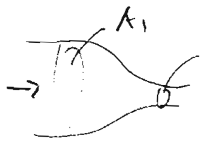
Q1



(1) $A_1 v_1 = A_2 v_2 \Rightarrow v_2 = \frac{r_1^2}{r_2^2} v_1 = 12\ m/s$

$A_1 = \pi r_1^2 \qquad A_2 = \pi r_2^2$

(2) $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$ Bernoulli

$\Rightarrow p_2 = p_1 + \frac{1}{2}\rho(v_1^2 - v_2^2)$

$= 132.5\ kPa$

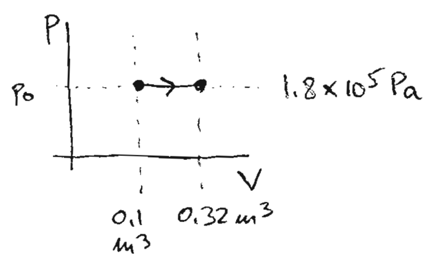
Q2

(1) $v_{RMS} = \sqrt{\frac{3 k_B T}{m}} = \dots = 6.4 \times 10^{-3}\ m/s$

(2) If the particle is in thermal equilibrium with its surroundings, the motion <u>only</u> depends on surrounding temperature, not on the mass of the individual particles

Q3

(1)



$W = \int p\,dV = p_0(V_2 - V_1)$

$= 1.8 \times 10^5 Pa \cdot 0.22\ m^3$

$= 4.0 \times 10^4\ J$

(2) $p\Delta V = nR\Delta T \Rightarrow \Delta T = \frac{p\Delta V}{nR} = 48\ K$

(3) $\Delta U = \frac{3}{2} nR\Delta T = 6.0 \times 10^4\ J$

Q4

(1) For SHM, $a_x = -\omega^2 x = -(2\pi f)^2 x \Rightarrow a_x(0) = -2.71\ m/s^2$

(2)
$$x(t) = A\cos(\omega t+\varphi) \equiv x$$
$$x'(t) = -\omega A\sin(\omega t+\varphi) \equiv V_x$$
$$x''(t) = -\omega^2 A\cos(\omega t+\varphi) \equiv a_x$$

Determine φ and A: from initial conditions.

$$\left.\begin{aligned} x(0) &= A\cos\varphi \\ v_x(0) &= -\omega A\sin\varphi \end{aligned}\right\} \Rightarrow \underbrace{\frac{-\omega A\sin\varphi}{A\cos\varphi}}_{-\omega\tan\varphi} = \frac{V_x(0)}{x(0)}$$

$$\Rightarrow \varphi = \arctan\left(\frac{-V_x(0)}{\omega\cdot x(0)}\right) = 0.715\ \text{rad}$$

$x(0) = 1.1\times10^{-2}\ m$
$v(0) = -15\times10^{-2}\ m/s$
$\omega = 2\pi f = 15.7\ rad/s$

$$\left.\begin{aligned} x(0) &= A\cos\varphi \\ v_x(0) &= -\omega A\sin\varphi \end{aligned}\right\} \Rightarrow \begin{cases} \cos\varphi = x(0)/A \\ \sin\varphi = -V_x(0)/\omega A \end{cases}$$

$$\Rightarrow \underbrace{\cos^2\varphi + \sin^2\varphi}_{=1} = \left(\frac{x(0)}{A}\right)^2 + \left(\frac{V_x(0)}{\omega A}\right)^2$$

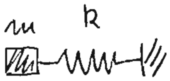
$$\Rightarrow A^2 = x(0)^2 + V_x^2(0)/\omega^2$$

$$\Rightarrow A = \sqrt{x(0)^2 + \frac{V_x^2(0)}{\omega^2}} = 1.46\ cm$$

Final result:

$$x(t) = (1.46\ cm)\cdot\cos\left(15.7\ \tfrac{rad}{s}\ t + 0.715\ rad\right)$$
$$v(t) = -(1.46\ cm)\cdot(15.7\ rad/s)\cdot\sin(\dots)$$
$$a(t) = -(1.46\ cm)\,(15.7\ rad/s)^2\cdot\cos(\dots)$$

Q5



(a) $\omega = \sqrt{\frac{k}{m}} = 14.1 \frac{rad}{s} \Rightarrow T = \frac{1}{f} = \frac{2\pi}{\omega} = 0.44\,s$

(b) $E_{initial} = \underbrace{\cancel{E_{kinetic,\,initial}}}_{0} + \underbrace{E_{pot,\,initial}}_{=}$

$$\frac{1}{2}kA^2 = \frac{1}{2} \cdot 400 \frac{N}{m} \cdot (3\times10^{-2})^2 m^2$$

$$= 0.18\,J$$

$U = \frac{1}{2}kA^2 = 0.99 \frac{1}{2}kA_0^2$

(c) $x(t) = Ae^{-(b/2m)t}\cos(\omega' t + \varphi)$

$x(0) = A$

$x(T) = Ae^{-(b/2m)\cdot T} \overset{!}{=} \sqrt{0.99}\,x(0) = \sqrt{0.99}\,A$?

$\Rightarrow e^{-(b/2m)T} = \sqrt{0.99} =$

$\Rightarrow -\frac{b}{2m}T = \ln(\sqrt{0.99})$

$\Rightarrow b = -\frac{2m}{T}\ln(\sqrt{0.99}) = -\frac{4\,kg}{0.44\,s}\cdot\ln(\sqrt{0.99})$

$= \cancel{0.091}\ 0.046\ kg/s.$

Q6

$$y(x,t) = \underbrace{(6.5\,\text{mm})}_{\substack{(1)\\ A=6.5\,\text{mm}}} \cos\Big[\underbrace{2\pi\Big(\frac{x}{2.8\,\text{cm}} - \frac{t}{0.036\,\text{s}}\Big)}_{\underbrace{\frac{2\pi}{2.8\,\text{cm}}}_{k}\,x \;-\; \underbrace{\frac{2\pi}{0.036\,\text{s}}}_{\omega}\,t}\Big]$$

$$k = \frac{2\pi}{\lambda}$$

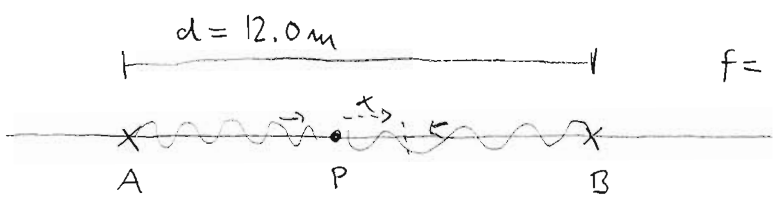
$$\omega = 2\pi f \;\Rightarrow\; f = \frac{\cancel{2\pi}/\cancel{2\pi}}{0.036\,\text{s}} = \underline{\underline{27.8\ \text{Hz}}} \quad (2)$$

$$\Rightarrow \lambda = \frac{2\pi}{k} = \frac{\cancel{2\pi}}{\cancel{2\pi}}\cdot 2.8\,\text{cm}$$
(2)

(3) $v = \lambda f = 2.8\,\text{cm} \cdot 27.8\ \text{Hz} = 0.78\ \text{m/s}$

wave traveling in +x direction.

Q7



$f = 688\ \text{Hz}$

(1) $\lambda = v/f = 344\ \text{m/s} / 688\ \text{Hz} = 0.5\ \text{m}$

(2) To move from constructive to destructive interference, the path length difference must change by $\lambda/2$. If you move a distance x toward speaker B, the distance to B gets shorter by x and the distance to A gets longer by x, such that the path length difference changes by 2x $\Rightarrow x = \lambda/4 = 0.125\ \text{m}$