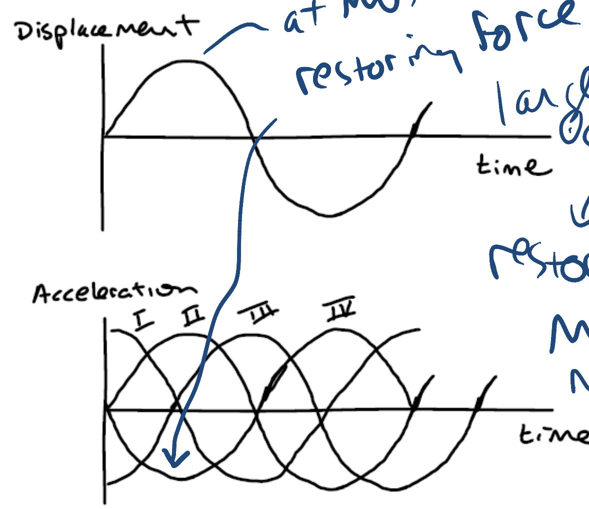
P123 University of Rochester NAME Soln key - SM
S. Manly Spring 2013

Exam 1 (February 28, 2013)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given unless specified otherwise.

<u>Problem 1 (12 pts, 4 pts for each part):</u>

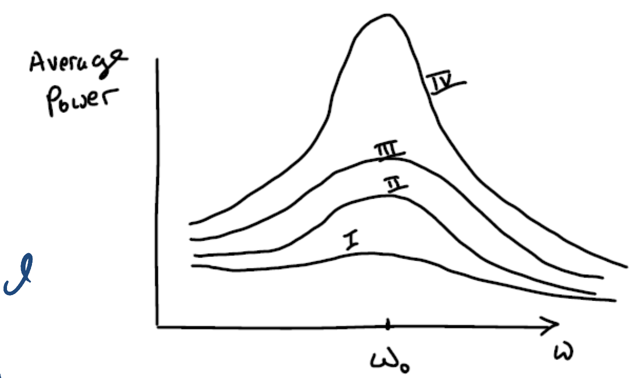
The top graph represents the variation of displacement with time for a particle executing simple harmonic motion. Which curve in the bottom graph represents the variation of acceleration with time for the same particle?



at most + point restoring force is largest so restoring means negative

a) I
b) II
c) III
d) IV
e) None of the curves

The graph shows the average power delivered to 4 oscillating system as a function of the driving frequency, ω. The natural frequency of each system is ω_o. The damping is least for which system?



a) I
b) II
c) III
d) IV

Damping least so resonance larger

If two identical waves with a phase difference of 3π are added, the result is

a) A wave with the same frequency but twice the amplitude
b) A wave with the same amplitude but twice the frequency
c) A wave with zero amplitude
d) A wave with zero frequency
e) A wave with the twice the amplitude and twice the wavelength
f) The wavelength must be specified to answer this problem

3π change in phase puts waves <u>exactly</u> out of phase

destr. interference

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Problem 2 (12 pts, 4 pts for each part):

Your spaceship is traveling directly away from the earth with a speed of c/2, where c is the speed of light. A light signal is sent from earth to a planet along your line of travel. The speed with which this light passes your spaceship is

a) c/4
b) c/2
c) c
d) 3c/4
e) $c/[1-(1/4)^2]^{1/2}$

one of the two underlying postulates for Spec. Rel.

Spaceman Spiff zips past you at 0.98c holding a meterstick straight up (at right angles to his motion) and a clock. To you, the meterstick appears to be _____ and the clock appears _____.

a) too short; to run too fast.
b) too long; to run too slow.
c) a meter in length; to run too fast.
d) a meter in length; to run too slow.
e) too short; to run too slow.
f) too long; to run too fast.

No length contraction except along motion

have time dilation

$\gamma t_{prop} = t$

spiff's frame

A spaceship travels at a speed of 0.95c to the nearest star, 4.3 light years away. How long does the trip take from the point of view of the passengers on the ship? (Ignore any acceleration at the beginning and end of the trip.)

a) 1.4 y
~~b) 1.0 y~~
c) 4.5 y
d) 14 y
e) 0.44 y

at 0.95c $\gamma = \dfrac{1}{\sqrt{1-.95^2}} = 3.2$

Passengers perceive distance to be

$\dfrac{4.3}{\gamma}\,ly = 1.34\,ly$

at 0.95 c length $= \dfrac{1.34}{0.95} = 1.41$ years

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Problem 3 (13 pts):

Sorority Sally yells loudly across the quad to a friend inquiring about the upcoming meeting of the sorority book group. Biff Jones, who is standing 5 m from Sally perceives her yell to have an intensity of 90 dB (and he's not too happy about it). A person standing 300 meters away would perceive the yell to have what intensity? *Ignore the effect of surrounding buildings and trees and the such (not a good assumption in real life, but don't let that get in the way).*

$\beta = 10 \log I/I_0$

$\frac{I_{300}}{I_5} = \frac{5^2}{300^2}$ $I_{300} = 2.7\times10^{-4} I_5$

$\log I_5/I_0$

$\beta_{300} = 10 \log \frac{(2.7\times10^{-4}) I_5}{I_0}$

$\beta_{300} = 90 + 10 \log(2.7\times10^{-4}) = 54.3$

$90 - 36.2$

Problem 4 (14 pts):

Steelgut McPhee is the toughest cop in town. In spite of his gruff exterior, Steelgut has a musical side and is able to identify musical notes accurately when he hears them. He sees some rowdy college students driving out on Elmwood headed to an after-exam party. For some unfathomable reason, the students are honking the car horn as they drive down Elmwood. Steelgut notices that the sound of the horn is a distinct B note at 494 Hz as the car approaches him and it drops to a distinct A note at 440 Hz as the car passes by. Steelgut sighs, hops on his motorcycle and gives chase. Steelgut gives the driver of the car a speeding ticket. With what speed does Steelgut claim the car was traveling?

dB as horn

$\frac{340}{340 - V_{source}}$

as horn recedes $f = 440 = f\left(\frac{340}{340 + V_{source}}\right)$

$340 + V_{source} \cdot \frac{494}{440} = 340 + V_{source}$

$V_{source} = .06 \ldots$ m/s

$2.12\, V_{source}$

1)	/9
2)	/9
3)	/12
4)	/12
5)	/14
6)	/14
7)	/14
8)	/16
tot	/100

*

change to 4.1×10^{-10}

Problem 5 (15 pts, 5 pts for each part):

Biff Jones, physics graduate student extraordinaire, spends most of his days driving his Maserati and schmoozing with movie stars at fine restaurants. When he tires of that, Biff studies the K_S^o particle (called the "K-zero-short"). Biff observes a K_S^o particle (created in his lab by a proton beam hitting a target) to travel 0.12 meters and live 4×10^{-10} s before decaying in the lab. According to Biff's data, the K_S^o particle decays into two other particles, a π^+ and a π^- ("pi-plus" and "pi-minus") with the following energies and momenta:

π^+: E = 183.74 MeV, P_x = 84.1 MeV/c, P_y = 84.1 MeV/c, P_z = 0

π^-: E = 972 MeV, P_x = 958.3 MeV/c, P_y = -83.9 MeV/c, P_z = 0

a) What is the proper lifetime the K_S^o particle, i.e. its lifetime in its rest frame?

0.976 ↓ I rounded

K_s^0 goes .12 m in 4×10^{-10} s in lab, $V = \left(\dfrac{.12}{4.1\times10^{-10}\,s}\right)/3\times10^{8} = 0.98c$

In K_s^0 rest frame

$$\tau = \frac{t_{lab}}{\gamma} \qquad \gamma = \frac{1}{\sqrt{1-.98^2}}$$

$$\gamma = 5$$

$$\boxed{\tau = \frac{4.1\times10^{-10}}{5} = 8.2\times10^{-11}\,s}$$

b) What is the invariant mass of one of the pions (both have the same mass)?

$$-m^2c^2 = -\frac{E^2}{c^2} + p^2 \qquad m^2c^4 = E^2 - p^2c^2$$

$$= (183.74)^2\,\text{MeV}^2 - (2)(84.1)^2\,\frac{\text{MeV}^2}{c^2}c^2$$

$$m^2c^4 = 19.61\,\text{MeV}^2$$

$$\boxed{m = 140\,\text{MeV}/c^2}$$

c) What is the invariant mass of the K_S^o particle?

4 vector P cons $\qquad P_{K_s} = P_{\pi^+} + P_{\pi^-}$

So K_s 4 vector

$E = 183.74 + 972 = 1155.74$

$P_x = 84.1 + 958.3 = 1042.4$

$P_y = 84.1 - 83.9 = 0.2$

$P_z = 0$

$$m^2c^4 = E^2 - p^2c^2$$

$$m^2c^4 = 1155.74^2 - 1042.4^2 - 0.2^2$$

$$m^2c^4 = 249.14$$

$$\boxed{m = 499\,\text{MeV}/c^2}$$

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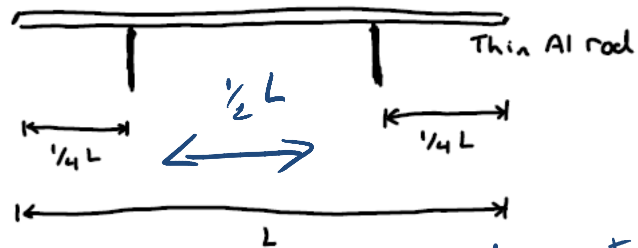
Problem 6 (14 pts):

A long, thin aluminum rod of length L=90 cm rests on two narrow supports located ¼ L in from each end, as shown in the sketch. When stroked properly, this rod "sings", emitting a clear, loud ringing noise. Determine the resonant frequencies for this rod. *To aid you in this endeavor, an engineer with a thing for metal rods has determined that the waves traveling in the rod which make the sound move at speed of 5100 m/s.*



$L = 1\lambda$

$L = 3\lambda$

$\vdots$

$L = n\lambda$

$n = 1, 3, 5 \ldots$

$\lambda = \frac{L}{n}$

$v = \lambda f$

$\lambda = v/f$

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

$f_n = \frac{vn}{L} = \frac{5100}{90} n = 56.7\, n$ Hz

$n = 1, 3, 5 \ldots$

$L = 2\lambda$ does Not work

need Antinode here

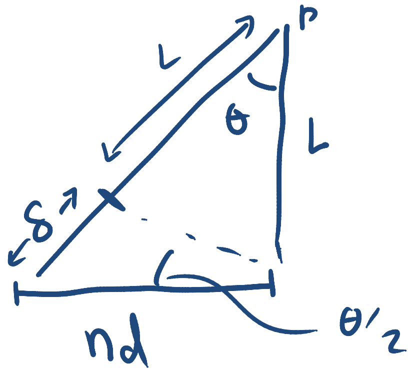
During exam ∞ array, "zero" to 1 figure incorrect

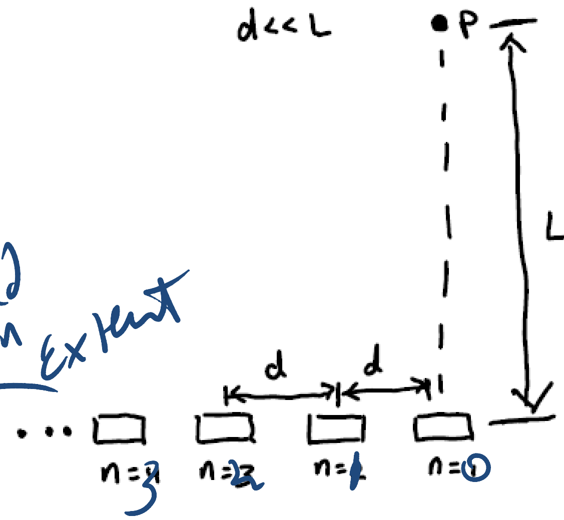
BAD problem... graded accordingly

change * points

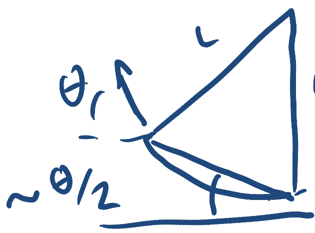
Problem ~~8~~ 7 (20 pts):

Consider an array of speakers arranged as in the sketch below numbered from zero to N as shown. Assume the speakers send out sound coherently (that is to say, they all emit the same sounds at the same times in phase). Show that the ~~maximum~~ wavelength, λ, where the sound from all the speakers add constructively at point P is ~~d^2/L~~ $d^2/2L$. *Assume L>>d in this problem.* *



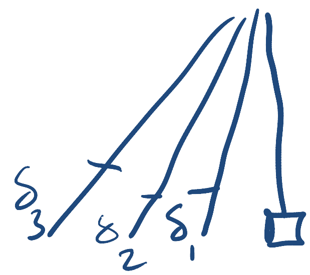


limited in extent



$$\frac{\delta}{nd} = \sin\frac{\theta}{2}$$

θ small because d<<L



$$\frac{\delta}{nd} = \frac{\theta}{2}$$

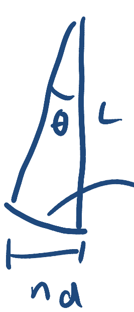
When $\lambda = \frac{d^2}{2L}$

$$\delta = \frac{nd\theta}{2} \longrightarrow \delta = \frac{n^2 d^2}{2L}$$

get constructive interference on each path

sub in

Since δ_n is integral multiple of λ



$S \sim nd$

$S = L\theta$

so $\theta \sim \frac{S}{L} \sim \frac{nd}{L}$

Smaller λ will not work since $\delta_1 < 2\pi$