Reading Quiz

1. A mechanical wave in a medium transports:

a) energy and mass

b) energy and momentum

c) momentum and mass

d) None of the above

2. Deep inside a fluid (i.e. liquid or gas), the type(s) of mechanical waves which can be found is/are:

a) transverse

b) longitudinal

c) Both transverse and longitudinal

d) Depends on the fluid.

3. Solids can support the following type(s) of mechanical wave:

a) transverse

b) longitudinal

c) both transverse and longitudinal

d) neither - waves in solids are impossible

4. For a sound wave in air, as the frequency is increased, the wavelength:

a) increases

b) stays the same

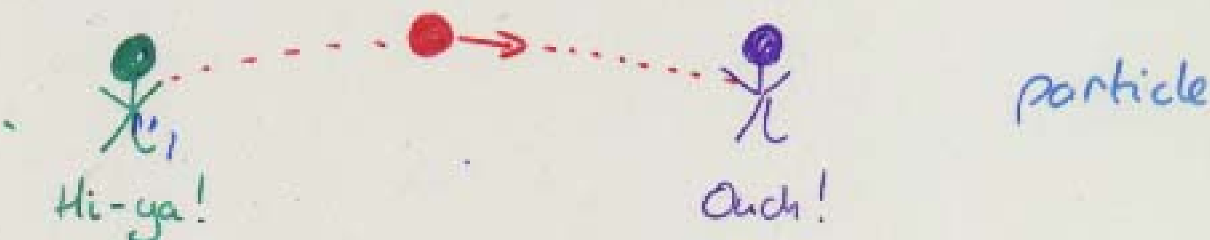
c) decreases

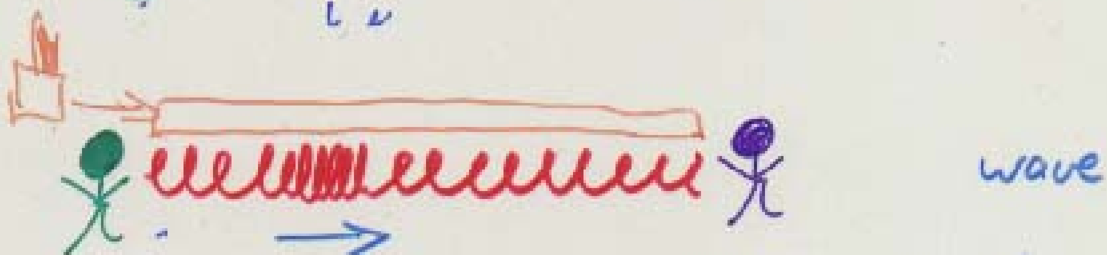
d) not enough info.

$\underline{v} = f\lambda$

Mechanical Waves (Hecht ch. 11)

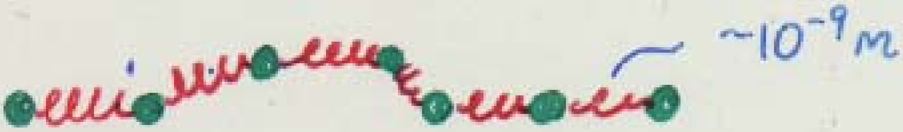
Waves transport energy + momentum (and information) through a medium:





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

Caused by: forces between neighbor molecules



electric attractive force ~ spring

$\Rightarrow$ restoring force on each molecule

- disturbance propagates through medium.

Week 5

H.W: Chapter 11 : 2, 3, 15, 31, 57, 68, 79, 113, 115.

Tuesday: Review

Wednesday: Review, office hours, problem section

Thursday: No lecture, TA office hours

Friday: Final exam 9:30–12:30 WLH2005.

Wave Characteristics

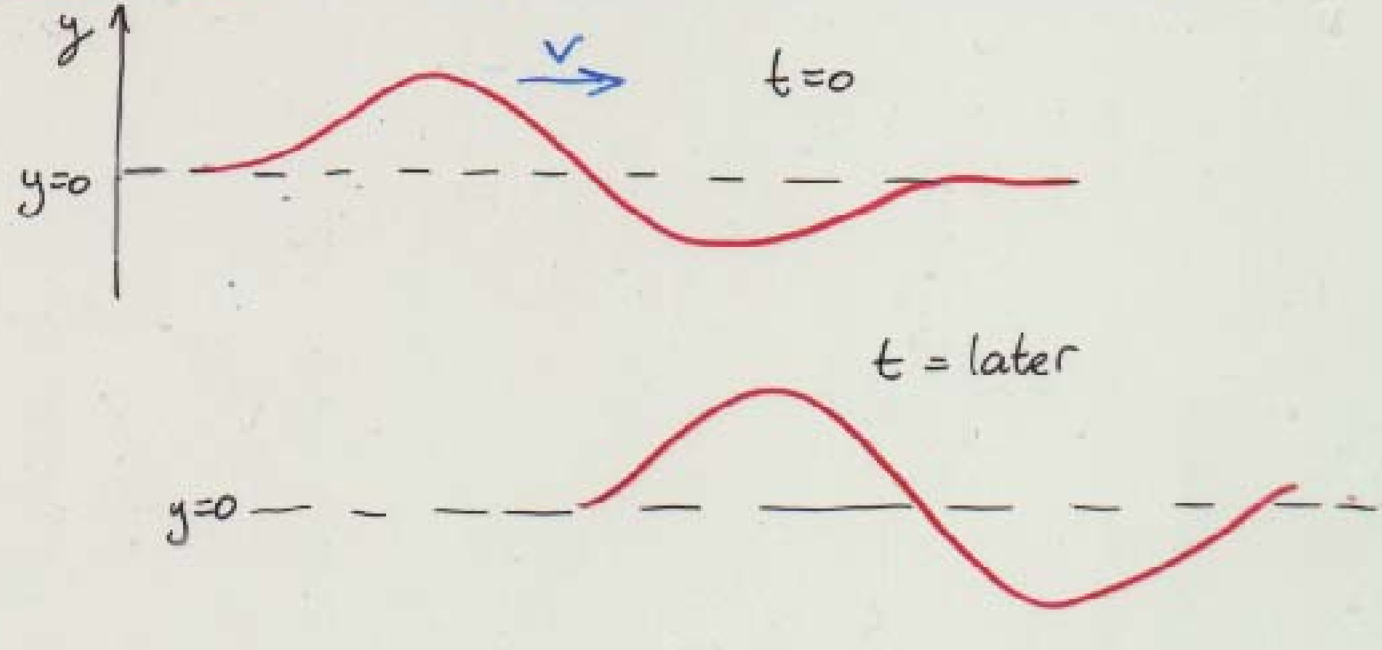
Longitudinal : Displacement along direction of travel

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

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

also solid bars, bones, earthquakes, ...

Transverse : Displacement $\perp$ to direction of travel



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

Figure 11.3
Transverse wave in a spring

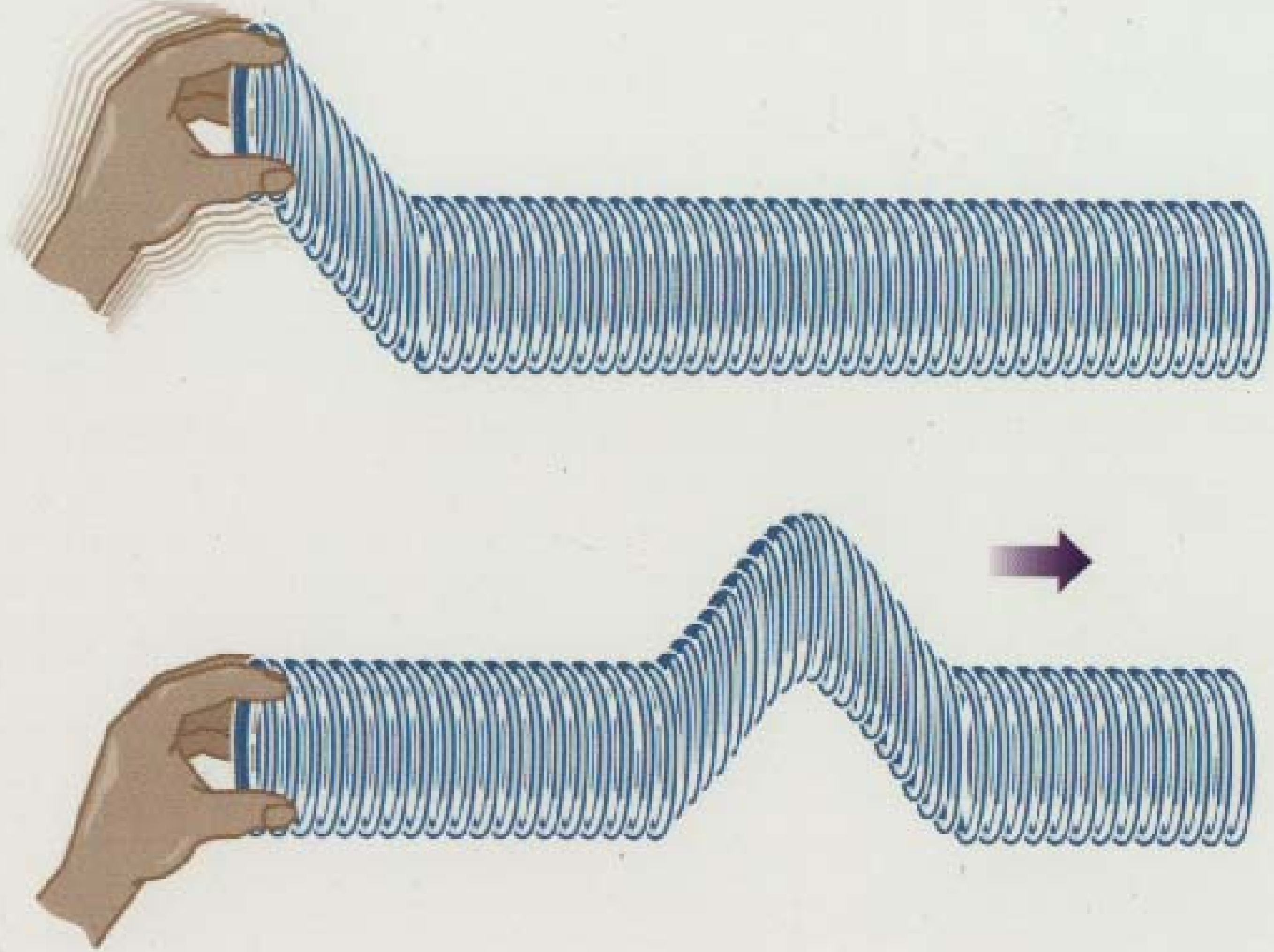
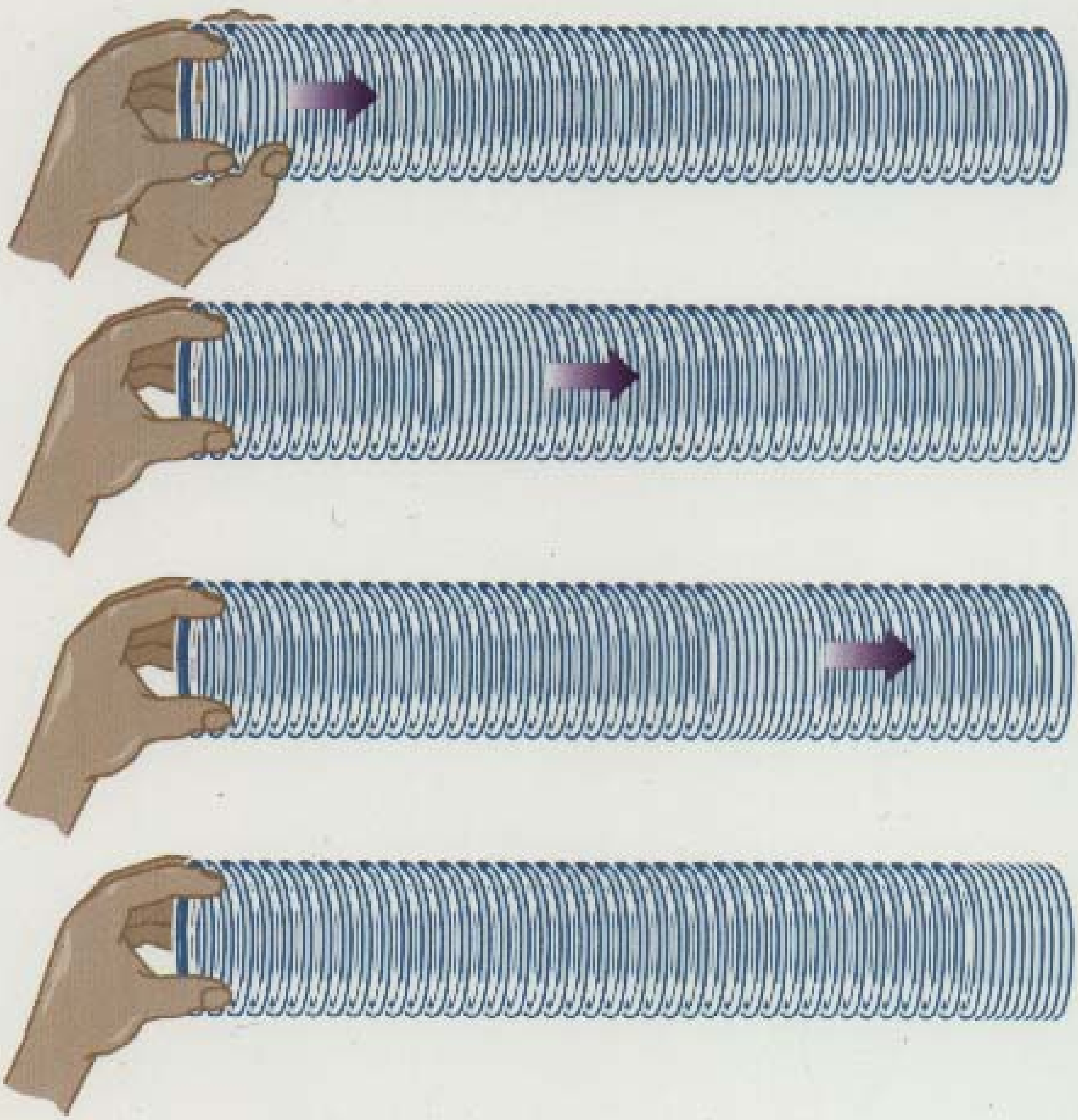


Figure 11.2

Longitudinal wave in a spring



Waveforms

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

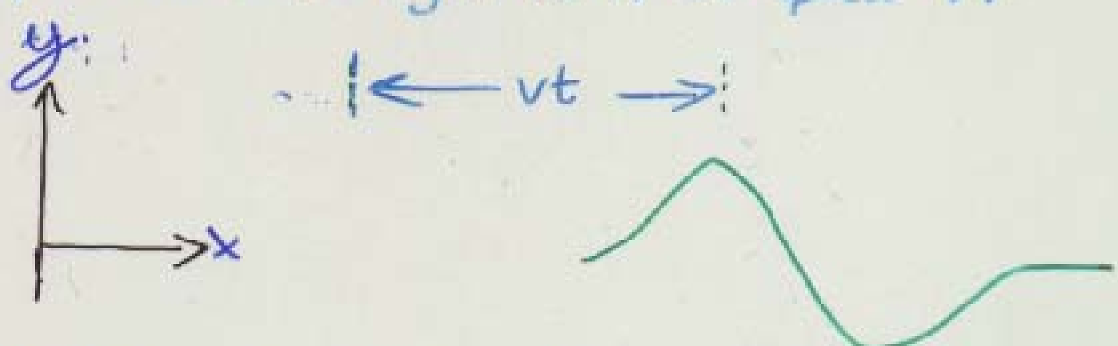
$\Rightarrow$ Wave function $\psi(x,t)$

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

e.g.

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

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



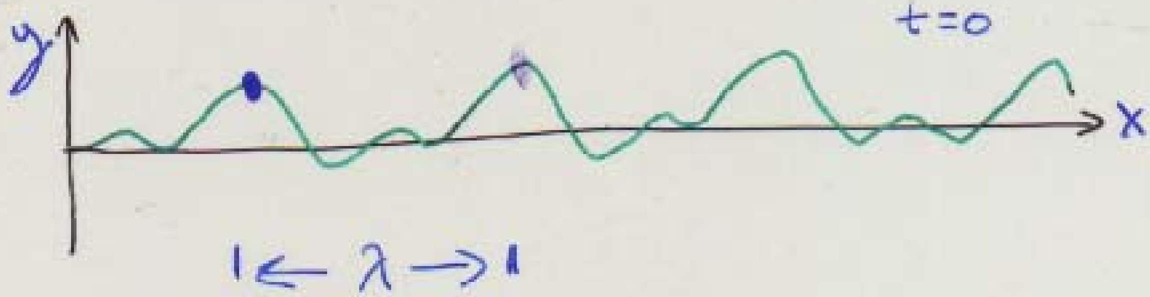
Now displacement $f(x) = f(x - vt)$

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

(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 $\equiv \lambda$ [m]

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

As waveform passes through,

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

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

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

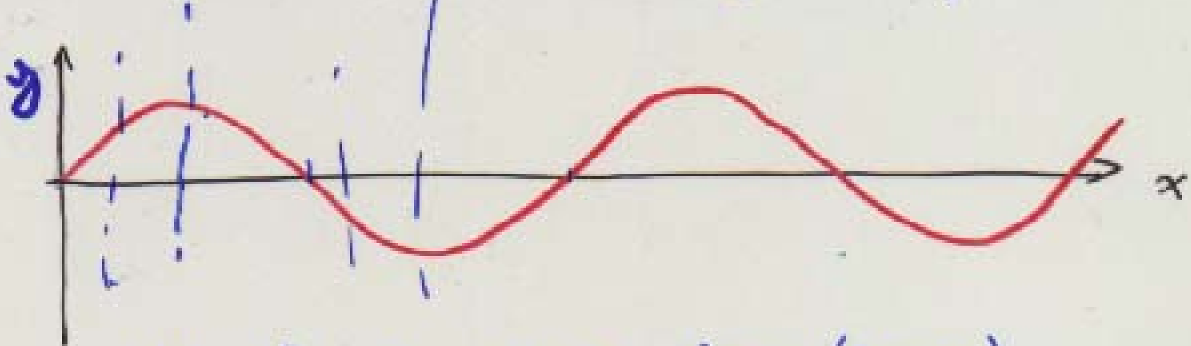
for any periodic wave

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

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

Harmonic Waves

If each point on wave executes SHM,



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

- repeats every 2π radians

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

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

For traveling 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

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

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

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

]

Example: A wave on a string is described by:

$y = 0.02 \sin(6.28\,\underline{x} - 15\underline{t})$ 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. $y = A \sin \frac{2\pi}{\lambda}(x - vt)$

Here $y = 0.02 \sin 6.28 \left(x - \frac{15}{6.28} t\right)$

$\Rightarrow$ amplitude 0.02m, $\frac{2\pi}{\lambda} = 6.28$ so $\lambda = 1.0m$, $v = \frac{15}{6.28} = 2.39\,m/s$

2. For a point at $x = 0.25m$ $(= \frac{1}{4}\lambda)$, disp. $y = 0.02 \sin(\underbrace{6.28 \times 0.25}_{1.57} - 15t)$

$\underline{y = 0.02 \sin(1.57 - \overset{\omega}{15}t)}$ *

= SHM with $\omega = 15$ rad/s, $A = 0.02m$.

So transverse speed of bead $\frac{dy}{dt} = -15 \times 0.02 \sin(1.57 - 15t)$

So max. speed = $A\omega = 15 \times 0.02 = \underline{0.3\,m/s}$

– unrelated to wave speed v.

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

has max. accel $= (-)\omega^2 A = 15^2 \times 0.02 = 4.5\,m/s^2$