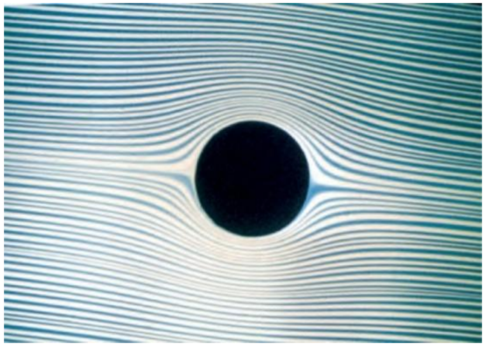
Copyright statement

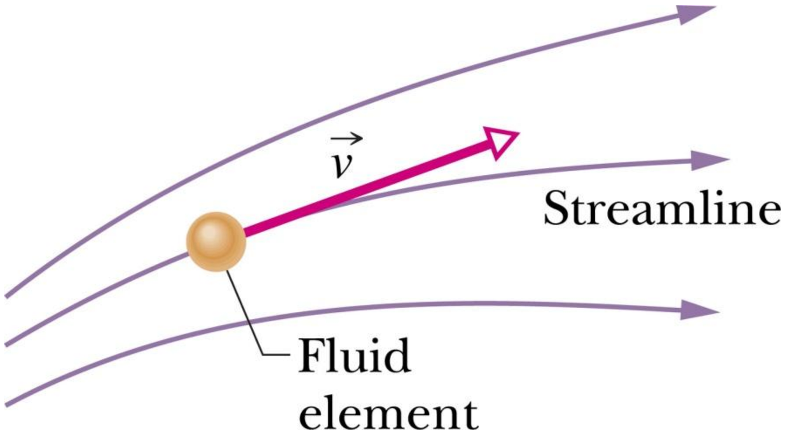
- The images and the pictures in this lecture are provided by the CDs accompanied by the books
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8th and 9th Ed.
- The rest is made by me.

Ideal flow의 운동

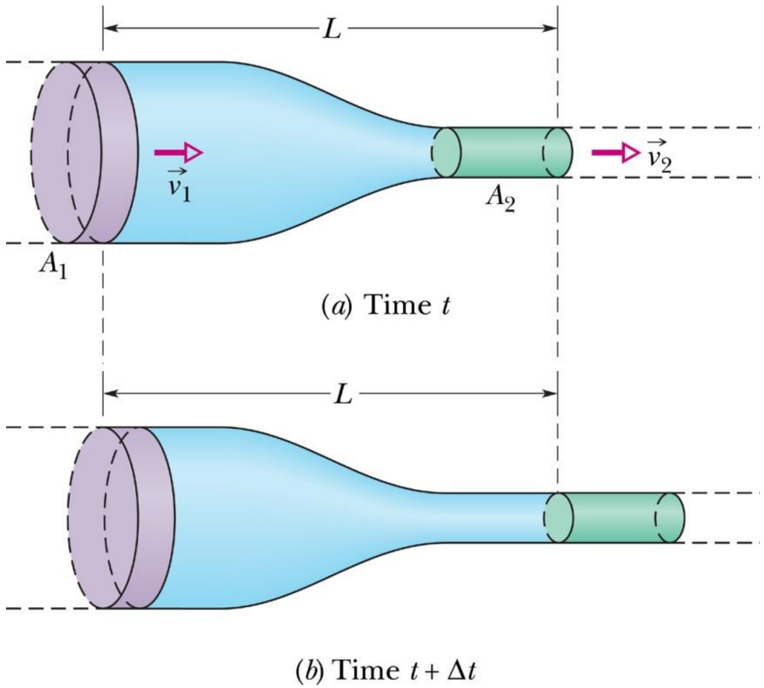
1. steady flow
2. incompressible flow
3. nonviscous flow
4. irrotational flow

streamline





Continuity equation

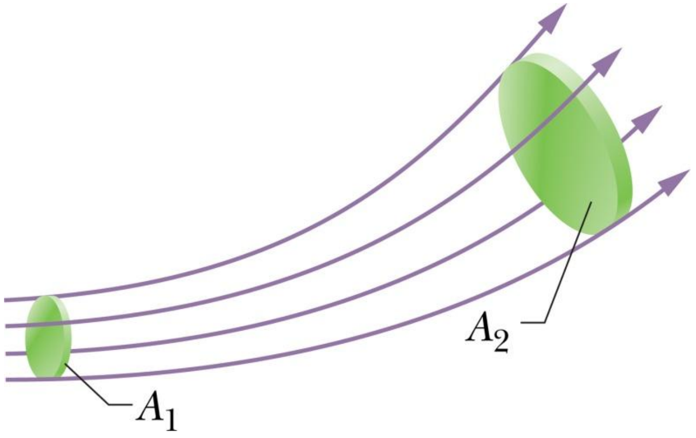


$$\Delta V = A\Delta x = Av\Delta t$$

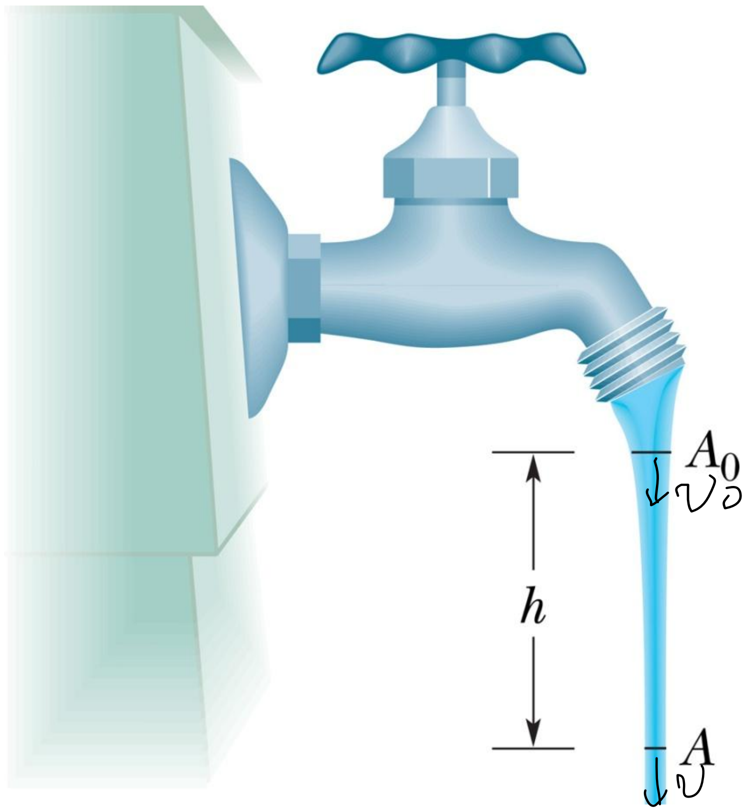
$$\Delta V = A_1 v_1 \Delta t = A_2 v_2 \Delta t$$

$$A_1 v_1 = A_2 v_2$$

continuity equation



Sample prob.



$$v_0^2\left(\frac{A_0^2-A^2}{A^2}\right)=2gh$$

$$A_0 v_0 = A v$$

$$\frac{A_0^2}{A^2}v_0^2 = v^2 = v_0^2 + 2gh$$

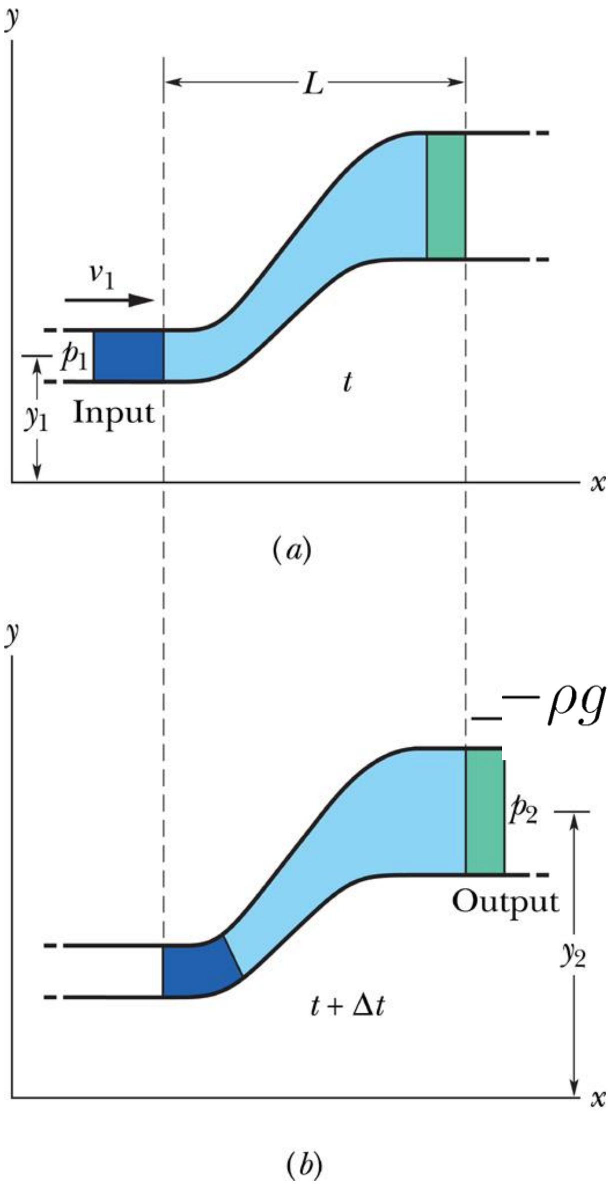
$$v_0 = \sqrt{\frac{2ghA^2}{A_0^2 - A^2}}$$

$$v_0 = \sqrt{\frac{2ghA^2}{A_0^2 - A^2}}$$

$$R_V = A_0 v_0 = \sqrt{\frac{2ghA^2}{1 - A^2/A_0^2}}$$

$A_0 = 1.2\ \text{cm}^2,\ A = 0.35\ \text{cm}^2,\ h = 45\ \text{mm}$

Bernoulli 방정식



$$W = \Delta K$$

$$\Delta K = \frac{1}{2}\Delta m v_2^2 - \frac{1}{2}\Delta m v_1^2 = \frac{1}{2}\rho \Delta V (v_2^2 - v_1^2)$$

$$W_g = -\Delta m g (y_2 - y_1) = -\rho g \Delta V (y_2 - y_1)$$

$$F \Delta x = p A \Delta x = p(A \Delta x) = p \Delta V$$

$$W_p = -p_2 \Delta V + p_1 \Delta V = -(p_2 - p_1)\Delta V$$

$$-\rho g \Delta V (y_2 - y_1) - \Delta V (p_2 - p_1) = \frac{1}{2}\rho \Delta V (v_2^2 - v_1^2)$$

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$p + \frac{1}{2}\rho v^2 + \rho g y = \text{const.}$$

Bernoulli 방정식

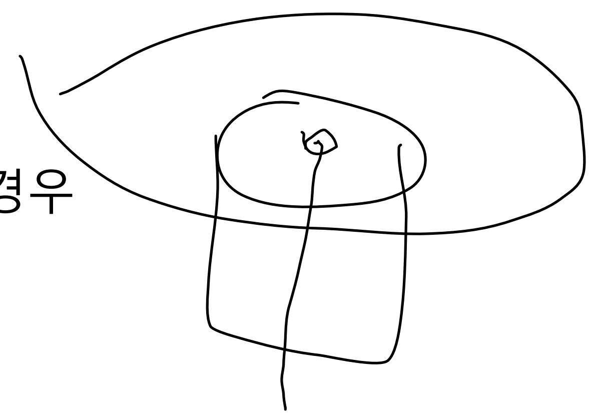
Bernoulli 방정식의 특별한 경우

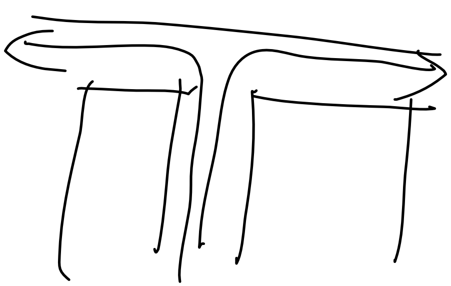
(1) 정지한 유체 $v_1 = v_2 = 0$

$$p_2 = p_1 + \rho g(y_1 - y_2)$$

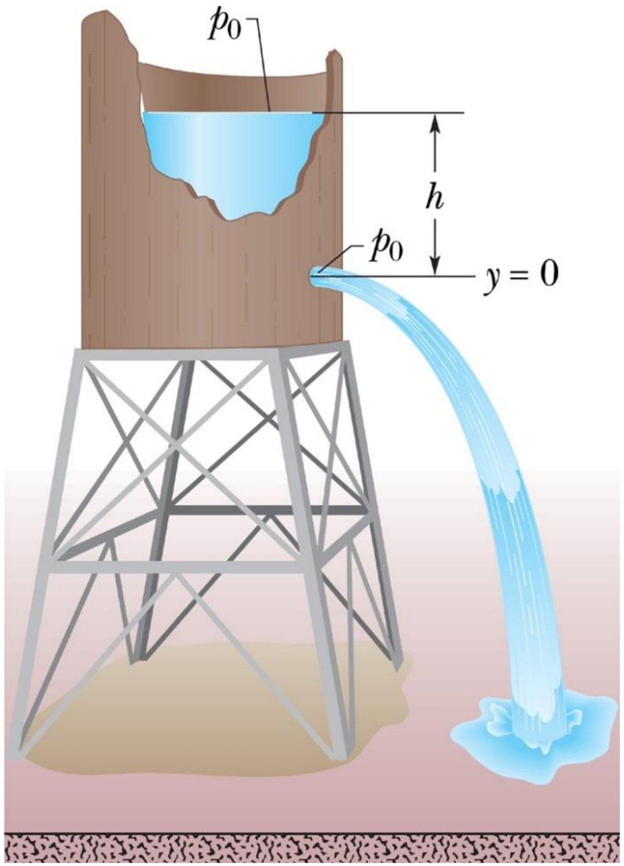
(2) 같은 높이의 유체 $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

예: 1) 차창 밖으로 나가는 담배연기
2) 바람 부는 날 문이 세게 닫히는 경우
3) 실패로 만든 장난감





Sample prob.



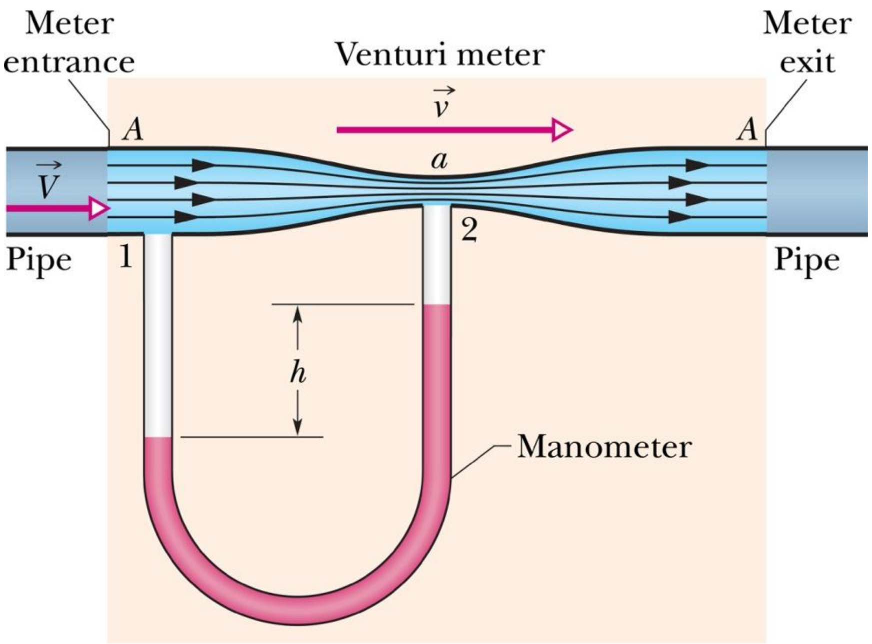
$$av = Av_0 \longrightarrow v_0 = \frac{a}{A}v$$

$$(a \ll A \to v_0 \ll v)$$

$$p_0 + \frac{1}{2}\rho v_0^2 + \rho gh = p_0 + \frac{1}{2}\rho v^2$$

$$v = \sqrt{2gh}$$

Venturi tube



$$v_A = \sqrt{\frac{2a^2 \Delta p}{\rho (A^2 - a^2)}}$$

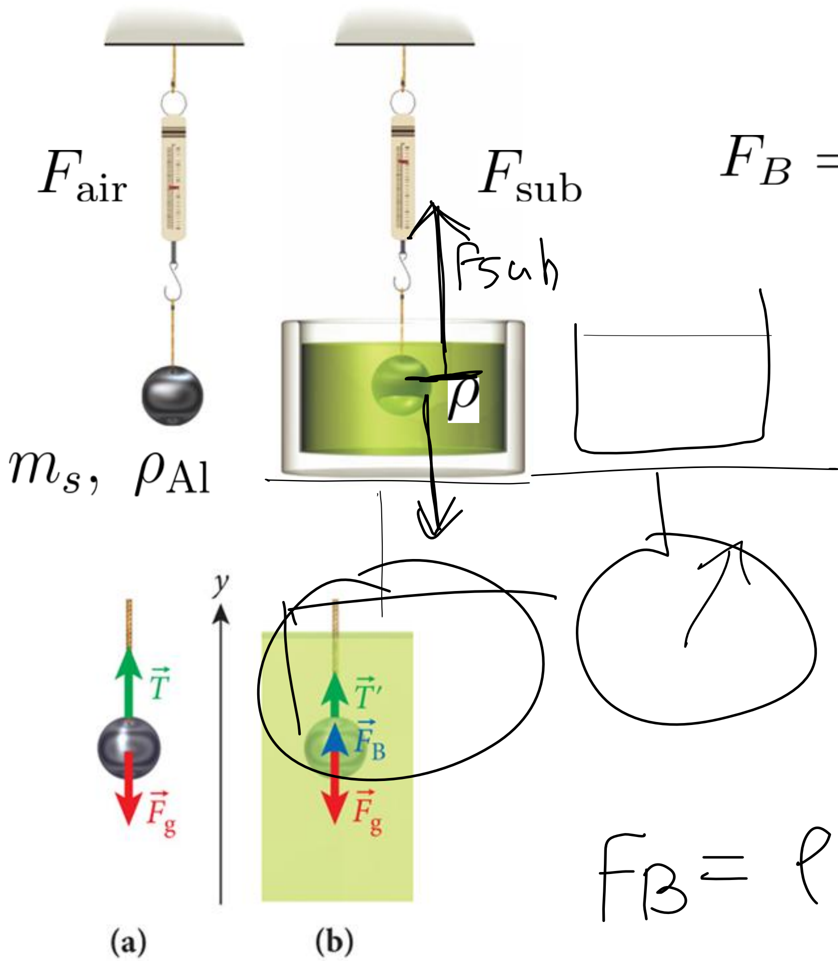
$$AV = av$$

$$\Delta p = p_1 - p_2$$

$$p_1 + \frac{1}{2}\rho V^2 = p_2 + \frac{1}{2}\rho v^2 = p_2 + \frac{1}{2}\rho \left(\frac{A}{a}\right)^2 V^2$$

$$\frac{1}{2}\rho V^2 \left[\frac{A^2}{a^2} - 1\right] = \Delta p \qquad V^2 = \frac{2\Delta p}{\rho} \frac{a^2}{A^2 - a^2}$$

SP 13.3 Density of unknown liquid



$$F_B = F_{air} - F_{sub} = mg = \rho V g$$

$$V = \frac{m_s}{\rho_{Al}} = \frac{F_{air}}{\rho_{Al} g}$$

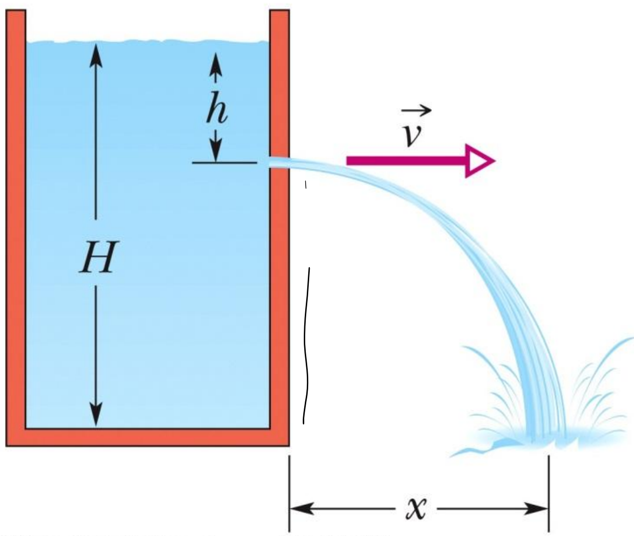
$$\rho = \rho_{Al} \frac{F_{air} - F_{sub}}{F_{air}}$$

$$F_B = \rho \frac{F_{air}}{\rho_{Al}} \Rightarrow \rho = \rho_{Al} \frac{F_{air} - F_{sub}}{F_{air}}$$

Problem 1

$$h^2 - hH + \frac{x^2}{4} = 0$$

$$h = \frac{1}{2}\left(H \pm \sqrt{H^2 - x^2}\right)$$



halliday_9e_fig_14_54

h for given x
Maximum x

$$v = \sqrt{2gh}$$

$$H - h = \frac{1}{2} g t^2$$

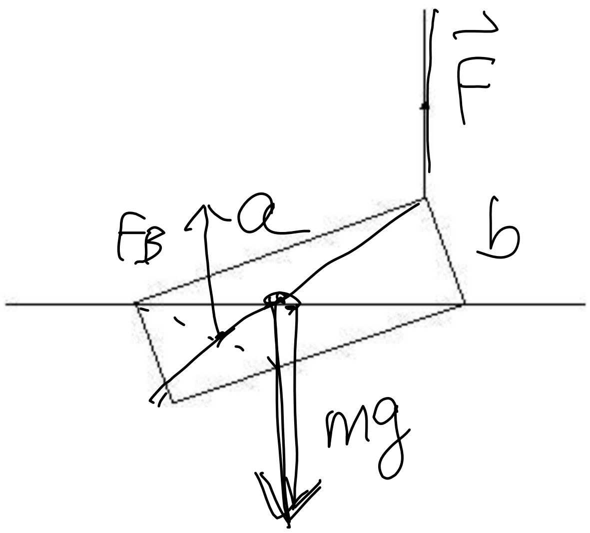
$$t = \sqrt{\frac{2(H-h)}{g}}$$

$$\sqrt{2gh}\sqrt{\frac{2(H-h)}{g}} = x$$

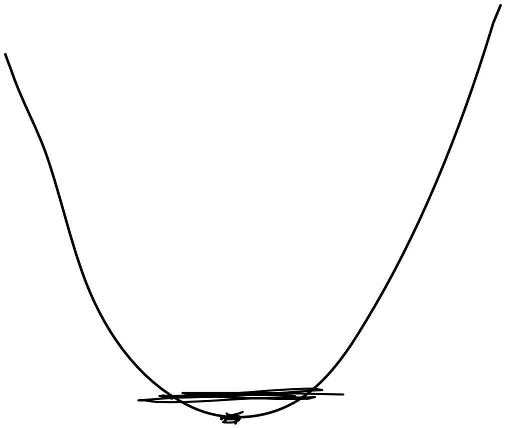
$$x = 2\sqrt{h(H-h)} \qquad \frac{x^2}{4} = hH - h^2$$

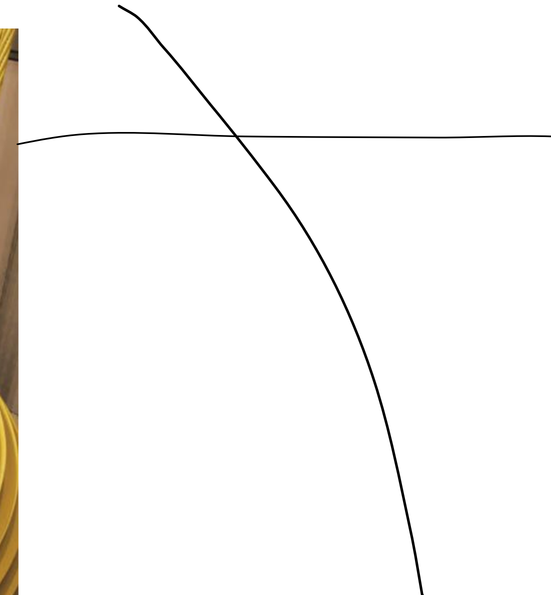
$$hH - h^2 = -(h^2 - hH) = -\left(h - \frac{H}{2}\right)^2 + \frac{H^2}{4}$$

Problem 2

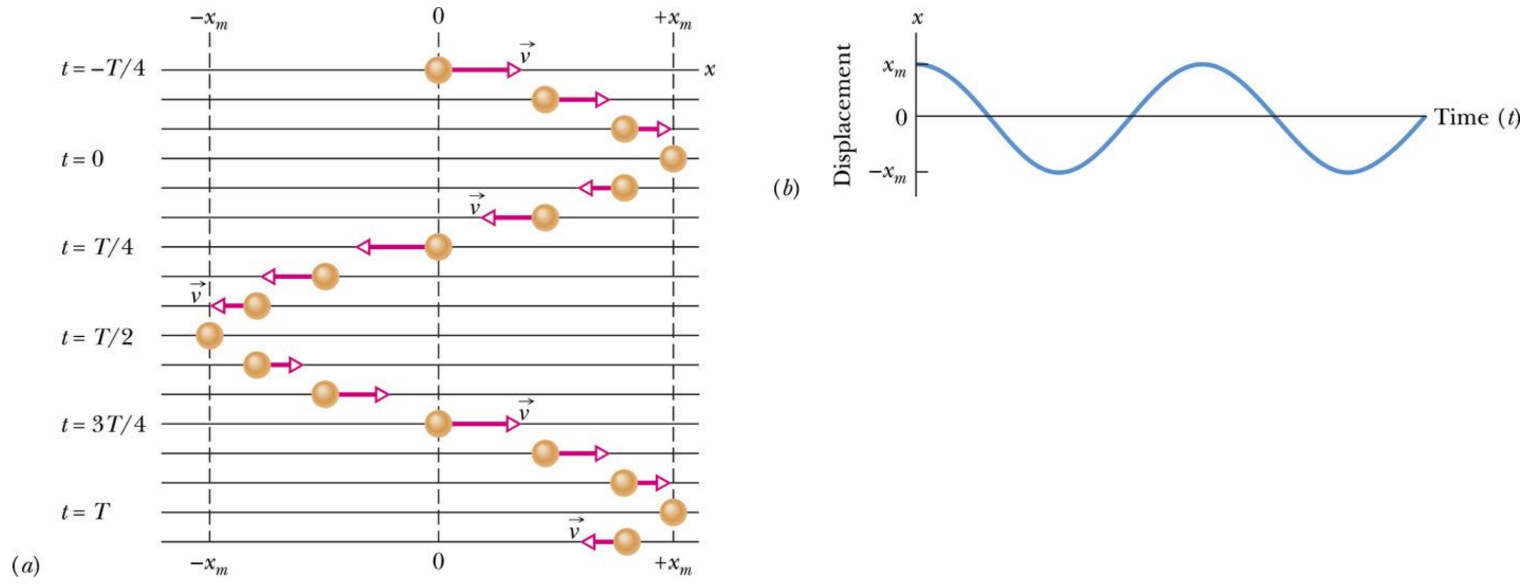


Ch. 14. Oscillations





Simple harmonic motion



periodic motion, harmonic motion

frequency: 1 hertz = 1 Hz = 초당 1회 진동 = $1\ \mathrm{s}^{-1}$

period T $T = \dfrac{1}{f}$

Displacemnt at time t

Phase

$$x(t) = x_m \cos(\omega t + \phi)$$

Amplitude

Time

Angular frequency

Phase constant or phase angle

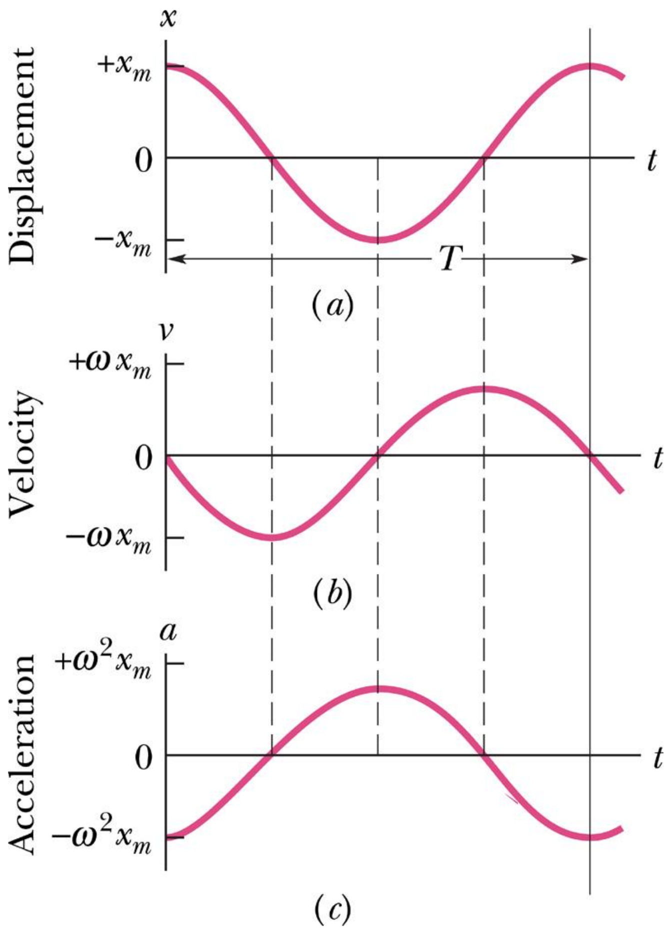
$$x_m \cos \omega t = x_m \cos \omega (t + T)$$

$$\omega (t + T) = \omega t + 2\pi$$

$$\omega T = 2\pi$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

SHO의 속도, 가속도



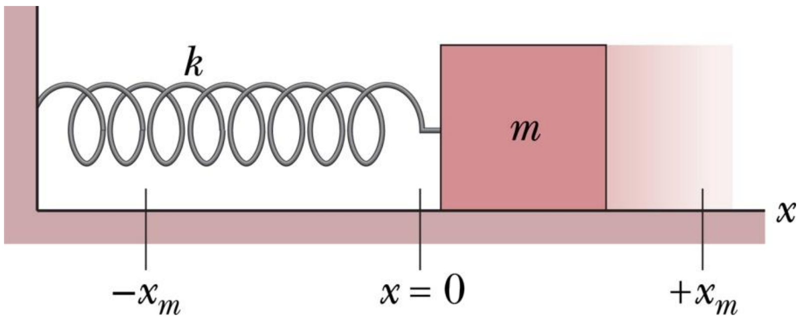
$$x(t) = x_m \cos(\omega t + \phi)$$

$$v(t) = \frac{dx}{dt} = -\omega x_m \sin(\omega t + \phi)$$

$$a(t) = \frac{dv}{dt} = -\omega^2 x_m \cos(\omega t + \phi)$$

$$a(t) = -\omega^2 x(t)$$

Simple harmonic motion의 힘



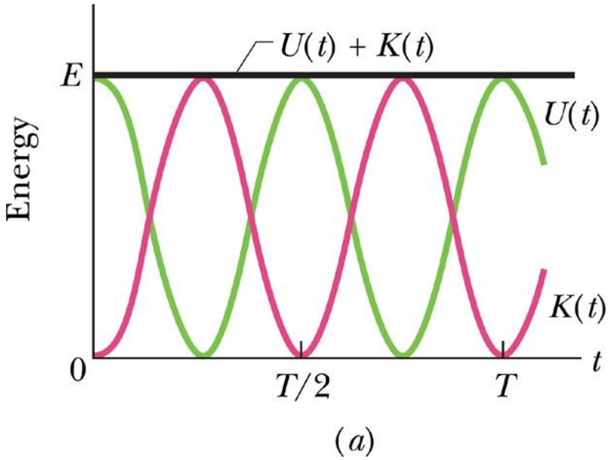
$$F = ma = -m\omega^2 x = -kx$$

$$k = m\omega^2$$

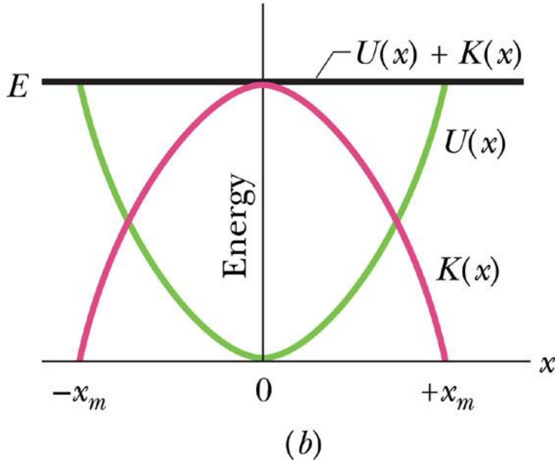
Angular frequency $$\omega = \sqrt{\frac{k}{m}}$$

period $$T = 2\pi\sqrt{\frac{m}{k}}$$

Simple harmonic motion의 에너지



(a)



(b)

퍼텐셜에너지

$$U(t) = \frac{1}{2}kx^2 = \frac{1}{2}kx_m^2 \cos^2(\omega t + \phi)$$

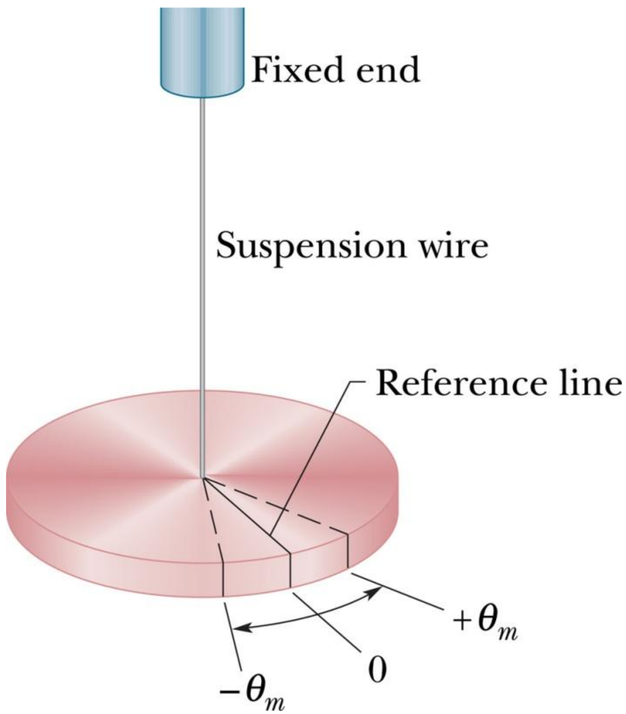
운동에너지

$$K(t) = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2 x_m^2 \sin^2(\omega t + \phi)$$

역학적 에너지

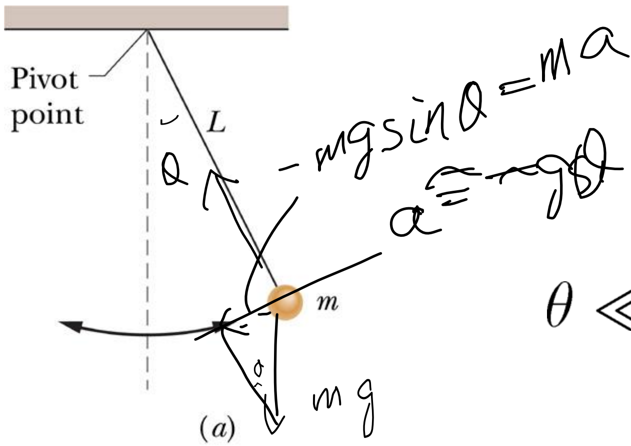
$$E = U(t) + K(t) = \frac{1}{2}kx_m^2$$

Angular simple harmonic ocsillator



$$\tau = -\kappa\theta \qquad T = 2\pi\sqrt{\frac{I}{\kappa}}$$

Pendulum

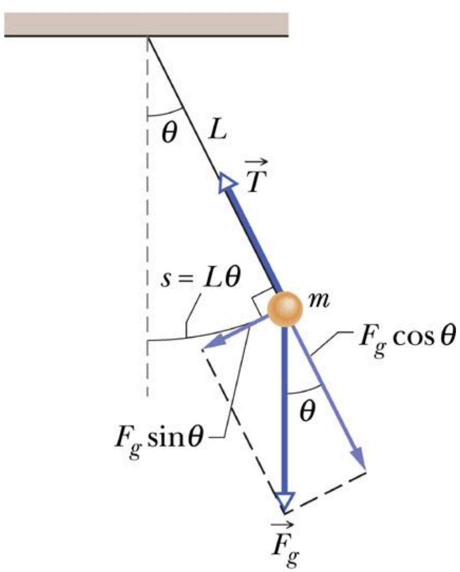


(a)

$$\tau = -L(F_g \sin\theta) = I\alpha$$

$\theta \ll 1$ 일 때

$$\alpha = \frac{mgL}{I}\theta$$

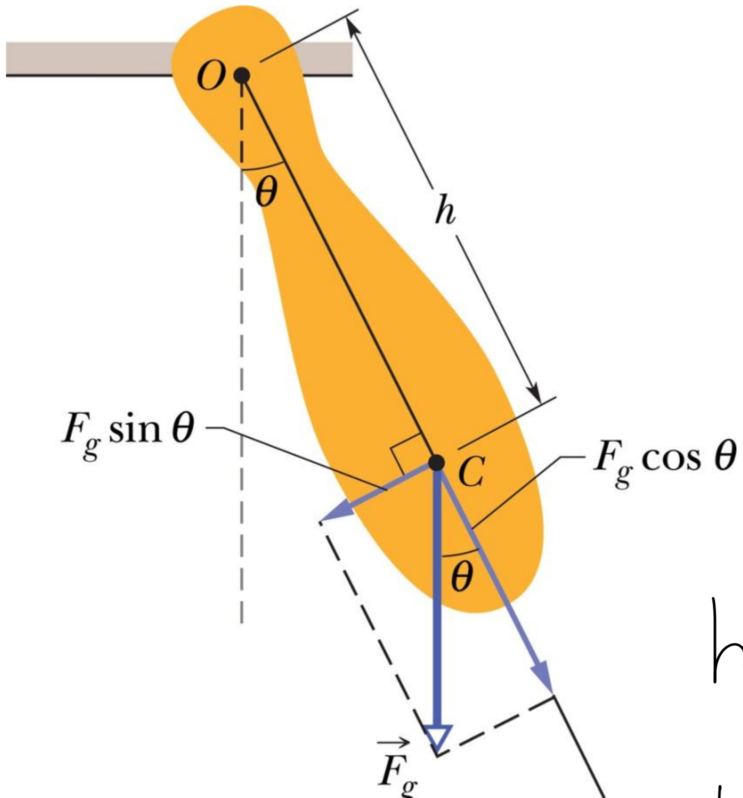


(b)

$$\omega = \sqrt{mgL/I} \qquad I = mL^2 \qquad \omega = \sqrt{\frac{g}{L}}$$

$$T = 2\pi\sqrt{\frac{I}{mgL}} = 2\pi\sqrt{\frac{L}{g}}$$

Physical pendulum



$$T = 2\pi\sqrt{\frac{I}{mgh}}$$

$$\frac{I}{mgh} = \frac{L_0}{g} \rightarrow L_0 = \frac{I}{mh}$$

$$hF_g \sin\theta = I\alpha \quad \omega^2$$

$$hF_g\theta \qquad \alpha = \frac{mgh}{I}\theta$$

$$\omega = \sqrt{\frac{mgh}{I}}$$