Answers to selected exercises for chapter 1

1.1   Apply $\cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$, then

$$f_1(t) + f_2(t)$$
$$= A_1\cos\omega t\cos\phi_1 - A_1\sin\omega t\sin\phi_1 + A_2\cos\omega t\cos\phi_2 - A_2\sin\omega t\sin\phi_2$$
$$= (A_1\cos\phi_1 + A_2\cos\phi_2)\cos\omega t - (A_1\sin\phi_1 + A_2\sin\phi_2)\sin\omega t$$
$$= C_1\cos\omega t - C_2\sin\omega t,$$

where $C_1 = A_1\cos\phi_1 + A_2\cos\phi_2$ and $C_2 = A_1\sin\phi_1 + A_2\sin\phi_2$. Put $A = \sqrt{C_1^2 + C_2^2}$ and take ϕ such that $\cos\phi = C_1/A$ and $\sin\phi = C_2/A$ (this is possible since $(C_1/A)^2 + (C_2/A)^2 = 1$). Now $f_1(t) + f_2(t) = A(\cos\omega t\cos\phi - \sin\omega t\sin\phi) = A\cos(\omega t + \phi)$.

1.2   Put $c_1 = A_1 e^{i\phi_1}$ and $c_2 = A_2 e^{i\phi_2}$, then $f_1(t) + f_2(t) = (c_1 + c_2)e^{i\omega t}$. Let $c = c_1 + c_2$, then $f_1(t) + f_2(t) = ce^{i\omega t}$. The signal $f_1(t) + f_2(t)$ is again a time-harmonic signal with amplitude $|c|$ and initial phase $\arg c$.

1.5   The power P is given by

$$P = \frac{\omega}{2\pi}\int_{-\pi/\omega}^{\pi/\omega} A^2\cos^2(\omega t + \phi_0)\,dt = \frac{A^2\omega}{4\pi}\int_{-\pi/\omega}^{\pi/\omega}(1 + \cos(2\omega t + 2\phi_0))\,dt$$
$$= \frac{A^2}{2}.$$

1.6   The energy-content is $E = \int_0^\infty e^{-2t}\,dt = \frac{1}{2}$.

1.7   The power P is given by

$$P = \frac{1}{4}\sum_{n=0}^{3}|\cos(n\pi/2)|^2 = \frac{1}{2}.$$

1.8   The energy-content is $E = \sum_{n=0}^{\infty}e^{-2n}$, which is a geometric series with sum $1/(1 - e^{-2})$.

1.9   **a** If $u(t)$ is real, then the integral, and so $y(t)$, is also real.
b Since

$$\left|\int u(\tau)\,d\tau\right| \leq \int |u(\tau)|\,d\tau,$$

it follows from the boundedness of $u(t)$, so $|u(\tau)| \leq K$ for some constant K, that $y(t)$ is also bounded.
c The linearity follows immediately from the linearity of integration. The time-invariance follows from the substitution $\xi = \tau - t_0$ in the integral $\int_{t-1}^{t}u(\tau - t_0)\,d\tau$ representing the response to $u(t - t_0)$.
d Calculating $\int_{t-1}^{t}\cos(\omega\tau)\,d\tau$ gives the following response: $(\sin(\omega t) - \sin(\omega t - \omega))/\omega = 2\sin(\omega/2)\cos(\omega t - \omega/2)/\omega$.
e Calculating $\int_{t-1}^{t}\sin(\omega\tau)\,d\tau$ gives the following response: $(-\cos(\omega t) + \cos(\omega t - \omega))/\omega = 2\sin(\omega/2)\sin(\omega t - \omega/2)/\omega$.
f From the response to $\cos(\omega t)$ in d it follows that the amplitude response is $|2\sin(\omega/2)/\omega|$.
g From the response to $\cos(\omega t)$ in d it follows that the phase response is $-\omega/2$ if $2\sin(\omega/2)/\omega \geq 0$ and $-\omega/2 + \pi$ if $2\sin(\omega/2)/\omega < 0$. From

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Khamies El-Shennawy

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