Physics 7E study notes, UCI summer 2003

by Nasser M. Abbasi

June 27, 2003

Contents

1 chapter 15 fluids

Bernulli

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

continuity equation

$A_1 v_1 = A_2 v_2$

2 chapter 13 Simple Harmonic Motion

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

$2\pi f = \omega$

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

we can find ω from:

1. For spring given K and Mass attached to spring, $\omega = \sqrt{\frac{k}{m}}$
2. For normal pendilum, $\omega = \sqrt{\frac{g}{L}}$
3. For physical pendilum, $\omega = \sqrt{\frac{mgd}{I}}$.where d is distance from center of mass to pivot, and I is moment of inertia. For a rod, $I = 1/3\ ML^2$

Parallel axis theorm: moment of interia=$I_{cm} + MR^2$

2.1 Undamped spring SHM motion

$$-kx = ma$$

solution is $x = A\cos(\omega t + \phi_o)$
$v = -A\omega \sin(\omega t + \phi_o) = \pm\omega\sqrt{A^2 - x^2}$(use this form if given x and A and asked to find v)
$a = -A\omega^2 \cos(\omega t + \phi_o)$
Total energy in a spring $= \frac{1}{2}kA^2$ where A is the amplititude.
KE+PE=total energy.
KE=$\frac{1}{2}mv^2$
PE=$\frac{1}{2}kx^2$

2.2 Damped spring SHM oscillations

retadring force $R = -bv$

$$-kx - bv = ma$$

Solution is $x = Ae^{-\frac{b}{2m}t}\cos(\omega t + \phi_o)$ where $\omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2} = \sqrt{\omega_o - \left(\frac{b}{2m}\right)^2}$
There are 3 cases of damped oscillations:

1. underdamped: $R_{\max} = bv_{\max} < kA$
2. critical damped: $\frac{k}{m} = \left(\frac{b}{2m}\right)$ i.e. $\omega = 0$
3. over dampled: $\frac{k}{m} > \left(\frac{b}{2m}\right)$

2.3 Damped and external force spring SHM motion

Assume we apply a force $F_{ext}\cos(\omega t)$, in addition to damping force $-bv$,hence the ODE now is

$$F_{ext}\cos(\omega t) - kx - b\frac{dx}{dt} = m\ \frac{d^2x}{dt^2}$$

Solution is $x = A\cos(\omega t + \phi)$ where $A = \frac{\frac{F_{ext}}{m}}{\sqrt{(\omega^2-\omega_o^2)^2+\left(\frac{b\omega}{m}\right)^2}}$ where $\omega_o = \frac{k}{m}$

We see that as $\omega \longrightarrow \omega_o$ then $A = \frac{\frac{F_{ext}}{m}}{\left(\frac{b\omega}{m}\right)} = \frac{F_{ext}}{b\omega_o}$,Now in the absense of damping force, this means $b = 0$, then we see that $A \longrightarrow \infty$

2.4 Spring K arrangments

For springs in series, $\frac{1}{k_{total}} = \frac{1}{k_1} + \frac{1}{k_2}$, so $k_{total} = \frac{k_1 k_2}{k_1+k_2}$

For springs in parallel. $k_{total} = k_1 + k_2$

3 Chapter 16 Mechanical waves (Transverse)

see printout

4 Chapter 17 Mechanical waves (longtitudenal)

see printout

5 Chapter 17 Mechanical waves (doppler)

see printout

6 Chapter 18 Superposition and standing waves

If the path difference $\Delta r = 0, \lambda, 2\lambda, 3\lambda, \cdots$ then the result sum of the waves is constructive (more amplitude). If $\Delta r = 0.5\lambda, 1.5\lambda, 2.5\lambda, \cdots$ then the result is destructive.

In a pipe, which is open on one end and closed on the other end, we can only have the fundamental harmoic, then the 3rd then the 5th, etc... i.e. we skip the second and the fourth, etc.... so we get $f_1, 3f_1, 5f_1, \cdots$. here, $f_1 = \frac{v}{4L}$

If closed (or open) on both ends, i.e. we have standing waves, then we get $f_1, 2f_1, 3f_1, 4f_1, \cdots$. here, $f_1 = \frac{v}{2L}$ wher $v = \sqrt{\frac{T}{\mu}}$ or $v =$speed of sound depending on instrument.

given $y_1 = A\sin(kx - \omega t)$ and $y_2 = A\sin(kx + \omega t)$ i.e. same waves but travelling towards each others (i.e. in opposit directions), their sum is $y = (2A\sin kx)\cos\omega t$

In a standing wave (both ends are closed) and when the waves are in phase, and have the same frequency and amplitude, then the locations of the nodes and antinodes are given by

nodes: $x = 0, \quad 0.5\lambda, \quad \lambda, \quad 1.5\lambda, \cdots$

antinodes: $x = 0.25\lambda, \quad 0.75\lambda, \quad 1.25\lambda, \quad 1.75\lambda, \cdots$

So, to find locations of nodes/antinodes, simply calculate λ

Also, we can write $L = \frac{1}{2}\lambda_1 = \frac{2}{2}\lambda_2 = \frac{3}{2}\lambda_3 = \frac{4}{2}\lambda_4 = \cdots$ we can use this to find L if given two different and successive λ

7 Chapter 38 Diffraction and polarization

Diffraction is the divergence of light from its initial line of travel (as it leaves a slit). To see diffraction use single slit. (to see interference of light, use 2 slits).

For diffraction, slit width is used. For interference, distance between slits is used.

The angle θ at which dark bands are seen on the screen is found from $a\sin\theta = m\lambda$, where $m = \pm 1, \pm 2, \cdots$

Also notice that the central maxiumum band is twice as wide as the second maxima.

To find intensity at different maxima and minima use this:

$I = I_{\max}\left(\frac{\sin\left(\frac{\beta}{2}\right)}{\frac{\beta}{2}}\right)^2$ here, $\frac{\beta}{2}$is the phase difference

where $\frac{\beta}{2} = m\pi$, $m = \pm 1, \pm 2, \cdots$ for minima (we get I=0)

and $\frac{\beta}{2} = (m + \frac{1}{2})\pi$, $m = \pm 1, \pm 2, \cdots$ for maxima (we get I=0)

For example, for $m = 1$, maxima intensity is found

$I = I_{\max}\left(\frac{\sin\left(\frac{\pi}{2}\right)}{\frac{\pi}{2}}\right)^2 = I_{\max}\left(\frac{1}{\frac{\pi}{2}}\right)^2 = I_{\max}\left(\frac{4}{\pi^2}\right) = 0.405\,28\ I_{\max}$

for $m = 2$

$I = I_{\max}\left(\frac{\sin\left(\frac{5\pi}{2}\right)}{\frac{5\pi}{2}}\right)^2 = I_{\max}\ \ 1.621\,1 \times 10^{-2}$

for $m = 3$

$I = I_{\max}\left(\frac{\sin\left(\frac{7\pi}{2}\right)}{\frac{7\pi}{2}}\right)^2 = I_{\max}\ \ 8.271\,1 \times 10^{-3}$

For angular resolution of 2 sources, use $\theta_{\min} = \frac{\lambda}{a}$ where a is the width of the slit.

If the slit was circular, with diameter D then $\theta_{\min} = 1.22\frac{\lambda}{D}$

Diffraction granting is used to resolve/find wave length.

Resolving power R of a diffracting granting is $R = \frac{average\ \lambda}{\Delta\lambda}$

R is also given by $R = Nm$, where N is the number of lines/grids, and m is the order number. $m = 0, 1, 2, ...$

Polrization: $I = I_{\max}\cos^2\theta$

Polarization by relfection: When $\tan\theta_p = n$, then reflected light is polarized.

8 Chapter 37 interference (2 slits)

One course, but 2 slits. Hence, we consider the light comming from the slits as 2 coherent sources (since from the same original source). (So, same frequency ω and the same amplitude E_0.

Now, as rays leave the slits, they travel different directions. And the path difference travelled causes a phase difference between the rays. Let this pahse difference be ϕ

$E_1 = E_0\sin(\omega t)$

$E_2 = E_0\sin(\omega t + \phi)$

So, E_p which is E at point p on the screen is given by $E = 2E_0\cos\left(\frac{\phi}{2}\right)\sin\left(\omega t + \frac{\phi}{2}\right)$

Intensity $I = E_p^2 = 4E_0^2\cos^2\left(\frac{\phi}{2}\right)\sin^2\left(\omega t + \frac{\phi}{2}\right)$

time averaged intensity is $I = 4E_0^2\cos^2\left(\frac{\phi}{2}\right)\frac{1}{2} = 2E_0^2\cos^2\left(\frac{\phi}{2}\right) = I_{\max}\cos^2\left(\frac{\phi}{2}\right)$

where $I_{\max} = 2E_0^2$

Notice that here, ϕ is the phase difference between the 2 rays measure AT THE WALL.

we see that when phase difference is $0, 2\pi, 4\pi, \cdots$ then we get a maxima. When phase difference is $\pi, 3\pi, \cdots$ we get a minima

We can find phase difference ϕ given angle θ. since $\frac{\delta}{\lambda} = \frac{\phi}{2\pi}$

this leads to $\phi = \frac{2\pi}{\lambda}d\sin\phi$

This leads to $I = I_{\max}\cos^2\left(\frac{\pi}{\lambda}d\sin\phi\right) = I_{\max}\cos^2\left(\frac{\pi}{\lambda}d\frac{y}{L}\right)$

So, this gives the intensity at hight y from the center.

From this we see that $y_{bright} = \frac{\lambda L}{d}m$ for $m = 0, \pm 1, \pm 2,$

and $y_{dark} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right)$ for $m = 0, \pm 1, \pm 2$

If given wave length λ in vacume, and given a matrial whose index of refraction n, then the wave length in the matrial is found from $\lambda_n = \frac{\lambda}{n}$

9 Misc

area of circle πr^2
circumferance of circle $2\pi r$
area of sphere: $4\pi r^2$
$\frac{d}{dx}\cos kx = -k\sin x$