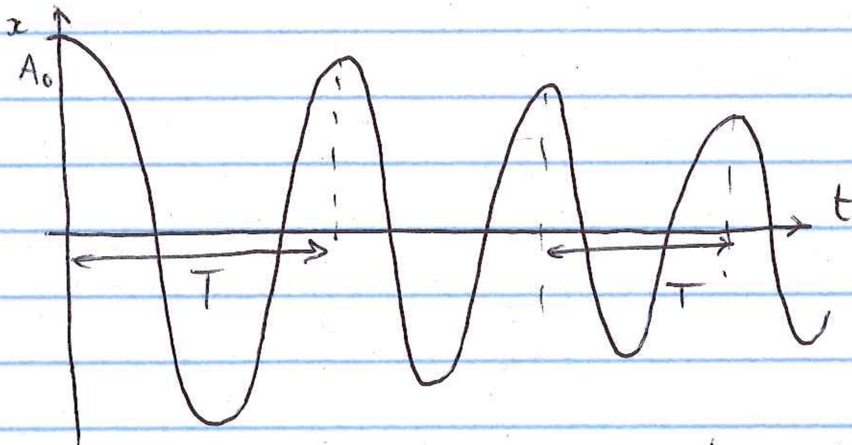
PHYS 107 - Week 13 - Friday

* Damped harmonic motion

damping due to non-conservative forces:

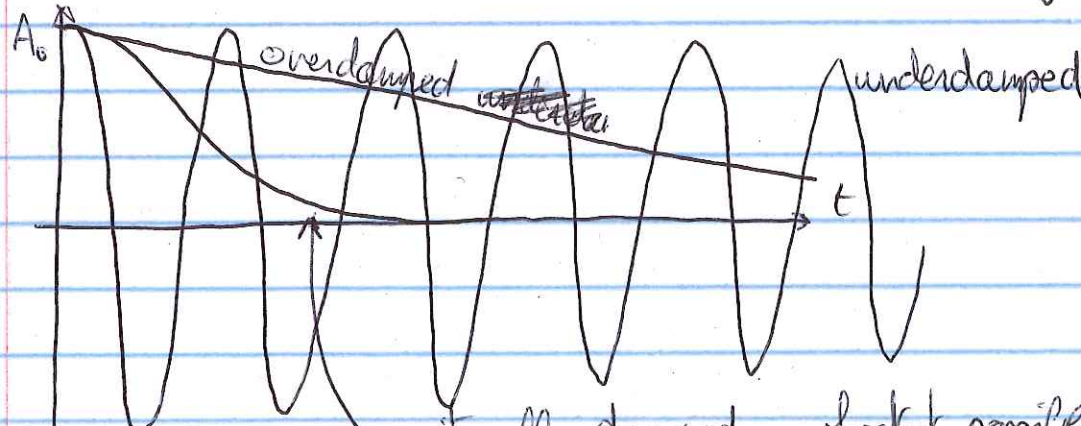
$$W_{nc} = \text{change in total energy} = \Delta(\underbrace{KE + PE})$$

$$E_{total} = \frac{1}{2}k\underbrace{A^2}_{x^2} = \frac{1}{2}m\underbrace{\omega^2 A^2}_{v^2}$$



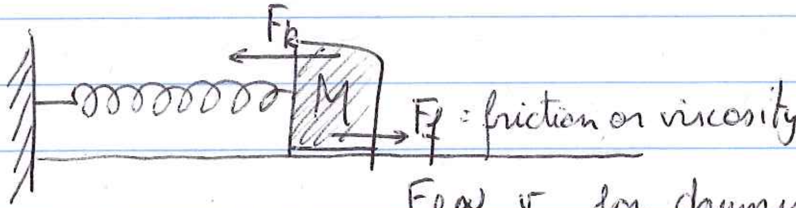

period and frequency unchanged when damping is small
amplitude gets smaller

if damping is large → period and frequency change




critically damped = shortest possible time equilibrium is stable position

- restoring force tries to bring system back to equilibrium
- dampening force works against the restoring force

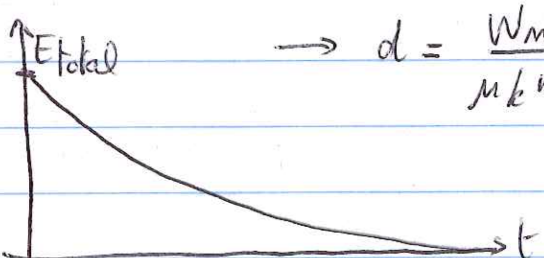



$F_f \propto v$ for damping

$F_f = \mu_k mg$ (even at equilibrium there is $\mu_k$ valid)

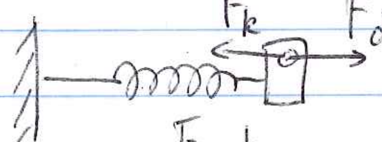
Total initial energy $= \frac{1}{2} k A_0^2 = KE_i + PE_i$

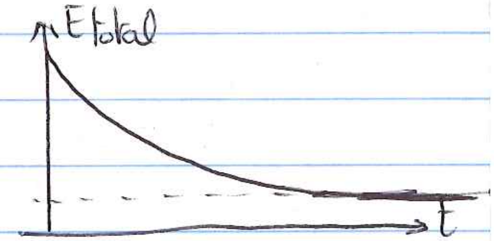
$$W_{nc} = F_f d = \mu_k Mgd$$




$\rightarrow d = \frac{W_{nc}}{\mu_k mg} = \frac{1}{2} \frac{kA^2}{\mu_k mg}$ = Total distance the harmonic motion will travel

Final position could be not at equilibrium, $x \neq 0$



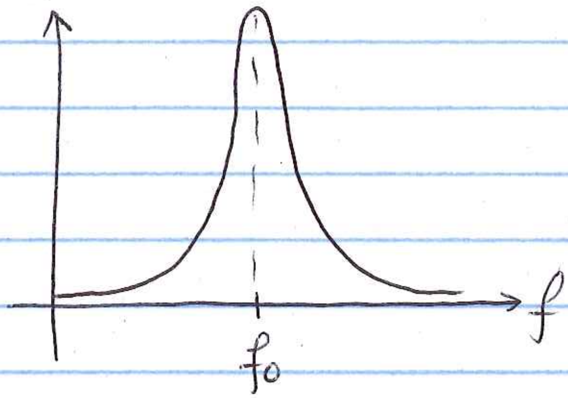




$F_k = kx$ $\quad F_d = \mu_k mg$

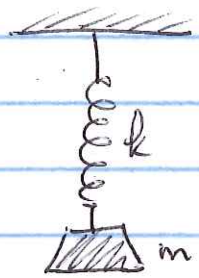
$\rightarrow kx = \mu_k mg \rightarrow x = \frac{\mu_k mg}{k}$

There will be final $PE_f = \frac{1}{2} k \left(\frac{\mu_k mg}{k}\right)^2$

* Forced oscillations : energy is <u>added</u> to the system
This changes the amplitude
- soldiers on a bridge
- musical instruments




$f$ = frequency of driving force
$f_0$ = natural frequency of the system




$$f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$ for spring and mass

largest amplitude when frequency $f$ of driving force $= f_0$

Resonance in wine glass

Example: Bay of Fundy:

- time for water to enter the Bay and flow back $= 12.4$ hrs
- time between the tides $= 12.42$ hrs

} <u>resonance</u>

Bay of Fundy

Resonance

* Waves: similar to simple harmonic motion but now moving in space, not just at one point

examples: water waves (vs. "single point going up/down)
waves on a string (vs. single point)
seismic waves
sound waves
nerve pulses
electromagnetic waves: light, X-rays, UV, IR
(no medium needed!)

Features: - energy is transported, but medium/matter is not
- propagation of a disturbance

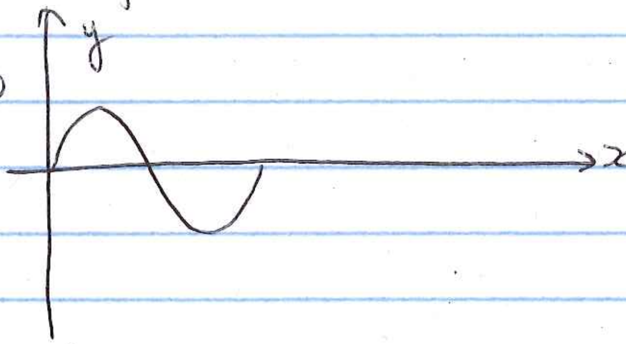
Types of waves: - transverse → string, electromagnetic
- longitudinal: motion is parallel to the direction of propagation
↳ sound waves, slinky Slinky

mixed waves too

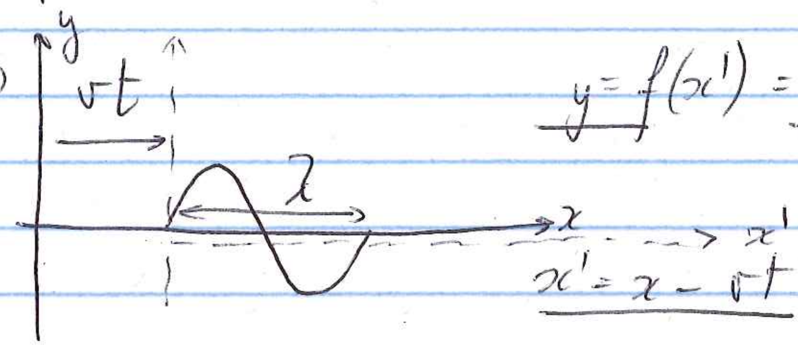
Phenomena of waves: interference, reflection

* Wave function

at $t=0$




at $t>0$




$\underline{y = f(x') = f(x-vt)}$

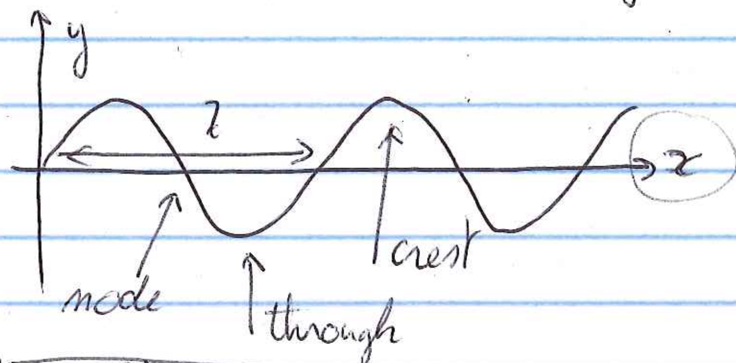
$\underline{x' = x - vt}$

Waves have form $\underline{y = f(x-vt)}$

Question 1a

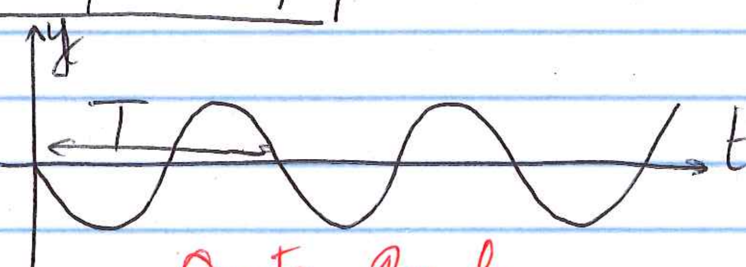
\+ Periodic waves → wave length $= \lambda$

at $t$




$$\boxed{v = \frac{\lambda}{T} = \lambda f}$$

at $x$




Question 2a-b

If $v$ = constant (depends on medium)

↳ large $\lambda$, small $f$
small $\lambda$, large $f$

WCWM: $f = 90.9$ MHz, $v = c = 3 \times 10^8$ m/s

↳ $\lambda = \frac{3 \times 10^8 \text{ m/s}}{90.9 \times 10^6 \text{ Hz}} = \underline{3.3\text{m}}$

microwave oven: $f = 2.45$ GHz, $v = c$

↳ $\lambda = 12.5$ cm → rotation

$v$ is determined by the medium properties

waves on a string → could depend on tension, mass of string, length $\ell$

$N = kg\ m/s^2$

mass of string → kg, length $\ell$ → m

$v^2 = \frac{m^2}{s^2} \longrightarrow v \propto \sqrt{\frac{\ell T}{m}}$ has correct units

↳ introduce $m/\ell = \mu$ as mass per unit length

$$v = \sqrt{\frac{T}{\mu}}$$