P5.9. $\mathbf{E} = 37.7 \cos(9\pi \times 10^7 t + 0.3\pi y)\, \mathbf{a}_x$ V/m

(a) $\omega = 9\pi \times 10^7$

$$f = \frac{\omega}{2\pi} = 4.5 \times 10^7 \text{ Hz} = 45 \text{ MHz}$$

(b) $\beta = 0.3\pi$

$$\lambda = \frac{2\pi}{\beta} = \frac{2}{0.3} = 6\frac{2}{3}\text{m}$$

(c) Direction of propagation is the $-y$ direction in view of the argument $(9\pi \times 10^7 t + 0.3\pi y)$ for the cosine function.

(d) Amplitude of $\mathbf{H} = \dfrac{37.7}{\eta_0} = 0.1$

At $y = 0$, $t = 0$, direction of $\mathbf{E}$ is along $\mathbf{a}_x$. For $\mathbf{E} \times \mathbf{H}$ to be along $-\mathbf{a}_y$, direction of $\mathbf{H}$ at $x = 0$, $t = 0$ must be along $\mathbf{a}_z$. Thus

$$\mathbf{H} = 0.1 \cos(9\pi \times 10^7 t + 0.3\pi y)\, \mathbf{a}_z \text{ A/m}$$

P5.10. $f = 100$ MHz, $\omega = 2\pi \times 10^8$

$$\beta = \frac{\omega}{v_p} = \frac{2\pi \times 10^8}{3 \times 10^8} = \frac{2\pi}{3}$$

Let the electric field be

$$\mathbf{E} = E_1 \cos\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + \phi\right) \mathbf{a}_x + E_1 \sin\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + \phi\right) \mathbf{a}_y$$

Note that for $\phi = 0$ and $z = 0$, $\mathbf{E} = E_1 \mathbf{a}_x$ for $\omega t = 0$, $E_1 \mathbf{a}_y$ for $\omega t = \frac{\pi}{2}$, and hence $\mathbf{E}$ is right circularly polarized. Now from (c),

$E_1 \cos \phi = E_0$, $E_1 \sin \phi = 0.75 E_0$

$$\therefore \; E_1 = \sqrt{E_0^2 + (0.75 E_0)^2} = 1.25 E_0$$

$\cos \phi = 0.8$, $\sin \phi = 0.6$

$\phi = 36.87^\circ$ or 0.2048π

Thus

$$\begin{aligned}\mathbf{E} &= 1.25 E_0 \cos\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_x \\ &\quad + 1.25 E_0 \sin\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_y \\ &= 1.25 E_0 \left[\cos\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_x \right. \\ &\qquad \left. + \sin\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_y\right]\end{aligned}$$

$$\begin{aligned}\mathbf{H} &= \frac{1.25 E_0}{120\pi}\left[-\sin\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_x \right. \\ &\qquad \left. + \cos\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_y\right] \\ &= \frac{E_0}{96\pi}\left[-\sin\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_x \right. \\ &\qquad \left. + \cos\left(2\pi \times 10^8 t - \frac{2\pi}{3} z + 0.2048\pi\right) \mathbf{a}_y\right]\end{aligned}$$

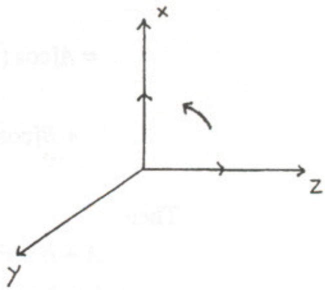
P5.13. (a) $E_0 \cos(\omega t - \beta y)\,\mathbf{a}_z + E_0 \sin(\omega t - \beta y)\,\mathbf{a}_x$

For $y = 0$, $\omega t = 0$, the field is $E_0\mathbf{a}_z$.

For $y = 0$, $\omega t = \dfrac{\pi}{2}$, the field is $E_0\mathbf{a}_x$.

Direction of propagation is $+y$.

$\therefore$ Polarization is right circular.



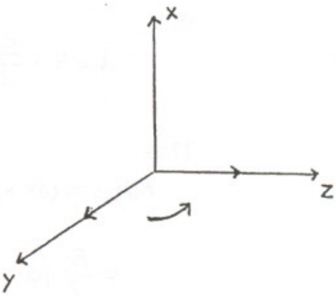
(b) $E_0 \cos(\omega t + \beta x)\,\mathbf{a}_y + E_0 \sin(\omega t + \beta x)\,\mathbf{a}_z$

For $x = 0$, $\omega t = 0$, the field is $E_0\mathbf{a}_y$.

For $x = 0$, $\omega t = \dfrac{\pi}{2}$, the field is $E_0\mathbf{a}_z$.

Direction of propagation is $-x$.

$\therefore$ Polarization is left circular.



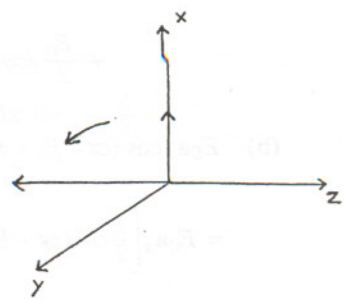
(c) $E_0 \cos(\omega t + \beta y)\,\mathbf{a}_x - 2E_0 \sin(\omega t + \beta y)\,\mathbf{a}_z$

For $y = 0$, $\omega t = 0$, the field is $E_0\mathbf{a}_x$.

For $y = 0$, $\omega t = \dfrac{\pi}{2}$, the field is $-2E_0\mathbf{a}_z$.

Direction of propagation is $-y$.

$\therefore$ Polarization is left elliptical.



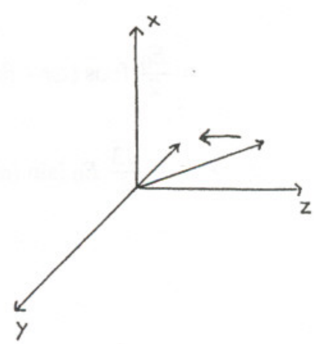
(d) $E_0 \cos(\omega t - \beta x)\,\mathbf{a}_z - E_0 \sin(\omega t - \beta x + \pi/4)\,\mathbf{a}_y$

For $x = 0$, $\omega t = 0$, the field is $E_0\left(\mathbf{a}_z - \dfrac{1}{\sqrt{2}}\mathbf{a}_y\right)$

For $x = 0$, $\omega t = \dfrac{\pi}{2}$, the field is $-\dfrac{1}{\sqrt{2}}E_0\mathbf{a}_y$.

The direction of propagation is $+x$.

$\therefore$ Polarization is right elliptical.



P5.21. (a) $e^{-28.65\alpha} = e^{-1}$, $\alpha = \dfrac{1}{28.65} = 0.0349$

$$111.2\beta = 2\pi,\ \beta = \frac{2\pi}{111.2} = 0.0565$$

$$\bar{\gamma} = 0.0349 + j0.0565$$

(b) $|\bar{\eta}| = 59.4$

$$\angle\bar{\gamma} = \tan^{-1}\frac{0.0565}{0.0349} = 58.3^\circ$$

Since $\bar{\gamma}\bar{\eta} = j\omega\mu$, 5.70(a) P278

$$\angle\bar{\eta} = 90^\circ - \angle\bar{\gamma} = 31.7^\circ$$

$$\therefore\ \bar{\eta} = 59.4\angle 31.7^\circ$$

(c) $\sigma = \text{Re}\left[\dfrac{\bar{\gamma}}{\bar{\eta}}\right] = \text{Re}\left[\dfrac{0.0349 + j0.0565}{59.4\angle 31.7^\circ}\right]$ 5.71 a

$$= \text{Re}\frac{0.0664\angle 58.3^\circ}{59.4\angle 31.7^\circ} = \text{Re}\ (0.001118\angle 26.6^\circ)$$

$$= 0.001118 \cos 26.6^\circ$$

$$= 0.001 = 10^{-3}\ \text{S/m}$$

$\varepsilon = \dfrac{1}{\omega}\text{Im}\dfrac{\bar{\gamma}}{\bar{\eta}} = \dfrac{1}{2\pi \times 5 \times 10^5}\ \text{Im}\ (0.001118\angle 26.6^\circ)$ 5.71 b

$$= \frac{1}{10^6\pi}(0.001118 \sin 26.6^\circ) = \frac{5 \times 10^{-4}}{10^6\pi}$$

$$= \frac{10^{-9}}{2\pi} = 18 \times \frac{10^{-9}}{36\pi} = 18\varepsilon_0$$

$\mu = \dfrac{\bar{\gamma}\bar{\eta}}{j\omega} = \dfrac{|\bar{\gamma}\bar{\eta}|}{\omega} = \dfrac{0.0664 \times 59.4}{2\pi \times 5 \times 10^5}$ 5.71 c

$$= 1.26 \times 10^{-6} = 4\pi \times 10^{-7} = \mu_0$$

P5.29. $\sigma = 4$ S/m, $\varepsilon = 80\varepsilon_0$, $\mu = \mu_0$

(a) $f = 10$ GHz, $\dfrac{\sigma}{\omega\varepsilon} = \dfrac{4\times 36\pi}{2\pi\times 10^{10}\times 80\times 10^{-9}} = \dfrac{9}{100} << 1$

The medium behaves like an imperfect dielectric.

$$\alpha \approx \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} = \frac{4}{2}\sqrt{\frac{\mu_0}{80\varepsilon_0}} = \frac{2\times 120\pi}{\sqrt{80}} = 84.3 \text{ Np/m}$$

$$\delta = \frac{1}{\alpha} = \frac{1}{84.3} = 0.0119 \text{ m} = 11.9 \text{ mm}$$

$$\beta \approx \omega\sqrt{\mu\varepsilon} = 2\pi\times 10^{10}\times\frac{\sqrt{80}}{3\times 10^{8}} = 1873 \text{ rad/m}$$

$$\lambda = \frac{2\pi}{\beta} = 3.355\times 10^{-3} \text{ m} = 3.355 \text{ mm}$$

$$v_p = \frac{\omega}{\beta} = \frac{2\pi\times 10^{10}}{1873} = 0.3355\times 10^{8} \text{ m/s}$$

$$\bar{\eta} \approx \sqrt{\frac{\mu}{\varepsilon}} = \frac{120\pi}{\sqrt{80}} = 42.15\ \Omega$$

(b) $f = 100$ kHz, $\dfrac{\sigma}{\omega\varepsilon} = \dfrac{4\times 36\pi}{2\pi\times 10^{5}\times 80\times 10^{-9}} = 9\times 10^{3} >> 1$

The medium behaves like a good conductor.

$$\alpha \approx \sqrt{\pi f\mu\sigma} = \sqrt{\pi\times 10^{5}\times 4\pi\times 10^{-7}\times 4} = 0.4\pi \text{ m}^{-1}$$

$$\delta = \frac{1}{\alpha} = \frac{1}{0.4\pi} = 0.796 \text{ m}$$

$$\beta \approx \sqrt{\pi f\mu\sigma} = 0.4\pi \text{ rad/m}$$

$$\lambda = \frac{2\pi}{\beta} = 5 \text{ m}$$

$$v_p = \frac{\omega}{\beta} = \frac{2\pi\times 10^{5}}{0.4\pi} = 5\times 10^{5} \text{ m/s}$$

$$\bar{\eta} \approx \sqrt{\frac{\pi f\mu}{\sigma}}(1+j) = \sqrt{\frac{\pi\times 10^{5}\times 4\pi\times 10^{-7}}{4}}(1+j)$$

$$= 0.1\pi(1+j)\ \Omega$$

P5.32. (a) $\mathbf{E} = E_0 \cos(\omega t - \beta z)\,\mathbf{a}_x + 2E_0 \cos(\omega t - \beta z)\,\mathbf{a}_y$

$$\mathbf{H} = \frac{E_0}{\eta_0}\left[-2\cos(\omega t - \beta z)\,\mathbf{a}_x + \cos(\omega t - \beta z)\,\mathbf{a}_y\right]$$

$$\mathbf{P} = \mathbf{E} \times \mathbf{H} = (E_x H_y - E_y H_x)\,\mathbf{a}_z$$

$$= \frac{5E_0^2}{\eta_0}\cos^2(\omega t - \beta z)\,\mathbf{a}_z$$

$$\langle \mathbf{P} \rangle = \frac{2.5E_0^2}{\eta_0}\,\mathbf{a}_z$$

(b) $\mathbf{E} = E_0 \cos(\omega t - \beta z)\,\mathbf{a}_x - E_0 \sin(\omega t - \beta z)\,\mathbf{a}_y$

$$\mathbf{H} = \frac{E_0}{\eta_0}\left[\sin(\omega t - \beta z)\,\mathbf{a}_x + \cos(\omega t - \beta z)\,\mathbf{a}_y\right]$$

$$\mathbf{P} = \frac{E_0^2}{\eta_0}\left[\cos^2(\omega t - \beta z) + \sin^2(\omega t - \beta z)\right]\mathbf{a}_z$$

$$= \frac{E_0^2}{\eta_0}\,\mathbf{a}_z$$

$$\langle \mathbf{P} \rangle = \frac{E_0^2}{\eta_0}\,\mathbf{a}_z$$

(c) $\mathbf{E} = E_0 \cos(\omega t - \beta z)\,\mathbf{a}_x + 2E_0 \sin(\omega t - \beta z)\,\mathbf{a}_y$

$$\mathbf{H} = \frac{E_0}{\eta_0}\left[-2E_0\sin(\omega t - \beta z)\,\mathbf{a}_x + E_0\cos(\omega t - \beta z)\,\mathbf{a}_y\right]$$

$$\mathbf{P} = \frac{E_0^2}{\eta_0}\left[\cos^2(\omega t - \beta z) + 4\sin^2(\omega t - \beta z)\right]\mathbf{a}_z$$

$$= \frac{E_0^2}{\eta_0}\left[1 + 3\sin^2(\omega t - \beta z)\right]\mathbf{a}_z$$

$$\langle \mathbf{P} \rangle = \frac{E_0^2}{\eta_0}\left(1 + \frac{3}{2}\right)\mathbf{a}_z$$

$$= \frac{2.5E_0^2}{\eta_0}\,\mathbf{a}_z$$

P5.35. For $\mathbf{H} = H_0 e^{-z} \cos(2\pi \times 10^6 t - 2z)\, \mathbf{a}_x$,

$$\bar{\gamma} = \alpha + j\beta = 1 + j2$$

$$\bar{\eta} = \frac{j\omega\mu}{\bar{\gamma}} = \frac{j2\pi \times 10^6 \times 4\pi \times 10^{-7}}{1 + j2}$$

$$= \frac{0.8\pi^2 \angle 90^\circ}{\sqrt{5} \angle 63.43^\circ} = 3.531 \angle 26.57^\circ$$

$$\therefore \quad \mathbf{H} = 3.531 H_0 e^{-z} \cos(2\pi \times 10^6 t - 2z + 0.1476\pi)\, \mathbf{a}_y$$

$$\mathbf{P} = \mathbf{E} \times \mathbf{H}$$

$$= 1.7655 H_0^2 e^{-2z} \left[\cos 0.1476\pi + \cos(4\pi \times 10^6 t - 4z - 0.1476\pi)\right] \mathbf{a}_z$$

(a) $\langle P_z \rangle = 1.7655 H_0^2 e^{-2z} \cos 0.1476\pi$

$$= 1.5791 H_0^2 e^{-2z} \text{ W/m}^2$$

(b) Time-average power dissipated in the given volume

$$= 1.5791 H_0^2 \left(1 - e^{-2}\right)$$

$$= 1.3654 H_0^2 \text{ W}$$

P5.36. For $\sigma = 10^{-4}$ S/m, $\varepsilon = 5\varepsilon_0$, $\mu = \mu_0$, $f = 1.5 \times 10^5$ Hz,

$$\bar{\gamma} = (6.283 + j9.425) \times 10^{-3}$$

$$\bar{\eta} = 104.559\underline{/33.69^\circ}$$

$$\therefore\ \bar{\Gamma} = \frac{\bar{\eta} - \eta_0}{\bar{\eta} + \eta_0} = \frac{104.559\underline{/33.69^\circ} - 377}{104.559\underline{/33.69^\circ} + 377}$$

$$= \frac{-290.002 + j57.999}{463.998 + j57.999} = \frac{295.745\underline{/168.69^\circ}}{467.609\underline{/7.125^\circ}}$$

$$= 0.6325\underline{/161.565^\circ}$$

$$\tau = 1 + \bar{\Gamma} = 1 + 0.6325\underline{/161.565^\circ}$$

$$= 0.4 + j0.2$$

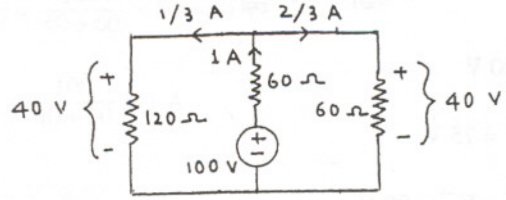
$$= 0.4472\underline{/26.565^\circ}$$

$$\mathbf{E}_r = 0.6325E_0 \cos(3\pi \times 10^5 t + 10^{-3}\pi z + 0.8976\pi)\ \mathbf{a}_x \text{ V/m}$$

$$\mathbf{E}_t = 0.4472E_0 e^{-6.283\times 10^{-3} z}$$

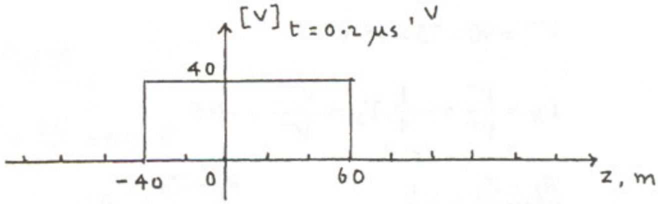
$$\cdot \cos(3\pi \times 10^5 t - 9.425 \times 10^{-3}\pi z + 0.1476\pi)\ \mathbf{a}_x \text{ V/m}$$

P6.21.



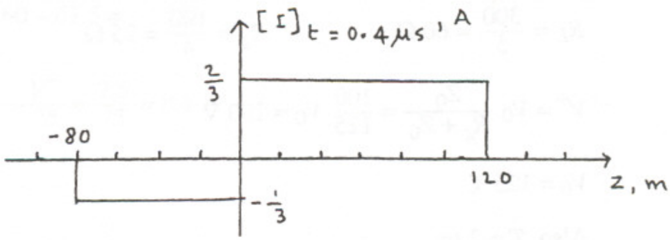
1/3 A
2/3 A
1 A
60 Ω
40 V
120 Ω
60 Ω
40 V
100 V

(a)



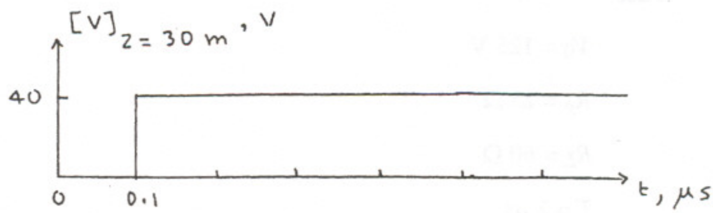
[V] t = 0.2 μs , V
40
-40
0
60
z, m

(b)



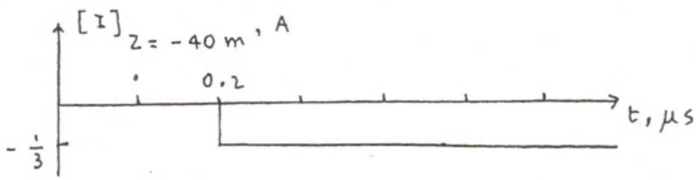
[I] t = 0.4 μs , A
2/3
-80
120
z, m
-1/3

(c)



[V] z = 30 m , V
40
0
0.1
t, μs

(d)



[I] z = -40 m , A
0.2
t, μs
-1/3

P6.22. From the sketches of $[V]_{z=0}$ and $[V]_{z=l}$, we can obtain

$$V^+ = 100 \text{ V}$$

$$V^+ + V^- = 75 \text{ V}$$

$$V^+ + V^- + V^{-+} = 90 \text{ V}$$

$$\therefore \quad V^- = 75 - 100 = -25 \text{ V}$$

$$V^{-+} = 90 - 75 = 15 \text{ V}$$

$$\Gamma_R = \frac{V^-}{V^+} = -\frac{1}{4}, \Gamma_S = \frac{V^{-+}}{V^-} = -0.6$$

$$\frac{R_L - Z_0}{R_L + Z_0} = -\frac{1}{4} \qquad \frac{R_g - Z_0}{R_g + Z_0} = -0.6$$

$$5R_L = 3Z_0 \qquad 1.6\, R_g = 0.4\, Z_0$$

$$R_L = \frac{300}{5} = 60\ \Omega \qquad R_g = \frac{100}{4} = 25\ \Omega$$

$$V^+ = V_0 \frac{Z_0}{R_g + Z_0} = \frac{100}{125} V_0 = 100 \text{ V}$$

$$V_0 = 125 \text{ V}$$

Also, $T = 2\ \mu\text{s}$

Thus

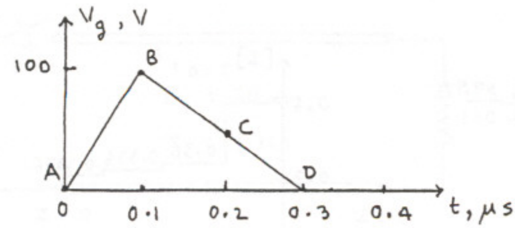
$$V_0 = 125 \text{ V}$$

$$R_g = 25\ \Omega$$

$$R_L = 60\ \Omega$$

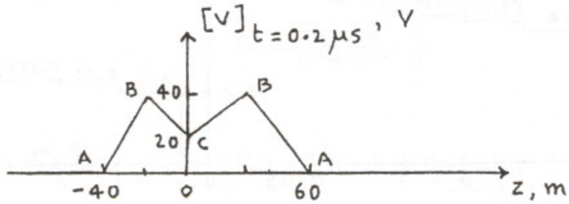
$$T = 2\ \mu\text{s}$$

P6.25.



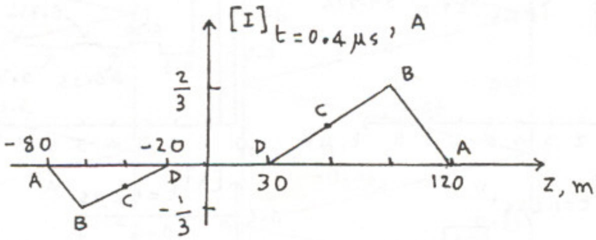
Vg , V
100
B
C
A
D
0
0.1
0.2
0.3
0.4
t, μs

(a)



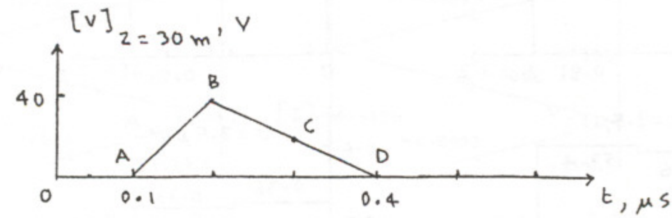
[V] t=0.2μs , V
B
40
B
20
C
A
A
-40
0
60
z, m

(b)



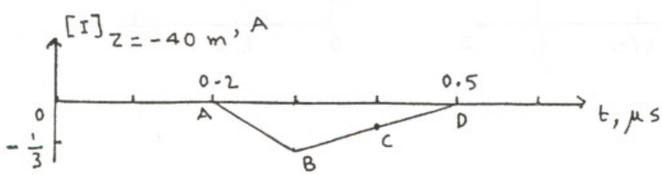
[I] t=0.4μs , A
2/3
B
C
-80
-20
D
A
A
D
30
120
z, m
C
-1/3
B

(c)



[V] z=30 m , V
B
40
C
A
D
0
0.1
0.4
t, μs

(d)



[I] z=-40 m , A
0.2
0.5
0
A
D
t, μs
-1/3
C
B