Week 10 Reading Quiz.

1. A mechanical wave in a medium transports:

[✓ a)] energy and momentum

b) energy and mass

c) momentum and mass

d) None of the above

2. The types of mechanical waves which can be found in (i) solids and (ii) liquids are:

	(i) Solids		(ii) Fluids
a)	transverse	,	longitudinal
[✓ (b)]	both	,	longitudinal
c)	both	,	transverse
d)	both	,	both

RQ 10 #2

3. For a sound wave of given speed in air, when the frequency is increased, the wavelength

a) increases

[✓ b) decreases]

$\underline{\underline{v}} = f\lambda$

c) stays the same

d) not enough info.

4. A firecracker explodes in mid-air and some of the sound energy is intercepted by a listener's ears at a distance of 5 m. Their twin, standing 50 m from the explosion, receives:

E

received $\propto \frac{E}{4\pi d^2}$

$\propto 1/d^2$

a) $1/10$

[✓ b) $1/100$]

c) 10^{-4}

d) 10^{-6}

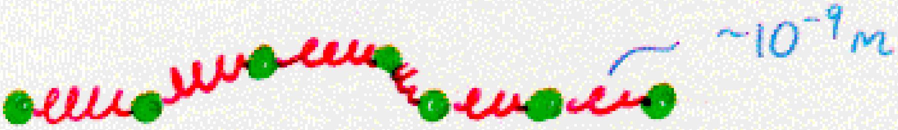
as much energy in their ears.

Mechanical Waves (Hecht ch. 11)

Waves transport energy + momentum (and information) through a medium:

Wave: disturbance moves through medium – the medium itself has no overall motion

Caused by: forces between neighbor molecules



electric attractive force ~ spring

⇒ restoring force on each molecule

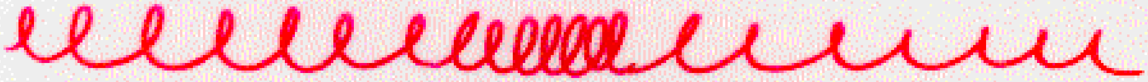
- disturbance propogates through medium.

Wave Characteristics

Longitudinal : Displacement along direction of travel

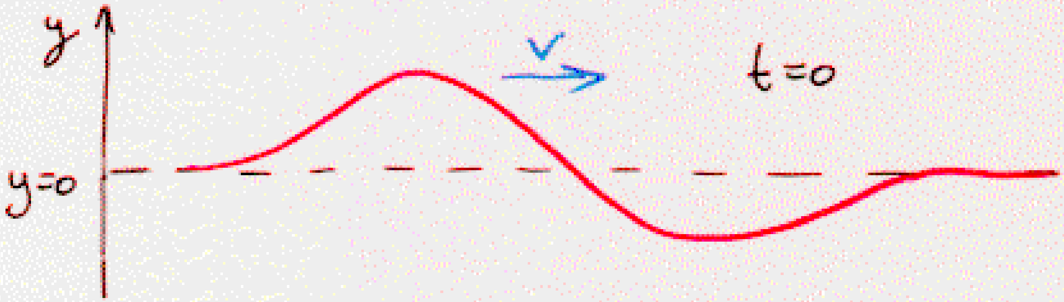
(or compression waves) e.g. sound waves in fluids

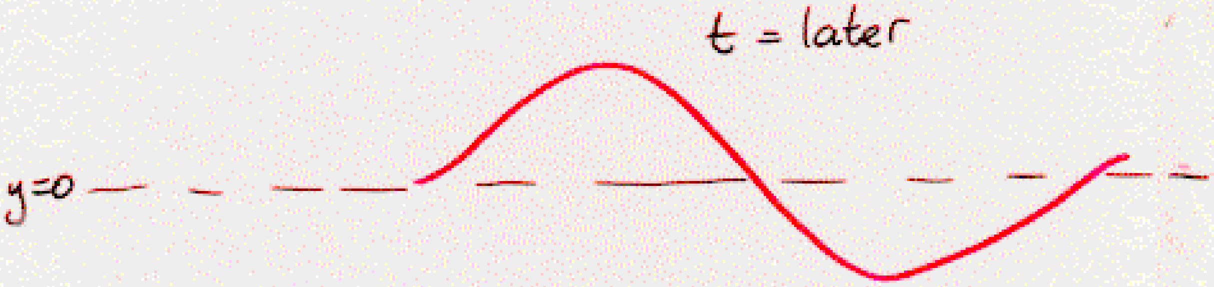
(fluids cannot support shear forces, only compression / stretching)



also solid bars, bones, earthquakes, ...

Transverse : Displacement ⊥ to direction of travel

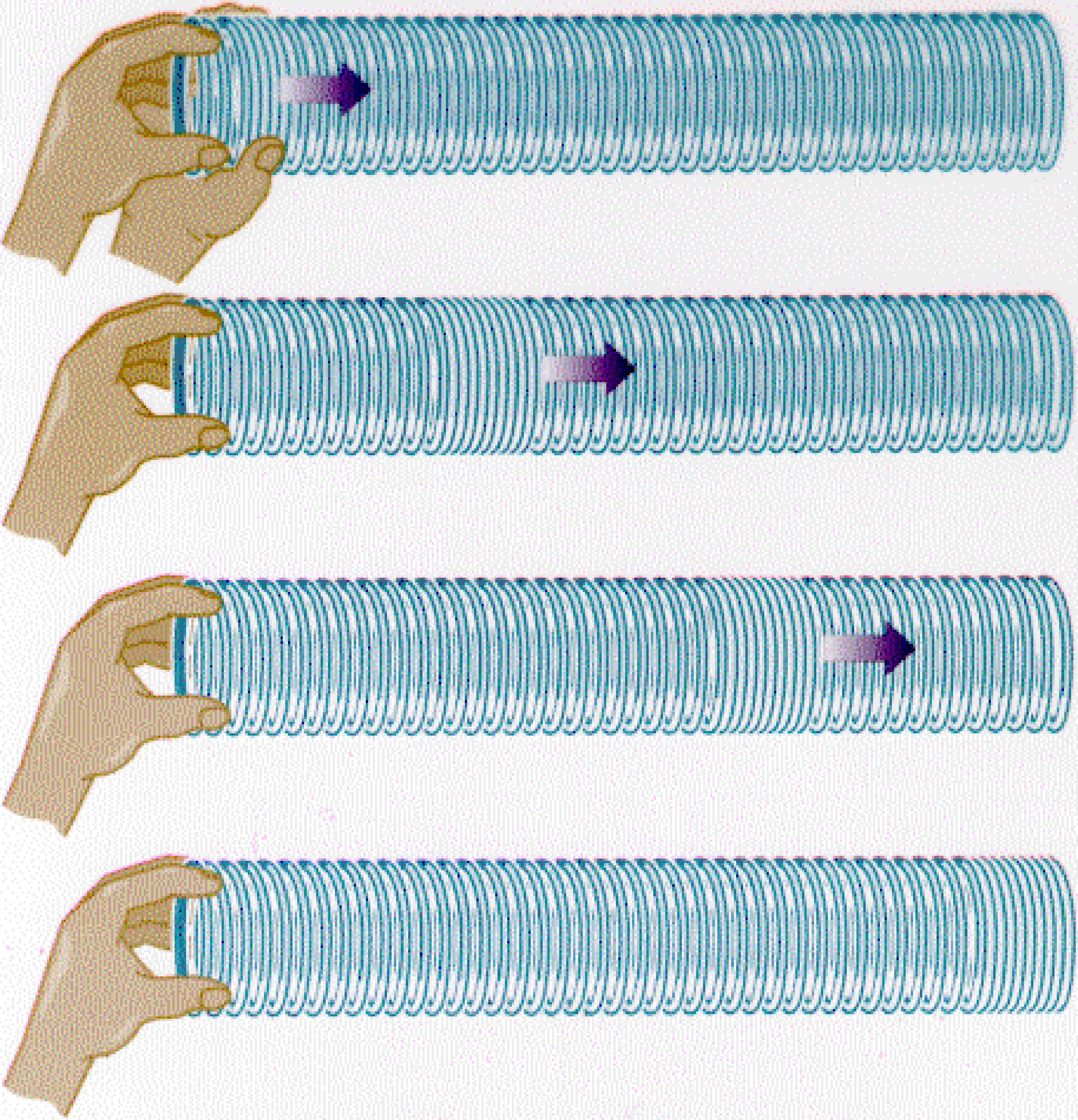




e.g. waves on rope, string, wires,
ocean surface,
earthquakes

Figure 11.2

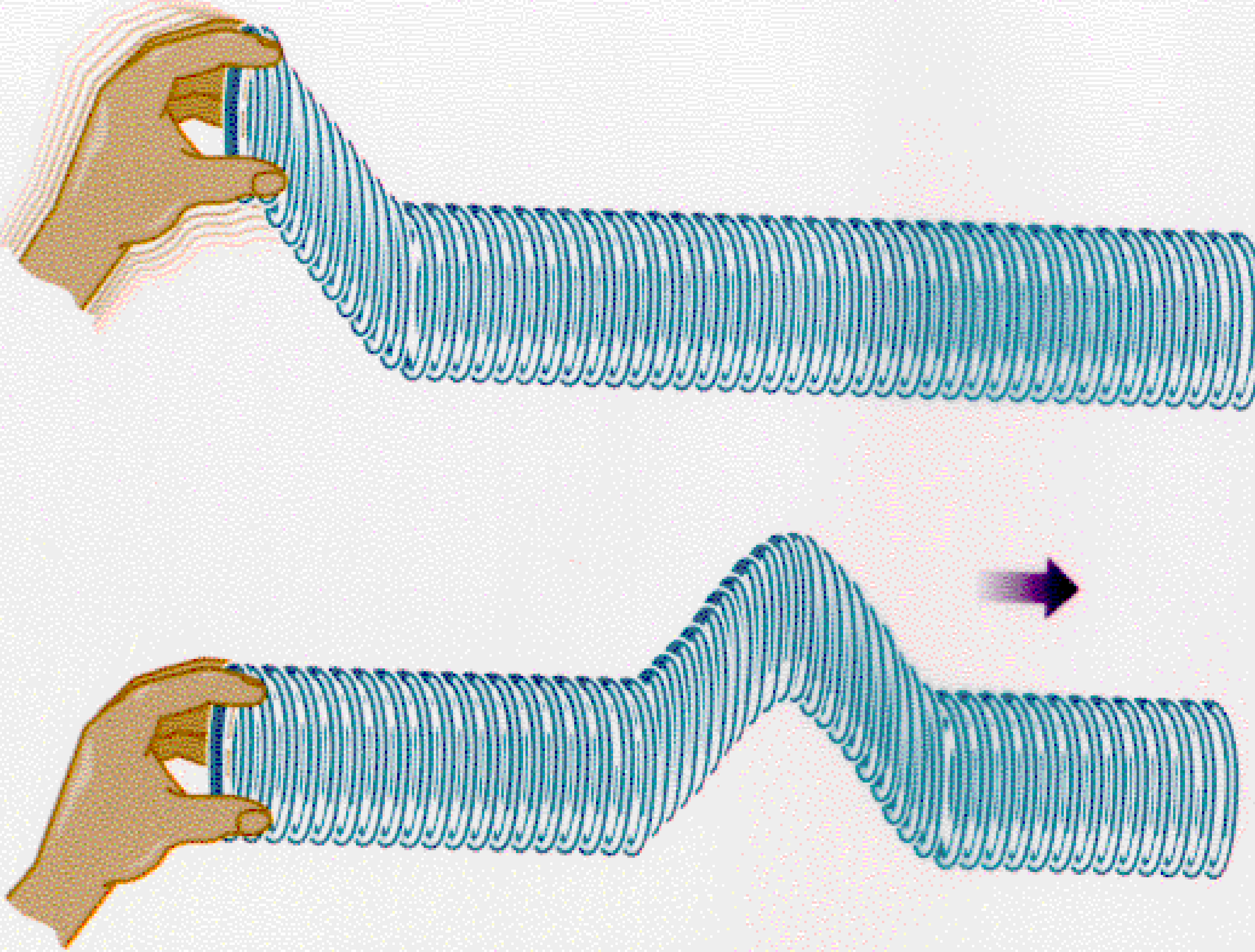
Longitudinal wave in a spring



Transparency 84

Figure 11.3

Transverse wave in a spring



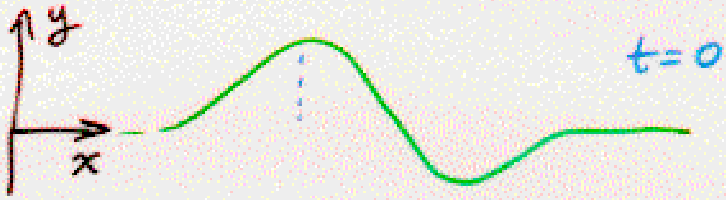
Waveforms

In general, point on (string, ocean) is displaced by wave depending on its position (x) and the time (t)

⇒ Wave function $\psi(x,t)$

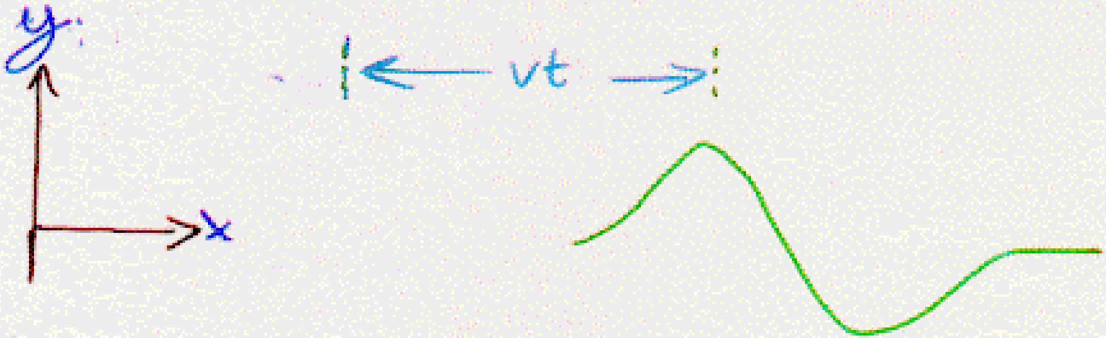
Can take "snapshot" of displacement at a moment in time:

e.g.



⇒ displacement $y = \underline{f(x)}$ wave form

If wave form moves to right ($x \uparrow$) at speed v:



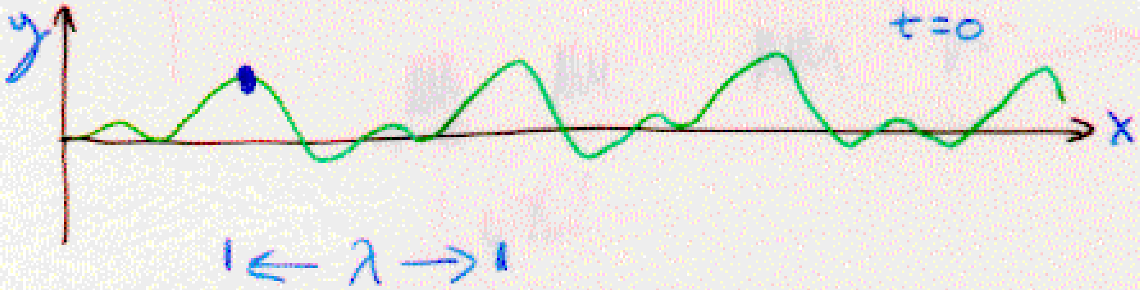
Now displacement $f(x) = f(x - vt)$

⇒ $y = \psi(x,t) = f\,\underline{\underline{(x - vt)}}$

(For wave to left, $\psi(x,t) = f(x + vt)$

Periodic Waves : Wavelength, Frequency

If wave-form repeats itself : (take snapshot)



Pattern repeats over a wavelength = λ [m]

For point at fixed position x, motion is periodic (e.g. string vibrates up+down)

As waveform passes through,

repeat period $T = \frac{\text{repeat distance}}{\text{wave speed}} = \frac{\lambda}{v} \frac{[m]}{[m/s]}$

∴ Vibration freq. $f = \frac{1}{T}$ [Hz] $= \frac{v}{\lambda}$

$$\Rightarrow \boxed{v = f\lambda}$$

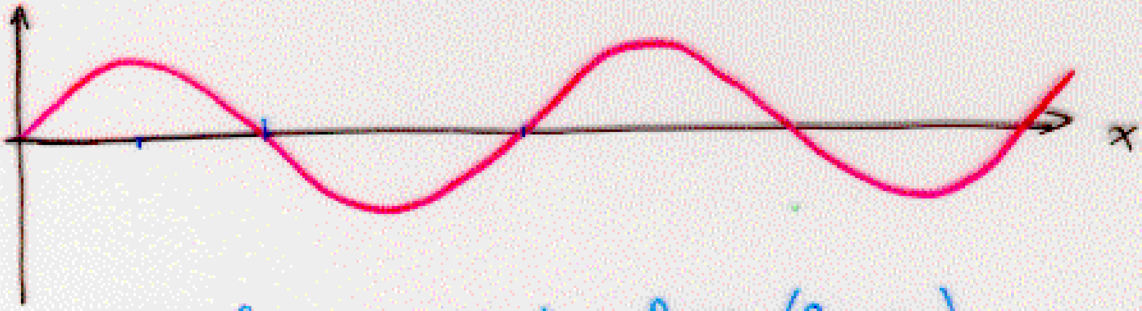
for any periodic wave

e.g. tuning fork vibrates at f = 440 Hz, in air sound speed = 330 m/s

$$\Rightarrow \lambda = v/f = \frac{330\,m/s}{440\,Hz} = 0.75m.$$

Harmonic Waves

If each point on wave executes SHM,



Waveform is $y(x) = A\sin\left(2\pi.\frac{x}{\lambda}\right)$

- repeats every 2π radians

i.e. $2\pi\frac{x}{\lambda} = 2\pi, 4\pi, \ldots.$

$\Rightarrow x = \lambda, 2\lambda, 3\lambda, \ldots\ldots$ as required

For travelling wave $y(x) \rightarrow y(x-vt)$

So $\boxed{y = A\sin\frac{2\pi}{\lambda}(x-vt)}$: Harmonic Wave Equation.

Note: Since $v = f\lambda = \lambda/T$, this becomes

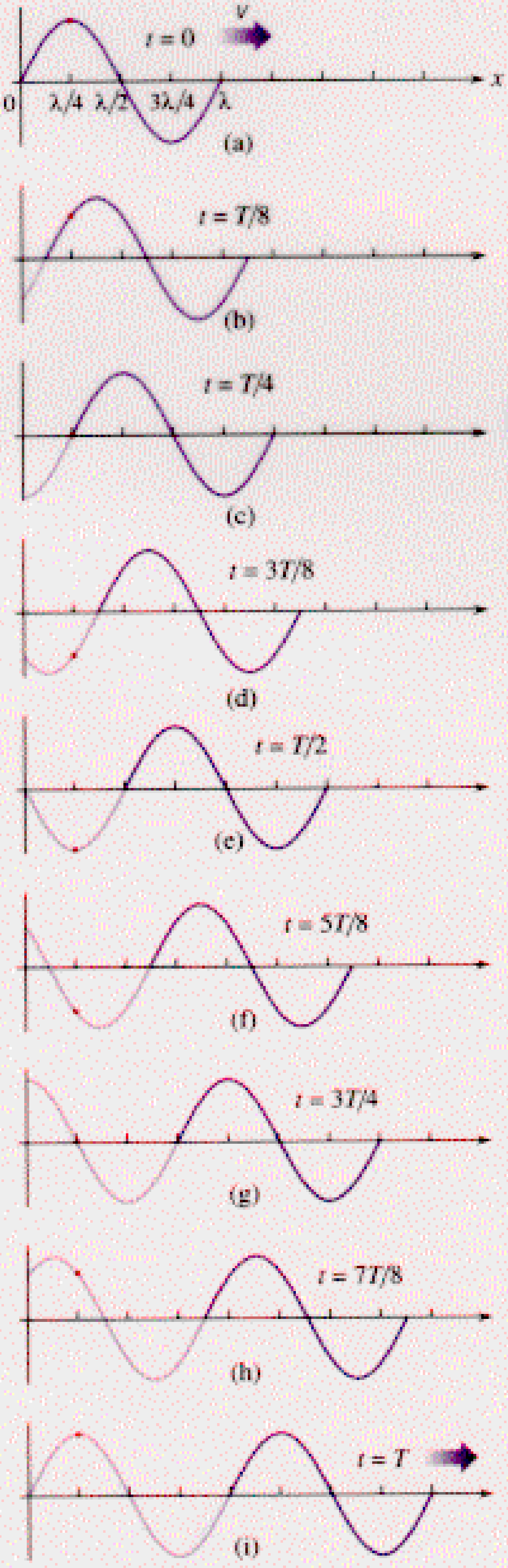
$\ast\ y = A\sin 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)$: repeats every λ and every period T.

[In general, depending on $y(t=0)$:

$y = A\sin\left[\frac{2\pi x}{\lambda} - 2\pi ft + \underbrace{\varphi}_{\text{phase at } t=0}\right]$]

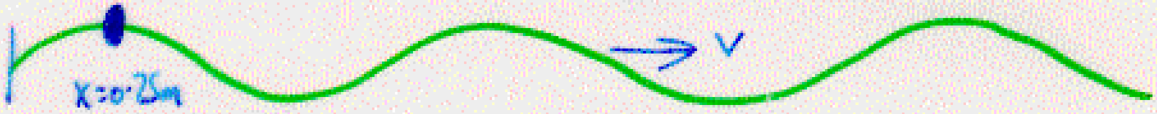
Figure 11.11

Harmonic wave moving along the x-axis



Example: A wave on a string is described by :

$y = 0{\cdot}02 \sin (6{\cdot}28 \underline{x} - 15\underline{t})$ Find:



1. Frequency and wavelength and speed of wave
2. Speed and acceleration of a bead on string at x = 0·25m

1. c.f. $y = A \sin \boxed{\frac{2\pi}{\lambda}} (x - \boxed{v}t)$

Here $y = 0{\cdot}02 \sin \boxed{6{\cdot}28} \left(x - \boxed{\frac{15}{6{\cdot}28}} t \right)$

$\Rightarrow$ amplitude 0·02m, $\frac{2\pi}{\lambda} = 6{\cdot}28$ so $\lambda = 1{\cdot}0$m, $V = \frac{15}{6{\cdot}28} = 2{\cdot}39$ m/s

2. For a point at $x = 0{\cdot}25$m, disp. $y = 0{\cdot}02 \sin (6{\cdot}28 \times 0{\cdot}25 - 15t)$
$(= \frac{1}{4} \lambda)$

$y = 0{\cdot}02 \sin (1{\cdot}57 - \overset{\omega}{15}t)$ *

= SHM with $\omega = 15$ rad/s
$A = 0{\cdot}02$m.

So transverse speed of bead $\frac{dy}{dt} = -15 \times 0{\cdot}02 \sin (1{\cdot}57 - 15t)$

So max. speed = $A\omega = 15 \times 0{\cdot}02 = \underline{0{\cdot}3 \text{ m/s}}$

– unrelated to wave speed V.

Accel. of bead (= force/mass) $\frac{d^2y}{dt^2} = -\omega^2 y$

has max. accel $= (-)\,\omega^2 A = 15^2 \times 0{\cdot}02 = 4{\cdot}5$ m/s^2