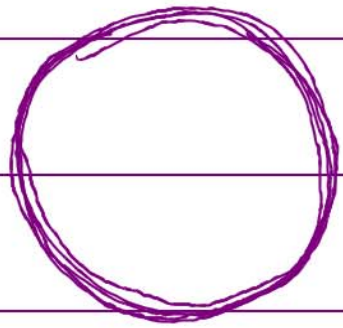


Phonon Quasi-particle
polaron

Plasmon

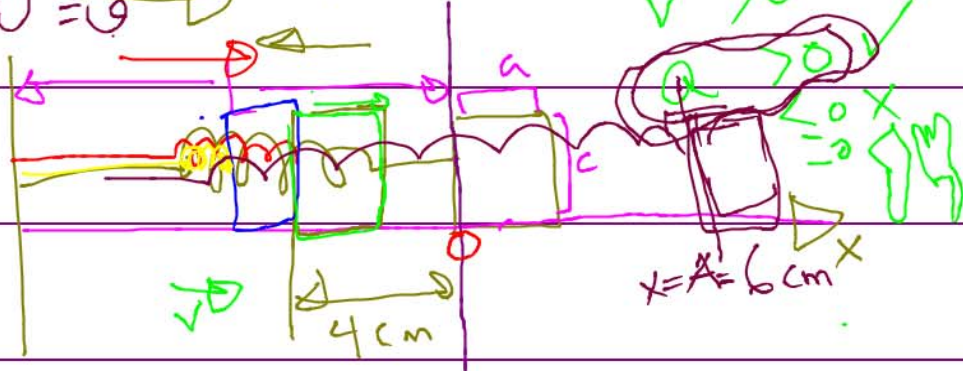
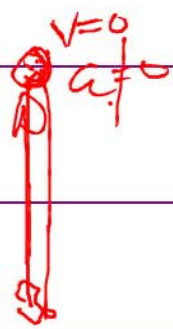
photon



stretched
ممدود

$ma = F$
 $\ddot{u} = \frac{F}{m}$
 $a > 0$ ✓
 $v < 0$
 $x < 0$

$x = -4 \text{ cm}$
 $v > 0$
 $a > 0$ ✓



$v(t) = \frac{v_0}{\omega} \sin \omega t$

$x = -4 \text{ cm}$
 -6 cm

compressed
مضغوط

$f = \frac{1}{T}$

x
 $v = 0$
 $x = -6 \text{ cm}$
 $a = 0$
 $\cos(\omega t + \delta) = A$
 $\Rightarrow A = 0$

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

$x(t) = A \cos(\omega t + \delta)$
 $x(t) = A \cos(\omega t + \delta)$

التردد الزاوي
angular frequency

$\omega = 2\pi f$

amplitude

angular frequency
التردد الزاوي

$x(t) = A \cos(\omega t + \delta)$

$$\frac{dx}{dt} \equiv v(t) = -A\omega \sin(\omega t + \delta)$$

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

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

$$x(t) = A \sin(\omega t + \delta)$$

$\frac{2\pi}{T} \equiv \omega$

$$k = 1000$$

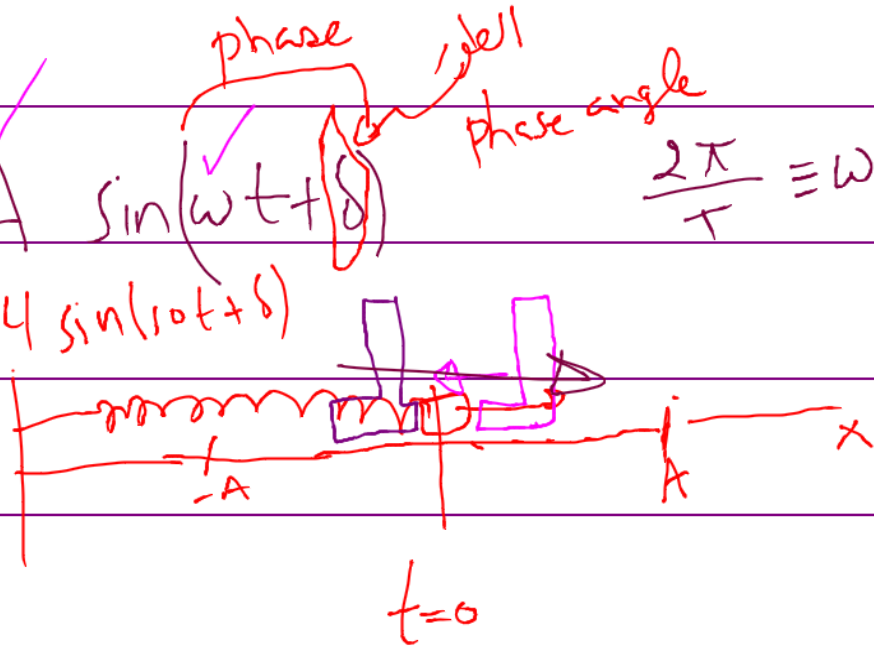
$$m = 10$$

$$f(t) = 4 \sin(10t + \delta)$$

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

$$= 10 \text{ s}^{-1}$$

$$= 10 \text{ Hz}$$



$$x(t=0) = 0 = A \sin(\omega t + \delta)$$

$$x(0) = 0$$

$$v(0) = A\omega$$

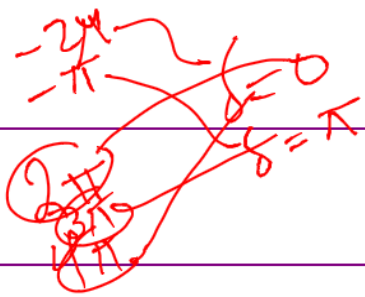
$$x(t=0) = 4 \sin(10 \cdot 0 + \delta) = 0$$

$$\sin(\delta) = 0$$

$$\delta = 0$$

$$x(t) = A \sin(\omega t + 0)$$

$$= A \sin \omega t$$



$$A \sin(\omega t + \pi)$$

$$\equiv -A \sin \omega t$$

$$v(t) = A\omega \cos(\omega t + \delta)$$

$$v(0) = A\omega \cos \delta$$

$$\delta = 0$$

$$\sin(\alpha + \pi)$$

$$= -\sin \alpha$$

$$\cos(\alpha + \pi) = -\cos \alpha$$



$$X(0) = A$$

$$V(0) = 0$$

$$X(t) = 6 \text{ cm} \sin(10t + \pi/2)$$

$$X(t) = A \sin(\omega t + \delta)$$

$$X(0) = A = 6 \text{ cm}$$

$$V(t) = A \omega \cos(\omega t + \delta)$$

$$X(0) = A \sin(10 \times 0 + \delta) = A$$

$$V(0) = A \omega \cos(10 \times 0 + \delta) = 0$$

$$\omega = 10 \text{ rad/s}$$

$$A \sin \delta = A \Rightarrow \delta = 90^\circ$$

$$\delta = \pi/2$$

$$A \omega \cos \delta = 0$$

$$\sin(\theta + \pi/2) = \cos \theta$$

$$\sin(\alpha + \beta) = \sin \alpha \cos \beta + \sin \beta \cos \alpha$$

$$\alpha = \theta$$

$$\beta = \pi/2$$

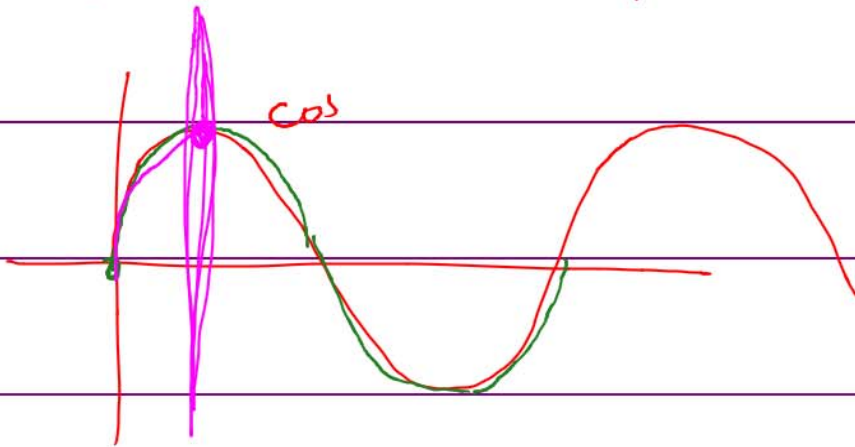
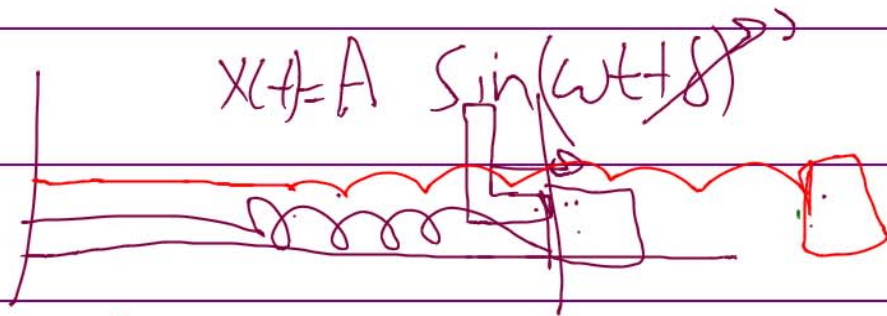
$$= \sin \theta \cos \pi/2 + \sin \pi/2 \cos \theta$$

$$= \cos \theta$$

$$\cos(\theta + \pi/2) = -\sin \theta$$

$$\cos \theta \cos \pi/2 - \sin \theta \sin \pi/2$$

$$\cos \alpha \cos \beta - \sin \alpha \sin \beta = \cos(\alpha + \beta)$$



$$X = A \cos \omega t$$

$$x(t) = A \sin(\omega t + \delta)$$

	t	δ	
hit to right	0	0	$\sin \omega t$
right extension	$T/4$	$\pi/2$	$\cos \omega t$
hit to left	$T/2$	π	$-\sin \omega t$
left extension	$3T/4$	$3\pi/2$	$-\cos \omega t$

$x(t) = A \sin(\omega t + \delta)$ $\frac{3\pi}{2}$

$$x(t=0) =$$

$$x(0) = -A$$

$$\sin(\omega t + 3\pi/2) = \sin \omega t \cancel{\cos 3\pi/2} + \cos \omega t \cancel{\sin 3\pi/2} = 0$$

$$= -\cos \omega t$$

$$X(t) = -A \cos \omega t$$

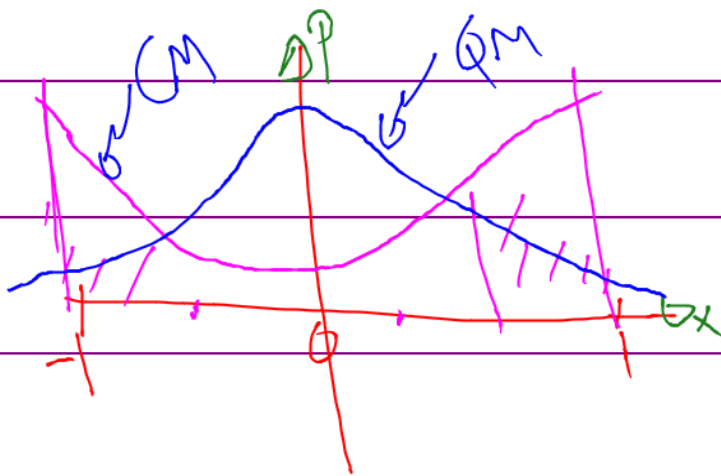
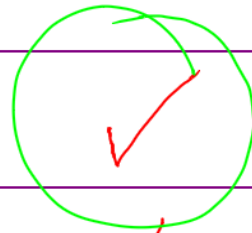
$$X(t) = A \sin(\omega t + \delta)$$

$$\left. \begin{array}{l} X(0) = \dots \\ v(0) = \dots \end{array} \right\} \rightarrow A, \delta$$

edges ↑ الحواف

middle ↑ الوصل

no difference



$$v(t) = X_m \sin(\omega t + \delta) \sqrt{1/m}$$

$$\theta(t) = \theta_m \sin(\omega t + \delta) \quad \sqrt{g/L}$$

$$\theta = \theta_m \sin(\omega t + \delta) \quad \sqrt{\frac{K}{I}} \quad \text{both modules}$$

