$ [illegible] modeled [illegible] value added [illegible] first harmonics [illegible] fundamental frequency (in Hz) given below:

$$s(t) = [illegible] \sum_{n=1}^{N} [illegible] \cos(2\pi n f_s t)$$

The highest frequency $s(t)$ $= N f_s$. The signal $s(t)$ modulates a sinusoidal carrier $\cos(2\pi f_c t)$. The $= 100$ MHz. The modulated modulated waveform $x(t)$ $s(t)\cos(2\pi f_c t)$. $= 100$ kHz, $= 1$ MHz, within band MHz passed through ideal bandpass filter with unity amplitude gain frequency within waveform $x(t)$ MHz [redacted] gain outside The phase introduced filter sinusoidal input possible distortions. $10^{-8} f)$ radians. Find output filter $y(t)$ discuss $= 0.2\pi$ above band filter

Solution. The input $\cos(2\pi f_c t) + \sum_{n=1}^{N} \cos(2\pi n f_s t)\cos(2\pi f_c t) = \cos(2\pi f_c t) + \sum_{n=1}^{N} C_n x_n(t)$

$x(t) = s(t)\cos(2\pi f_c t)$ $=$ $\cos(2\pi n f_s t)\cos(2\pi f_c t)$

where $x_n(t) =$ $\cos(a$ $b)$

phase

$= \left[\cos(a +\right.$

Therefore, $x_n(t) =$ [redacted] $2\pi(f_c +$ $n f_s)t$ $2\pi(f_c$ $n f_s)t$

passing through filter magnitude above remains changes lag. $= 0.2\pi$ $10^{-8} f)$ 0.4π 10^{-9} $f_c)$ component here 10^{8}. radians.

Frequency		Phase	
f		$= 0.4\pi$ 10^{-9} $f_c)$	
$+ n f_s$		$= 0.4\pi$ $10^{-9} n f_s$	
$n f_s$		$= 0.4\pi$ $10^{-9} n f_s$	
Input component		Output component	
$2\pi(f_c + n f_s)t$		$\cos[2\pi(f_c + n f_s)t$ 0.4π $10^{-9} n f_s]$ $= \cos\left[2\pi f_c(t - \tau_c) + 2\pi n f_s(t - \tau_s)\right]$ where $\tau_c = \frac{1}{5 f_c} = 2 \times 10^{-9}$ and $\tau_s = 10^{-9}$	
$2\pi(f_c$ $n f_s)$		$\cos[2\pi(f_c$ $n f_s)t$ $0.4\pi +$ $10^{-9} n f_s]$ $\left[2\pi f_c(t\right.$ $\tau_c)$ $2\pi n f_s$ $\tau_s)]$	

pair filter

The input-output

$x_n(t) =$ [redacted] $2\pi(f_c$ $n f_s)t$ $\tau_c)$ $\tau_s)$ $[2\pi f_c(t$ $\tau_c)$ $2\pi n f_s$ $\tau_s)]$

$y_n(t) =$ [redacted]

$+ nf_s)t + \cos 2\pi(f_c$

$[2\pi f_c(t$ $\quad 2\pi n f_s t$

But

$$\cos(a+b) + \cos(a-b) =$$ [redacted]

Therefore,

$y_n(t) = \cos 2\pi f_c(t - \tau_c)\cos 2\pi n f_s(t - \tau_s)$, where $= \times 10^{-9}$ and

$$y(t) = C_0 \cos 2\pi f_c(t - \tau_c) + \sum_{n=1}^{N}$$ [redacted] $$2\pi n f_s(t - \tau_s)\cos 2\pi f_c(t -$$

$$= s(t - \tau_s)\cos 2\pi f_c(t - \tau_c)$$

$= 10^{-9}$

$\tau_c)$

summary,

$$s(t)\cos 2\pi f_c t \Longrightarrow s(t-\tau_s)\cos 2\pi f_c(t-\tau_c)$$

[redacted] components [redacted] signal $s(t)$ undergo [redacted] equal delay [redacted] = [redacted] resulting [redacted] distortion. The sinusoidal [redacted] modulating carrier undergoes a delay [redacted] = [redacted] [redacted] other changes [redacted] $x(t)$.

Problem [redacted] phasor notation [redacted] show that [redacted] $\cos(\omega t$ [redacted] $\theta_1)$ [redacted] $\cos(\omega t$ [redacted] $\theta_2)$ [redacted] $\cos(\omega t$ [redacted] where

[redacted] $= \sqrt{V_1^2$ [redacted] V_2^2 [redacted] $2V_1V_2\cos(\theta_1-\theta_2)}$

[redacted] $= \tan^{-1}\left[\dfrac{V_1\sin\theta_1 + V_2\sin\theta_2}{V_1\cos\theta_1 + V_2\cos\theta_2}\right]$

Solution.

[redacted] $\cos(\omega t$ [redacted] $\theta_1) =$ [redacted] $\{V_1 e^{j\theta_1} e^{j\omega t}\}$

[redacted] $\cos(\omega t$ [redacted] $\theta_2) =$ [redacted] $\{V_2 e^{j\theta_2} e^{j\omega t}\}$

[redacted] $\cos(\omega t$ [redacted] $\theta_1)$ [redacted] $\cos(\omega t$ [redacted] $\theta_2) =$ [redacted] $\{(V_1 e^{j\theta_1}$ [redacted] $V_2 e^{j\theta_2})e^{j\omega t}\} =$ [redacted] $\{Ve^{j\theta}e^{j\omega t}\}$

$Ve^{j\theta} = V_1 e^{j\theta_1}$ [redacted] $V_2 e^{j\theta_2}$ $\Longrightarrow$ $\begin{cases} V\cos\theta = V_1\cos\theta_1 + V_2\cos\theta_2 & \text{(Eq-1)} \\ V\sin\theta = V_1\sin\theta_1 + V_2\sin\theta_2 & \text{(Eq-2)} \end{cases}$

[redacted] find [redacted] phase divide Eq-2 [redacted] Eq-1.

[redacted] $= \dfrac{V_1\sin\theta_1 + V_2\sin\theta_2}{V_1\cos\theta_1 + V_2\cos\theta_2}$

[redacted] find [redacted] magnitude, square Eq-1 [redacted] Eq-2 [redacted] them side-by-side.

[redacted] $= V_1^2$ [redacted] V_2^2 [redacted] $2V_1V_2(\cos$ [redacted] $\cos$ [redacted] $\sin$ [redacted] $\sin\theta_2)$

$= V_1^2$ [redacted] V_2^2 [redacted] $2V_1V_2\cos(\theta_1-\theta_2)$

Problem [redacted] Shift [redacted] periodic square-wave signal [redacted] Example [redacted] constant value [redacted] show that [redacted] shifted waveform may [redacted] represented [redacted] infinite series [redacted] following form:

$$x(t) = \sum_{n=1}^{\infty} [redacted] \left(\frac{2\pi nt}{T} [redacted] \theta_n\right),$$ where [redacted] $|a_n| = \dfrac{2A}{\pi n}$ [redacted] odd, obtained [redacted] Example [redacted]

Show that [redacted] shift does [redacted] affect conclusions regarding power distribution

Solution.

$x(t-$ [redacted] $) = \sum_{n=1}^{\infty}$ [redacted] $\left(\dfrac{2\pi n(t-\ [redacted]\ )}{T}\right)$

where [redacted] $=$ [redacted] $- \dfrac{2\pi n\tau}{T}$.

[redacted] description [redacted] sinusoids remains [redacted] power spectrum

$+\theta_n\Big) = \sum_{n=1}$ [redacted] $\Big(\frac{}{T} + \phi_n\Big)$;

$$|a_n| = \frac{2A}{\pi n}$$ [redacted]

[redacted] orthogonal [redacted] each other, [redacted] their

[redacted]. Time doesn't affect [redacted] power spectrum [redacted]

amplitude [redacted] changed. [redacted]

periodic signal.

Problem [redacted] The function $x(t) =$ [redacted] approximated during $-T/2$ [redacted] $T/2$ [redacted] finite series

$$y(t) = \frac{T}{\pi}\sum_{n=1}^{N}\frac{T}{\pi n}(-1)^{(n+1)} \text{[redacted]} \left(\frac{2\pi n t}{T}\right)$$

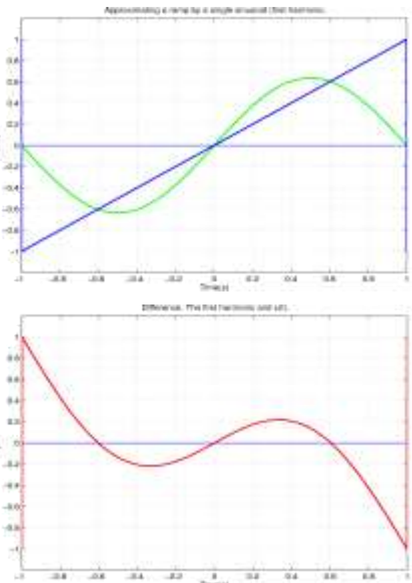
One measure [redacted] approximation [redacted] $= \frac{1}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} |x(t) - y(t)|^2 dt$. Write [redacted] program [redacted] generate $x(t)$ [redacted] $y(t)$.

plot them, [redacted] compute [redacted] 1, ···, [redacted] [redacted] plot [redacted] [redacted] [redacted] [redacted] [redacted] defined above.

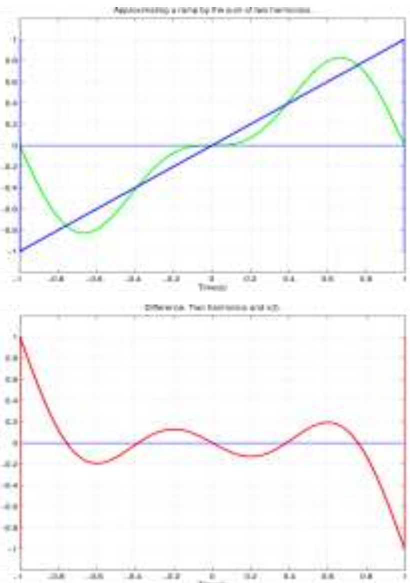
Solution. Run [redacted] program [redacted]

```
N=10;
t=linspace[redacted]1000*N);

[redacted]
for [redacted]
    for [redacted]1000*N;
        p(n,i)=[redacted](-1)^(n-1)*sin(n*pi*t[redacted](pi*n);
    end;
end;
y=sum(p,[redacted]);

e=x-y;
e2=e.^2;
AE=sum(e2)[redacted](1000*N)
```

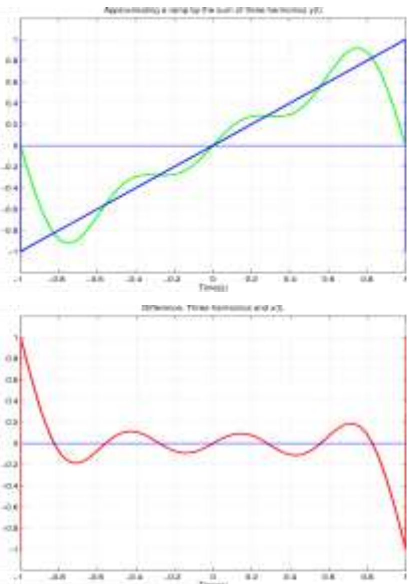
N	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
e	0.1307	0.0800	0.0575	0.0448	0.0367	0.0311	0.0270	0.0238	0.0213	0.0193



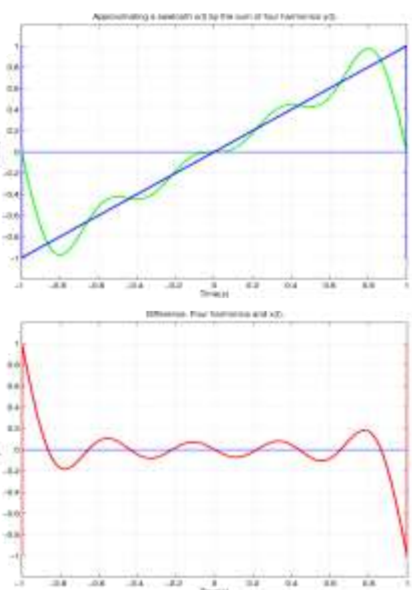
$N = 1$



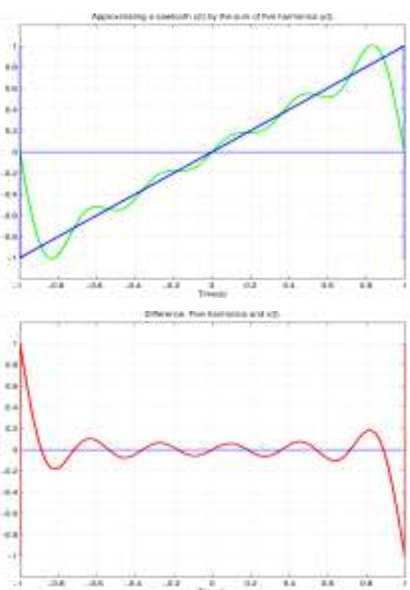
$N = 2$



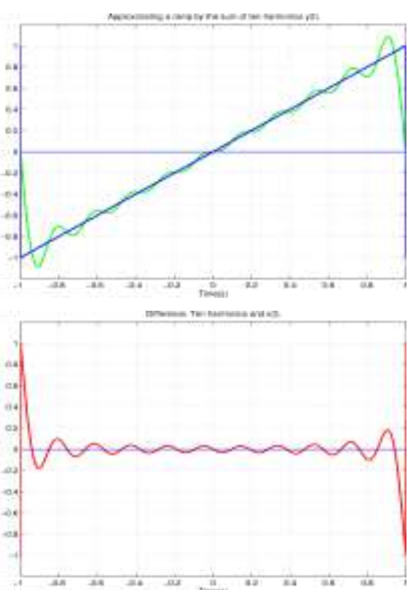
$N = 3$



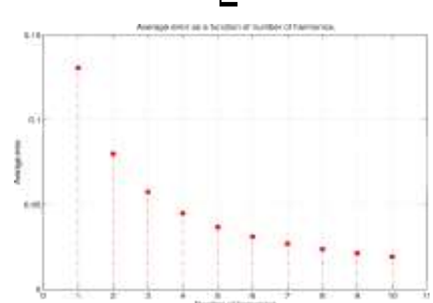
$N = 4$



$N = 5$



$N = 10$



$\bar{\varepsilon}$ vs $N = 1 \cdots 10$

Problem 31. Motion of a free electron in a sinusoidal electric field. An electron has a negative electric charge of $e = 1.602 \times 10^{-19}$ C and a mass of $m = 9.109 \times 10^{-31}$ kg. When placed in an electric field of field strength E it experiences a force of $F = eE$. Determine the span of the motion of an electron in vacuum when [illegible] [illegible] experiences [illegible] subjected [redacted] [redacted] electric field [redacted] 10 $^{6}\cos(2\pi ft)$ V/m [redacted] frequencies [redacted] [redacted] Hz, [redacted] kHz, [redacted] MHz, [redacted] GHz.

Solution.

$$a(t) = \frac{e\mathcal{E}(t)}{m} = [redacted]\cos(2\pi ft), \quad \text{where } [redacted] = 10^{6}\frac{e}{m}$$

[redacted] = [redacted] = [redacted]

$$\text{where } [redacted] = \frac{a_0}{(2\pi f)^2} = \frac{4454.8}{f^2}$$

$$x(t) = X_0\cos(2\pi ft).$$

Frequency	[redacted]	1 kHz	1 MHz	1 GHz
Span [redacted] oscillations	1.237455 [redacted]	4.455 [redacted]	4.455 [redacted]	4.455×10^{-15} [redacted]

Problem [redacted] The Matlab program [redacted] written [redacted] sweep from [redacted] [redacted] right [redacted] [redacted] [redacted] plane. [redacted] each sweep [redacted] plots [redacted] following a sinusoid, then [redacted] beam [redacted] moves down [redacted] incremental value, similar [redacted] [redacted] motion [redacted] [redacted] electron beam [redacted] a cathode [redacted] tube [redacted] operation [redacted] [redacted] recording element [redacted] a seismograph.

```
t=[redacted]:[redacted]:[redacted];
hold [redacted]
for [redacted]
    x=sin(2*pi*k*t)+10-2*k-0.[redacted];
    plot[redacted]);        axis([redacted] [redacted] [redacted]);
    xlabel('Time [redacted]');   ylabel('harmonics'); title(' harmonics [redacted]
    grid;
end
hold off
```

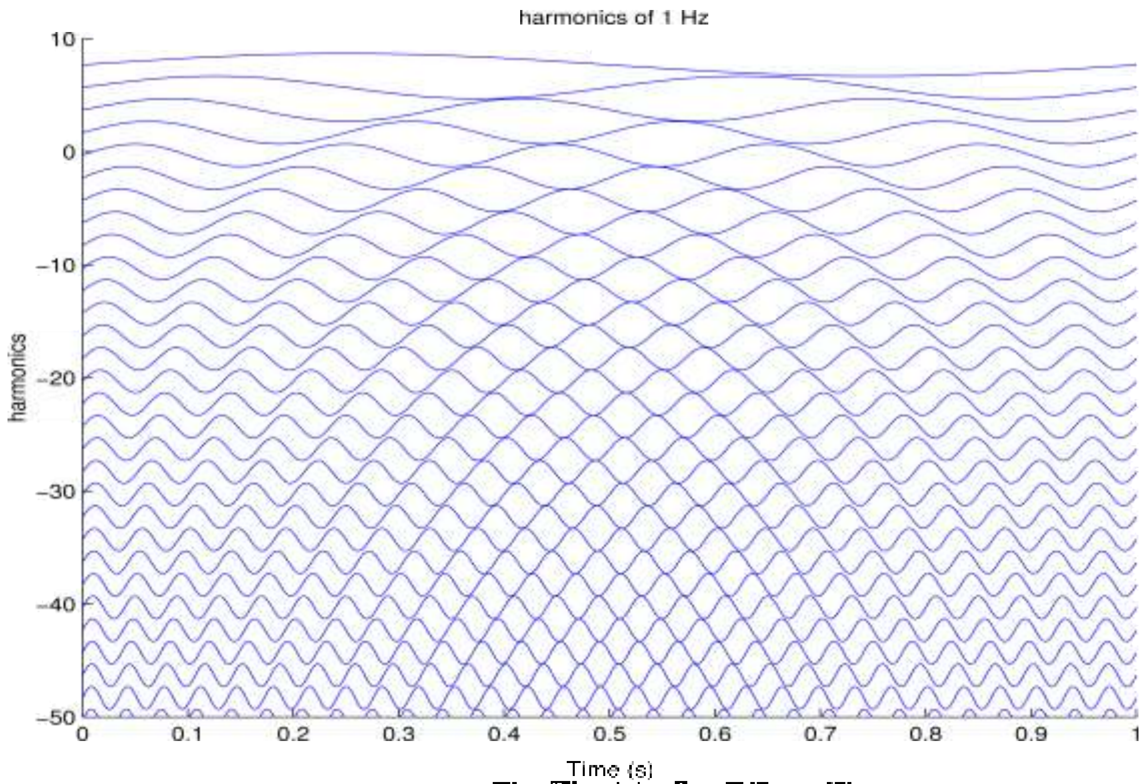
(a) Execute [redacted] program [redacted] examine [redacted] plot [redacted] verify that [redacted] agrees with expectation.

(b) [redacted] successive steps replace [redacted] fourth [redacted] [redacted] [redacted] program with a new command [redacted] from [redacted] following [redacted] [redacted] note [redacted] [redacted] resulting plot agrees with your expectation.

```
x=sin(2*pi*k*t)+2*k+0.[redacted];      axis([redacted] [redacted] [redacted]);
x=sin(2*pi*k*t)+50-2*k-0.[redacted];   axis([redacted] [redacted] [redacted]);
x=sin(2*pi*k*t)+60-2*k-0.[redacted];   axis([redacted] [redacted] [redacted]);
x=sin(2*pi*k*t)+90-2*k-1;      axis([redacted] [redacted] [redacted]);
x=sin(2*pi*k*t)+90-4*k-1;      axis([redacted] [redacted] [redacted]);
y=cos(2*pi*k*t)+90-4*k-3;      axis([redacted] [redacted] [redacted]);  plot[redacted]);
```

Explore [redacted] alternative [redacted] [redacted] variables which would enhance [redacted] wavy appearance [redacted] [redacted] two-dimensional plot.

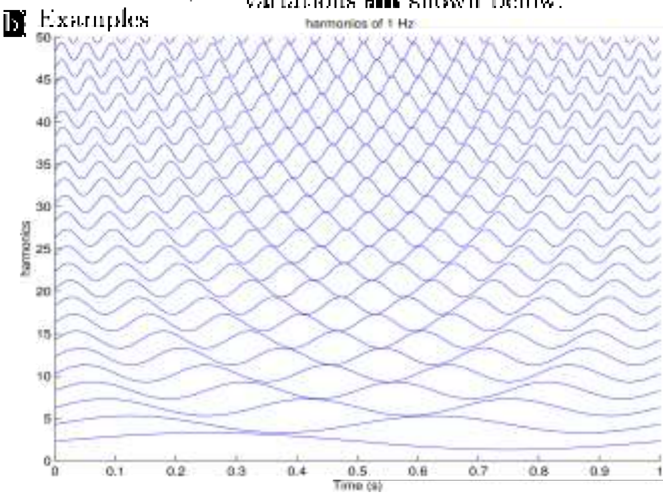
Solution. [redacted] The two-dimensional pattern generated [redacted] [redacted] program [redacted] shown below.

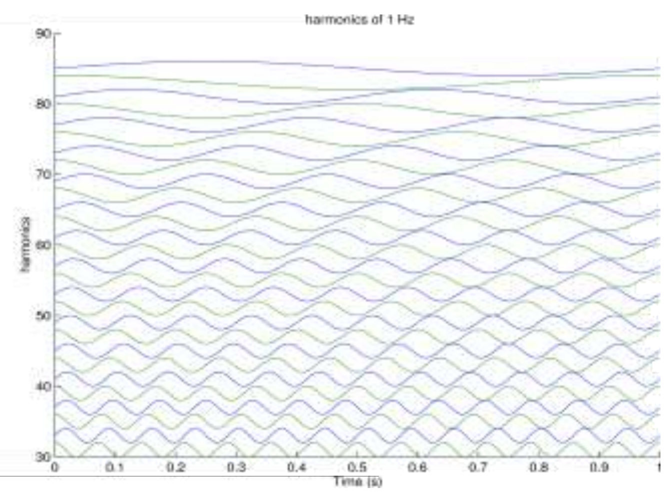


[redacted] $= \sin(2\pi kt)$ [redacted] · [redacted] · 0.3, [redacted] $=$ [redacted] $\cdots$, [redacted]

[redacted] plot variations [redacted] shown below.

[redacted] Examples





[redacted] · [redacted] [redacted] · [redacted] · [redacted] $=$ [redacted] $\cdots$, [redacted]

· , [redacted]

[redacted] $= \sin(2\pi kt)$ · [redacted] $=$ $\sin(2\pi kt)$ [redacted]

Matlab [redacted] 0.3, [redacted] , [redacted] [redacted] $= \cos(2\pi kt)$ [redacted] · [redacted] · [redacted] $=$ [redacted] $\cdots$

The following [redacted] generates plots above patterns.

```
t=[redacted]                                      [redacted]
figure[redacted]                                                        [redacted] sinusoids

hold [redacted]                                                         [redacted] [redacted]
for [redacted]
                       axis[redacted] =50 [redacted]); %Constructs
```

```
ylabel('harmonics');
title('
    harmonics
```

```
    x=sin(2*pi*k*t)+10-2*k-0.3;
plot(t,x)
xlabel('Time
```

```
grid;
   [redacted]
hold [redacted]
print -dpsc pattern_a.[redacted]
print -dtiff pattern_a.tiff   %Saves [redacted] plot [redacted] encapsulated post-script format
%                             %Saves [redacted] plot [redacted] tiff format
figure[redacted]
hold [redacted]
[redacted]
                              axis[redacted] il [redacted] [redacted];
      x=sin(2*pi*k*t)+2*k+0.[redacted];
plot[redacted];
xlabel('Time [redacted] [redacted];
ylabel('harmonics'[redacted];
title('   harmonics [redacted] il [redacted];
grid;
   [redacted]
   hold [redacted]
hold [redacted]
print -dpsc pattern_b.[redacted]
% .... ..............  . ..
figure[redacted]

hold [redacted]
[redacted]
   x=sin(2*pi*k*t)+90-4*k-1;
   y=cos(2*pi*k*t)+90-4*k-3;
   axis[redacted] il [redacted] [redacted]

   plot [redacted];
xlabel('Time [redacted] [redacted];
ylabel('harmonics'[redacted];
title('   harmonics [redacted] il [redacted];
grid;
   [redacted]
   hold [redacted]
hold [redacted]
print -dpsc pattern_f.[redacted]
```

Project: Trajectories, Wave Polarization, and Lissajous Patterns.

Purpose. [redacted] investigate [redacted] trajectories [redacted] sinusoidal motion [redacted] a point [redacted] [redacted] plane [redacted] obtain [redacted] motion from [redacted] patterns [redacted]

Introduction and Summary. The motion [redacted] vector drawn from [redacted] origin [redacted] [redacted] Cartesian coordinates [redacted] sections.

trajectories.

[redacted] point [redacted] plane

may [redacted] found [redacted] eliminating [redacted] point [redacted] The motion [redacted] described

amplitude, phase, [redacted] frequency functions [redacted] time. The path traversed [redacted]

aunne several [redacted] trajectories variable [redacted] from those equations. Some

classes may [redacted] deduced from [redacted] trajectory [redacted]

contains [redacted] where [redacted] coordinate values vary

[redacted] $x(t)$ [redacted] $y(t)$ have [redacted] frequency.

[redacted] The $x(t)$ [redacted] $y(t)$ have slightly different frequencies.

iii) The frequencies [redacted] $x(t)$ [redacted] $y(t)$ [redacted] harmonics [redacted] principle

iv) The frequencies [redacted] $x(t)$ [redacted] $y(t)$ [redacted] harmonics [redacted] principle [redacted] sampling rate.

[redacted] The effect electric circuit.

vi) **Implementation** through [redacted]

parame-

[redacted] stated [redacted] time-varying

[redacted] equations which specify [redacted]

[redacted] vector, called [redacted] trajectory,

parameters [redacted] motion (such [redacted]

[redacted] project [redacted] generate [redacted]

sinusoidally with time. The project

frequency.

frequency.

The present project may [redacted] time [redacted] physical oscillators. Examples from both [redacted] carried [redacted] mathematical simulation [redacted] included.

Section [redacted] $x(t)$ [redacted] $y(t)$ have [redacted] frequency. Consider [redacted] time-varying vector [redacted] plane drawn from [redacted] origin [redacted] point [redacted] whose projections [redacted] given [redacted]

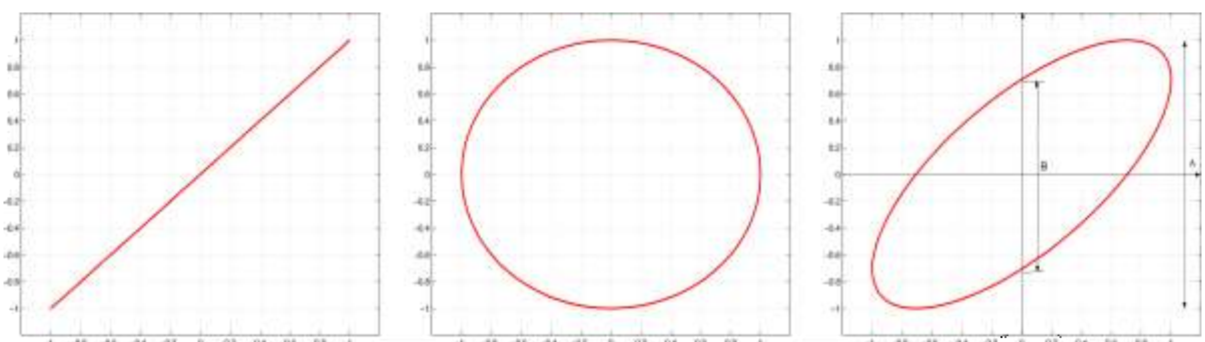
$$\begin{cases} x = E_x \cos \omega t \\ y = E_y \cos(\omega t + [redacted] \end{cases}$$

Depending [redacted] phase difference [redacted] amplitude ratio, three types [redacted] trajectories [redacted] observed: linear (zero phase [redacted] π), circular (equal amplitudes with $\pm\pi/2$ phase) [redacted] elliptical (all other values).

[redacted] **Linear Trajectory.** Show that [redacted] $\frac{E_y}{E_x}$ [redacted] trajectory [redacted] straight line. [redacted] Fig. 14-a. Rotate [redacted] coordinate system [redacted] angle [redacted] counter-clockwise direction [redacted] have [redacted] coordinate system [redacted] relationship between [redacted] coordinate systems [redacted] $\alpha\beta$. Show [redacted]

[redacted] value [redacted] represent [redacted] Determine [redacted] appropriate [redacted] only.

Find [redacted] equation [redacted] trajectory [redacted] coordinate system. [redacted] one-dimensional vector which oscillates [redacted] time along [redacted] α-axis



[redacted] Linear trajectory (b) Circular [redacted] Elliptical

$$\begin{cases} x = E_x \cos \omega t \\ y = E_y \cos \omega t \end{cases}$$

$$\begin{cases} x = E_x \cos \omega t \\ y = \pm E_y \sin \omega t \end{cases}$$

Fig. [redacted] motion [redacted] vector [redacted] plane. [redacted] trajectories [redacted] simple Lissajous patterns. Trajectories [redacted] general case, [redacted] form [redacted] circular [redacted] $\pi/4$) [redacted] have

[redacted] **Circular Trajectory.** Show that [redacted] determine $\frac{2xy}{E_x E_y}$ [redacted] $\pi/2$ [redacted] direction [redacted] motion [redacted] phase [redacted] found from [redacted] trajectory. See Fig. 14-b. Show [redacted] along trajectory.

[redacted] **Elliptical Trajectory.** [redacted] vector [redacted] Show that

$$\left(\frac{x}{E_x}\right)^{[redacted]} [redacted] \left(\frac{y}{E_y}\right)^{[redacted]}$$

[redacted] determine [redacted] direction [redacted] motion [redacted] that angle the the moves

trajectory. the

$$[redacted] = {}^{-1}(B/A)$$

where A and B are as shown in Fig. 14-c. Rotate the xy coordinate system by an x-axis along the major axis of the ellipse. Determine the rotation angle. Write the the new coordinate system.

Simulation by Computer. Run the Matlab code given below to generate a linear

on trajectory.

elliptical

appropriate angle to align equation for the trajectory

trajectory.

```
[redacted] w=2*pi*f; T=1/f; [redacted]; [redacted] [redacted] theta=0;      % Motion parameters
t=linspace[redacted]100*N*T)  x=a*cos(w*t); y=b*cos(w*t+theta)  plot[redacted]   % Trajectory
```

Change [redacted] parameters [redacted] motion [redacted] variables explore how each [redacted] may [redacted] may [redacted] change [redacted] shape [redacted] trajectory. From [redacted] amplitudes [redacted] horizontal [redacted] vertical motions [redacted] phase difference values used [redacted] simulation. [redacted] [redacted] above code [redacted] plots [redacted] trajectories obtain between them. Compare with [redacted]

Parallels with Electromagnetic vector [redacted] a time-varying [redacted] an electromagnetic plane wave [redacted] direction [redacted] propagation. [redacted] variation, [redacted] electric field follows:

Wave Polarization. The electric field vector [redacted] two components; namely, [redacted] which [redacted] [redacted] plane that [redacted] perpendicular [redacted] [redacted] [redacted] x [redacted] y directions. [redacted] [redacted] sinusoidal time [redacted] [redacted] vector with x [redacted] y components (each [redacted] which vary sinusoidally with time) [redacted]

$$\begin{cases} x = E_x \cos \omega t \\ y = E_y \cos(\omega t + [redacted]) \end{cases}$$

Each [redacted] [redacted] [redacted] [redacted] [redacted]

This [redacted] [redacted] same vector [redacted] discussed [redacted] [redacted] beginning [redacted] [redacted] section with three possible [redacted] trajectories. trajectory [redacted] associated with [redacted] type [redacted] wave polarization. The electromagnetic wave, therefore, [redacted] said polarized [redacted] [redacted] [redacted] [redacted] above types. [redacted] addition, [redacted] motion [redacted] [redacted] [redacted] [redacted] electric field vector clockwise [redacted] counter-clockwise directions, labeled [redacted] [redacted] right, circular [redacted] elliptical.

slightly different frequencies.

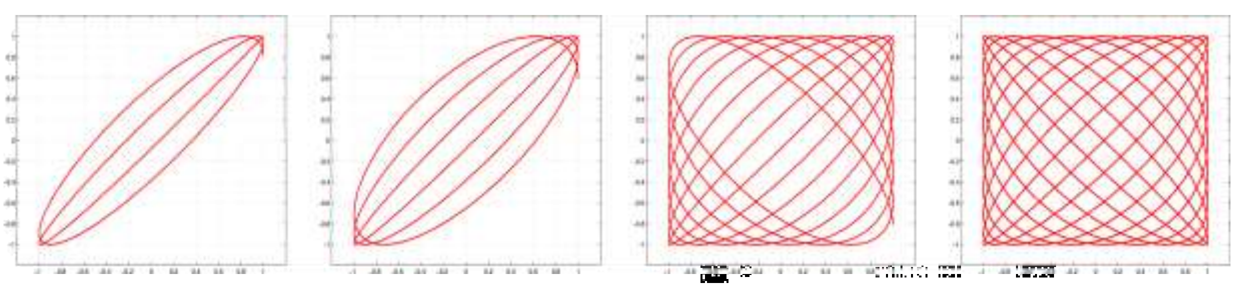
Section [redacted] $x(t)$ [redacted] $y(t)$ have

$$\begin{cases} x(t) = a \cos \omega_1 t \\ y(t) = b \cos \omega_2 t \end{cases}$$

With [redacted] [redacted] [redacted] approximately [redacted] [redacted] (but [redacted] exactly equal), [redacted] difference [redacted] frequencies [redacted] appear [redacted] a time-varying phase difference, resulting [redacted] a trajectory which slowly moves between [redacted] above three patterns. Construct [redacted] example where

$$\begin{cases} x(t) = \cos 2\pi t \\ y(t) = b \cos 2.1\pi t \end{cases}$$

(corresponding [redacted] [redacted] = [redacted] [redacted] [redacted] [redacted] = [redacted] Hz, respectively). Modify [redacted] Matlab program given [redacted] Section [redacted] [redacted] plot [redacted] Lissajous patterns [redacted] [redacted] example, allowing [redacted] plots [redacted] [redacted] generated [redacted] [redacted] [redacted] seconds, [redacted] [redacted] seconds, [redacted] [redacted] seconds, [redacted] [redacted] seconds. Determine [redacted] time needed [redacted] a [redacted] cycle [redacted] each plot.



[redacted] [redacted] seconds (b) [redacted] [redacted] [redacted] (d)

Four Lissajous patterns, [redacted] with a = [redacted] How long does [redacted]

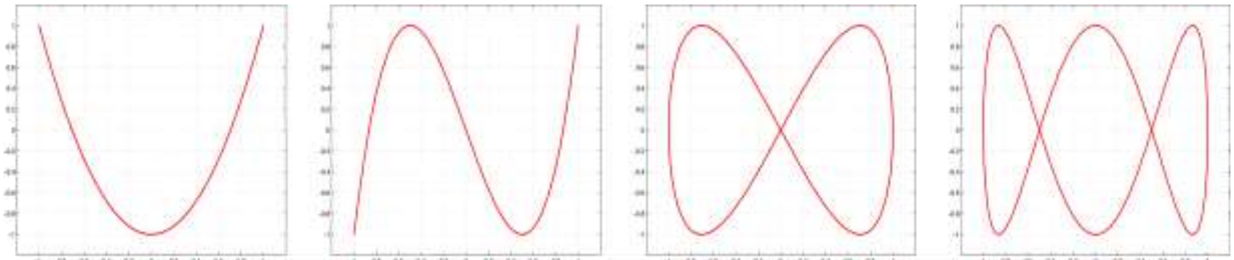
Explore [redacted] effect [redacted] [redacted] = [redacted] [redacted] $k) f_1$, with [redacted] = [redacted] ; 0.1, [redacted] 0.01.

frequencies [redacted] $x(t)$ [redacted] $y(t)$ [redacted] harmonics [redacted] principle [redacted] [redacted] whose shapes [redacted] parameters [redacted] associated with [redacted] frequencies. Fig. [redacted] [redacted] a = [redacted] [redacted] four different variations $y(t)$.

seconds

Section [illegible] The
patterns [illegible] generated
examples [illegible] shown [illegible]

[illegible] complex
[illegible] Four



[redacted] y = [redacted] (b) y = [redacted] [redacted] y = [redacted] (d) y = [redacted]

Fig. [redacted] Four Lissajous patterns with x = [redacted] and various y(t).

Using Matlab, plot [redacted] y versus x with x = $cos(at)$ [redacted] y = $cos(bt)$, [redacted] a/b = [redacted] 3/5. Repeat [redacted] $= cos(at)$ [redacted] trajectories [redacted] each [redacted] eliminate t between y [redacted] x [redacted] obtain [redacted] equation relating them together [redacted] verify y $sin(bt)$. [redacted] plot obtained through Matlab. Determine [redacted] number [redacted] crossings [redacted] horizontal [redacted] representation [redacted] [redacted] vertical [redacted] relate them [redacted] ratio a/b. Suggest a method [redacted] measure [redacted] frequency [redacted] signal from Lissajous patterns.

[redacted] a sinusoidal [redacted] harmonics [redacted] principle [redacted] theory, [redacted] take $x(t)$ [redacted] practice (e.g., simulation [redacted] Matlab [redacted]

Section [redacted] The [redacted] pattern [redacted] repeat itself. Run [redacted] tion [redacted] periodic frequencies oscillators), with [redacted] Repeat [redacted] procedure trend, [redacted] $y(t)$ compare

real-time experiment using [redacted] eventually following Matlab code, observe physical Lissajous Section after replacing [redacted] observations frequency. repeat.

[redacted] %Repeat [redacted] 3.1t. [redacted] This

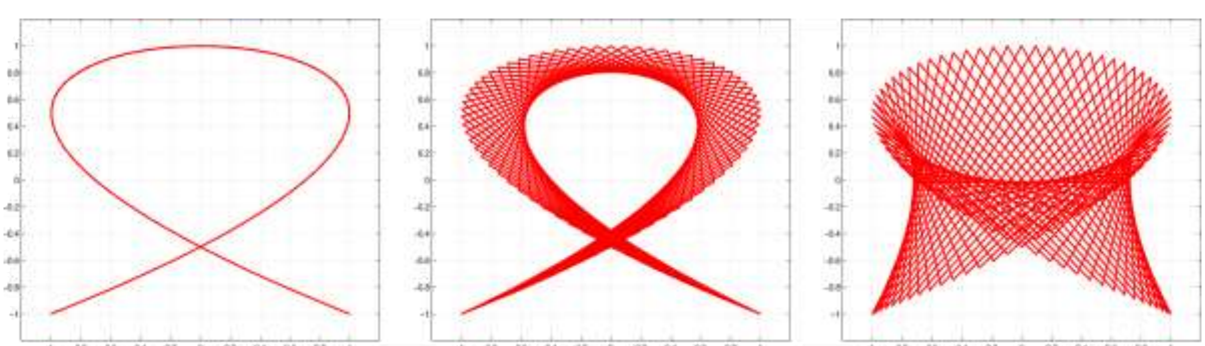
```
t=linspace[redacted]N*pi,800)
[redacted] y=cos([redacted]*t);
plot[redacted]
```

different sampling

Section [redacted] Effect [redacted] low sampling rate. [redacted] plotting a trajectory, [redacted] x [redacted] y coordinates sufficiently fast. Otherwise [redacted] plot [redacted] exhibit [redacted] artifacts caused [redacted] a [redacted] number shown [redacted] following [redacted] examples. examples [redacted] Lissajous patterns derived from [redacted] motion [redacted] with three samples.

[redacted] Generate three rates. You may [redacted] following code [redacted] purpose.

```
[redacted] % Repeat N=20
t=linspace[redacted]N*pi,100)
[redacted](2*t); y=sin(3*t); plot[redacted]
```



[redacted] [redacted] [redacted] time

[illegible] [illegible] = [illegible] (b) [illegible]

[illegible] [illegible] [illegible] following [illegible] [illegible] samples [illegible] (T)

[illegible] [illegible] = [illegible] [illegible] = 100, [illegible] [illegible]

[illegible] [illegible] = [illegible] [illegible] = [illegible] [illegible] [illegible]

(iii) [illegible] = 100, [illegible] = [illegible] [illegible]

(iv) [illegible] = 200, [illegible] = [illegible]

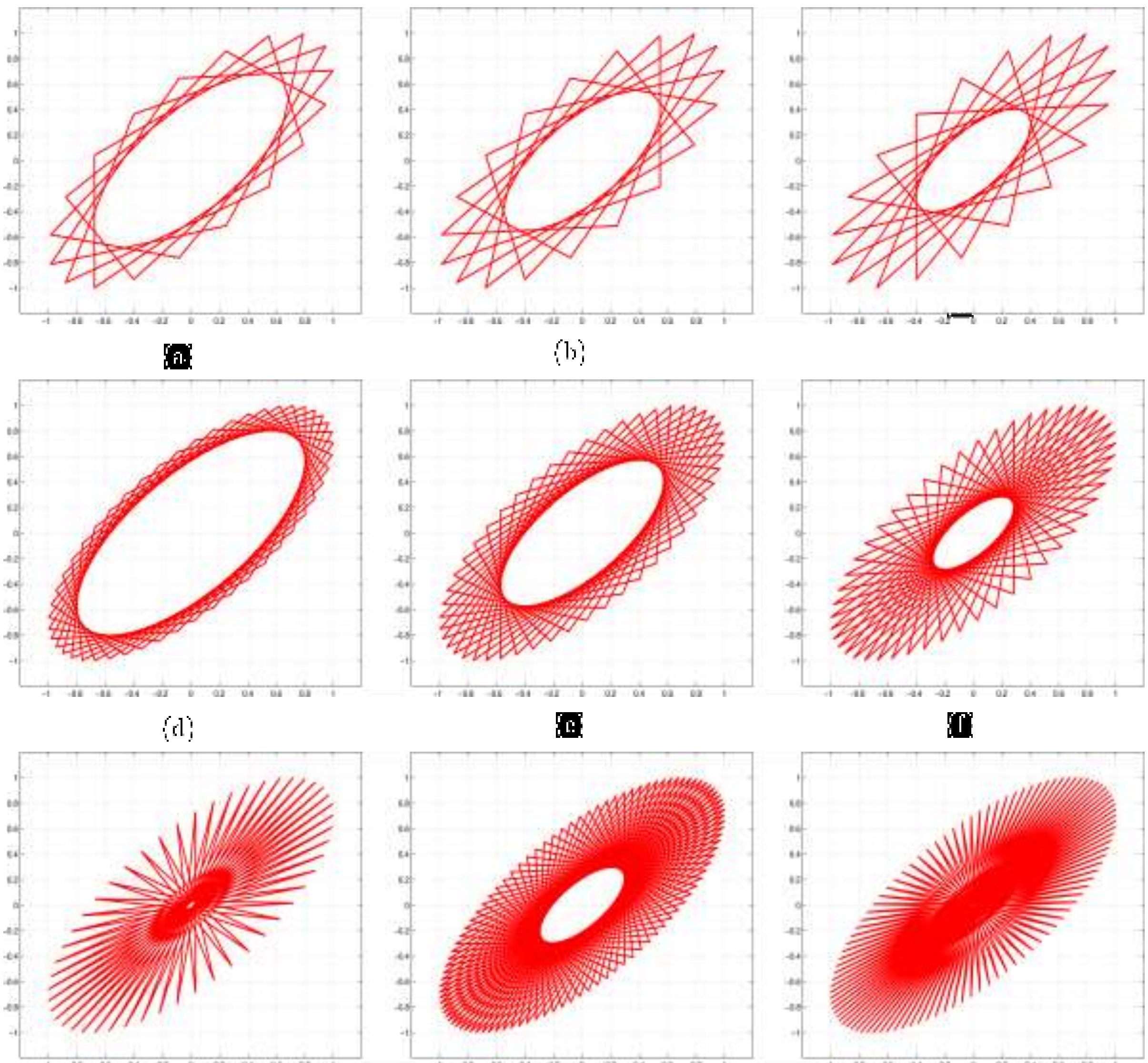
[illegible] sampled

effect

[illegible] =

[redacted] Matlab code given below [redacted] explain trends [redacted] plots.

```
t=linspace([redacted]);
[redacted](2*pi*t), y=cos(2*pi*t+pi/4); plot[redacted]
```



[redacted] (b) (d) [redacted] (h)

Section [redacted] Implementation through [redacted] Electric Circuit. [redacted] whose horizontal [redacted] them

deflections [redacted] controlled [redacted] signals $x(t)$ [redacted] $y(t)$, respectively, eliminates between [redacted] purpose, [redacted] ordinary oscilloscope [redacted] used [redacted] Fig. 16-a with [redacted] motion trajectory.

[redacted] described [redacted] Section [redacted] Configure circuit sinusoidal voltage signal [redacted]

[redacted] Start with [redacted] situation function generator [redacted] peak-to-peak [redacted] scope. [redacted]

[redacted] $C = 1$ [redacted] μF. [redacted] as shown, [redacted] horizontal [redacted] scope voltage [redacted]

[redacted] connect [redacted] voltage vertical [redacted] The between

1500 [redacted] terminal characteristics provide 2-[redacted] Kirchhoff's current [redacted]

deflection mode. Connect [redacted] reality [redacted] capacitor [redacted]

[redacted] for settings,

The result

project.

circuit

using

$\cos(\omega t$

above

Show that

$$\cos 10000t \quad - 0.707 \cos\left(10000t\right.$$

vertical

displays

deflection mode.

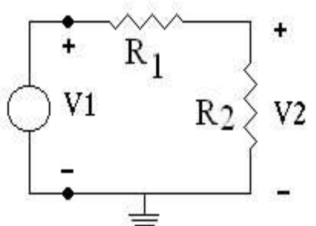
relationship

$$\frac{C^2\omega^2}{\sqrt{1+R^2C^2\omega^2}}, \qquad -\tan^{-1}(RC\omega)$$

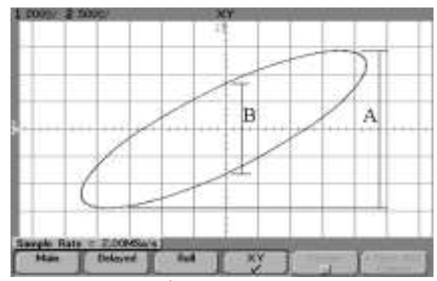
The elliptic pattern shown [redacted] Fig. 16-a should appear [redacted] [redacted] scope. Find [redacted] equation [redacted] [redacted] trajectory [redacted] [redacted] screen [redacted] predicted from theory. Compute [redacted] phase angle between [redacted] [redacted] [redacted] from

$$[redacted] = \;(B/A)$$

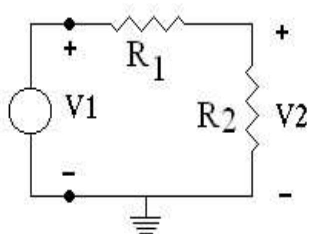
where [redacted] [redacted] [redacted] [redacted] shown [redacted] [redacted] ellipse. The phase angle [redacted] expected [redacted] [redacted] [redacted] The [redacted] amplitudes [redacted] [redacted] horizontal [redacted] vertical signals may [redacted] changed through [redacted] horizontal [redacted] vertical gains [redacted] [redacted] [redacted] scope. The phase angle between [redacted] horizontal [redacted] vertical signals [redacted] [redacted] changed [redacted] changing [redacted] frequency [redacted] [redacted] signal generator. Explore [redacted] effect [redacted] [redacted] above parameters [redacted] [redacted] shape [redacted] [redacted] trajectory.



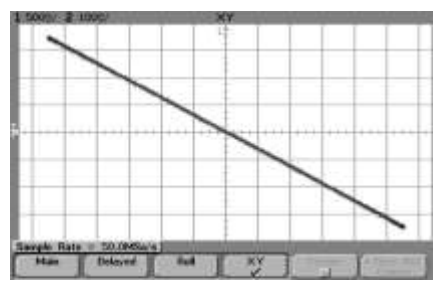
[redacted] [redacted] circuit.



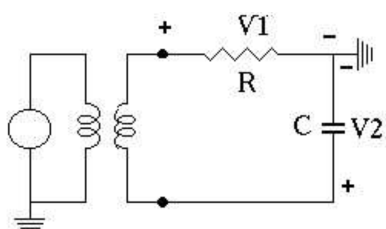
Elliptic trajectory



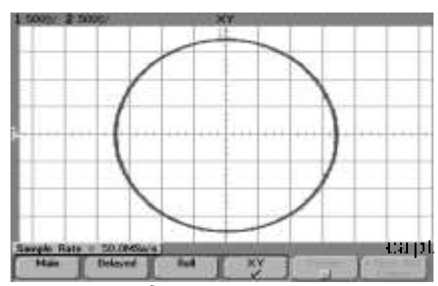
[redacted] [redacted] circuit



Linear trajectory



[redacted] [redacted] circuit [redacted] [redacted] isolation transformer



Circular trajectory

Fig. [redacted] Three circuits [redacted] generating [redacted] [redacted] [redacted] coordinate signals [redacted] [redacted] resulting trajectories captured [redacted] [redacted] oscilloscope.

[redacted] obtain [redacted] linear trajectory, replace [redacted] capacitor [redacted] [redacted] circuit [redacted] [redacted] resistor. The circuit [redacted] shown [redacted] Fig. 16-b. Relate [redacted] slope [redacted] [redacted] trajectory [redacted] [redacted] resistor values [redacted] [redacted] [redacted] resulting trajectory horizontal [redacted] vertical gains [redacted] [redacted] oscilloscope.

[redacted] obtain [redacted] circular trajectory [redacted] [redacted] circuit configuration [redacted] Fig. 16-c which contains [redacted] isolation transformer. [redacted] sections [redacted] III, IV, [redacted] [redacted] [redacted] that directly connected [redacted] [redacted] horizontal [redacted] vertical channels. [redacted] [redacted] situations described [redacted] digital approach computer) from

[redacted] Continue with real-time implementations [redacted] purpose [redacted] [redacted] employ [redacted] sinusoidal signal generators obtained

[illegible]

Conclusions. Describe your overall conclusions from the

[illegible] draw the line which distinguishes the results

[illegible] the function

the analog approach (using generator and

project. What applications may it have? Where

[illegible] (using the

oscilloscope)?