PHY131H1F - Class 24

The last class!!

Today:

- Finishing Ch.14 up to section 14.7:
- Standing Sound Waves
- Wind Instruments
- Course review
- Tips for the final exam

PHY131H1F	A - KI	WED 13 DEC	AM 9:00 - 11:00	EX 100
PHY131H1F	KL - ST	WED 13 DEC	AM 9:00 - 11:00	EX 200
PHY131H1F	SU - WAN	WED 13 DEC	AM 9:00 - 11:00	EX 300
PHY131H1F	WAS - Z	WED 13 DEC	AM 9:00 - 11:00	EX 310

Standing Waves on a String

There are three things to note about the normal modes of a string:

1. m is the number of *antinodes* on the standing wave.
2. The *fundamental mode*, with $m = 1$, has $\lambda_1 = 2L$.
3. The frequencies of the normal modes form a series: f_1, $2f_1$, $3f_1$, …These are also called **harmonics**. $2f_1$ is the "second harmonic", $3f_1$ is the "third harmonic", etc.

Learning Catalytics Discussion Question

The frequency of the third harmonic of a string is

A. One-third the frequency of the fundamental.
B. Equal to the frequency of the fundamental.
C. Three times the frequency of the fundamental.
D. Nine times the frequency of the fundamental.

m = mode number

$$f_m = m f_1$$

Musical Instruments

- Instruments such as the harp, the piano, and the violin have strings fixed at the ends and tightened to create tension.
- A disturbance generated on the string by plucking, striking, or bowing it creates a **standing wave** on the string.

- The fundamental frequency is the musical note you hear when the string is sounded:

$$f_1 = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$$

where F is the tension in the string and μ is its linear density.

$F \uparrow$, $f_1 \uparrow$

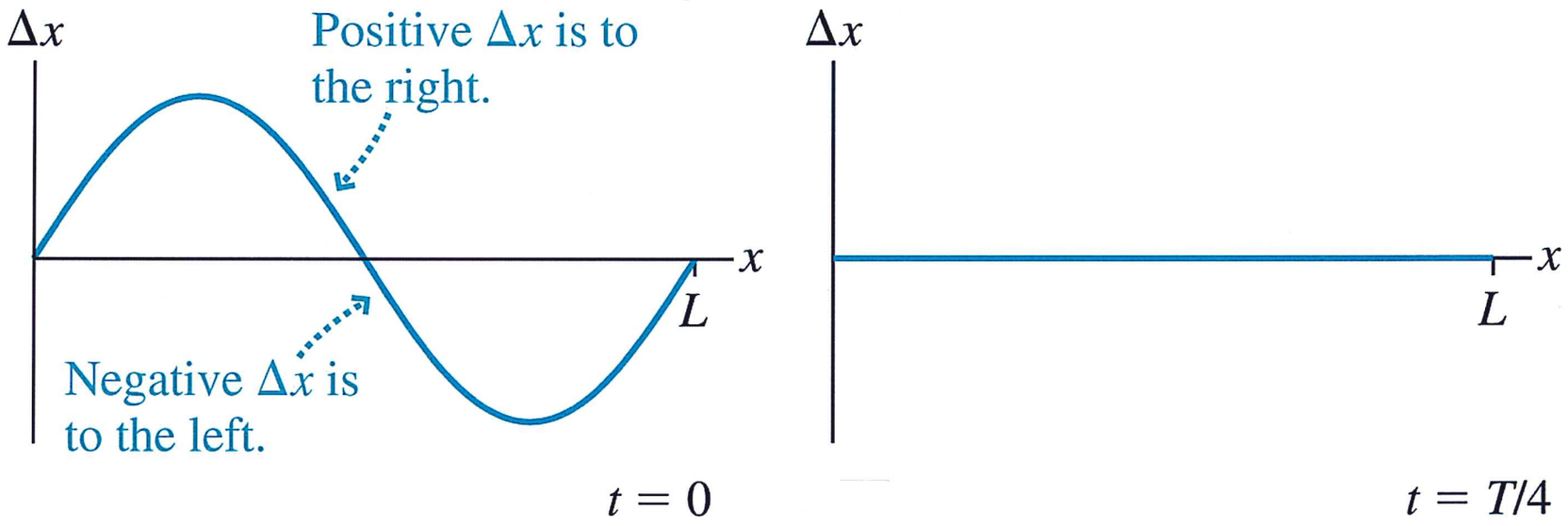
$\mu \uparrow$, $f_1 \downarrow$

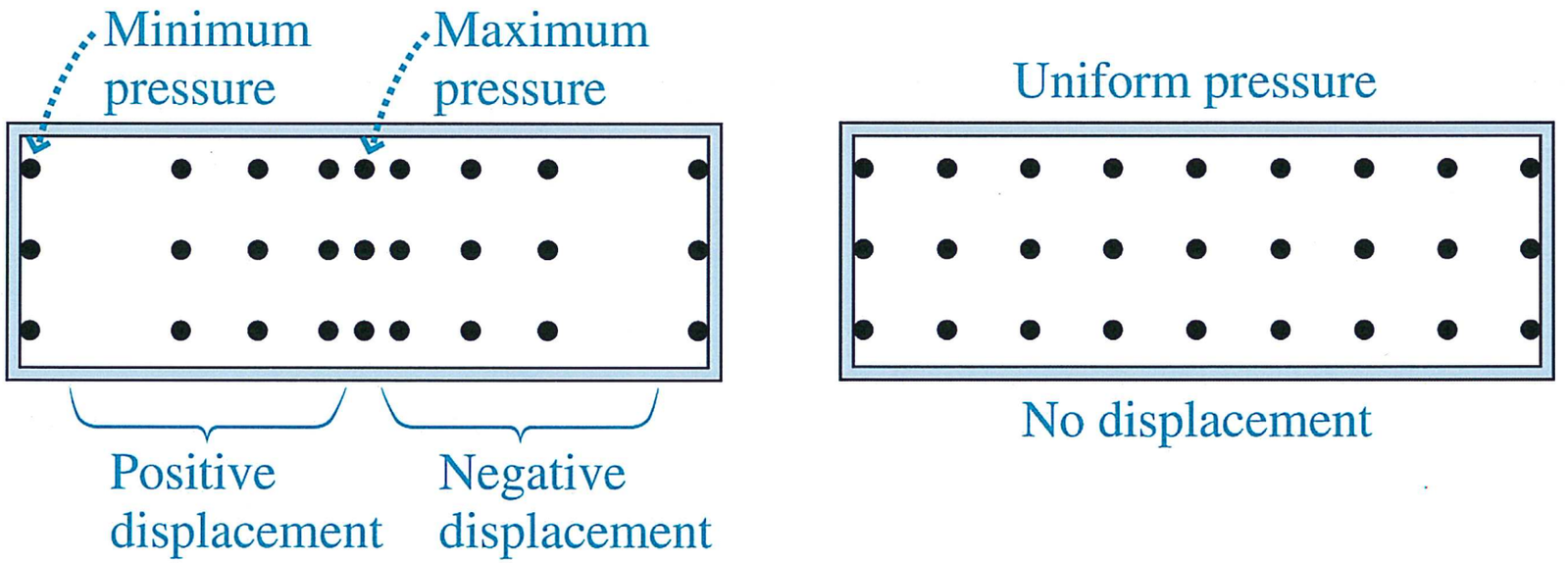
$L \uparrow$, $f \downarrow$

Standing Sound Waves

- A long, narrow column of air, such as the air in a tube or pipe, can support a longitudinal standing sound wave.
- A closed end of a column of air must be a displacement node. Thus the boundary conditions — nodes at the ends — are the same as for a standing wave on a string.
- It is often useful to think of sound as a pressure wave rather than a displacement wave. The pressure oscillates around its equilibrium value.
- The nodes and antinodes of the pressure wave are interchanged with those of the displacement wave.

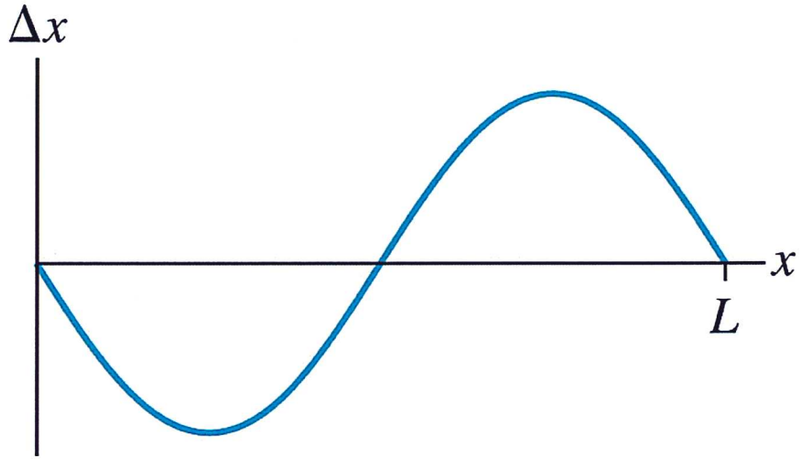
Standing Sound Waves



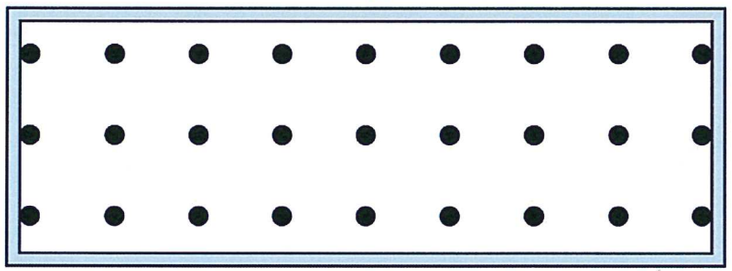


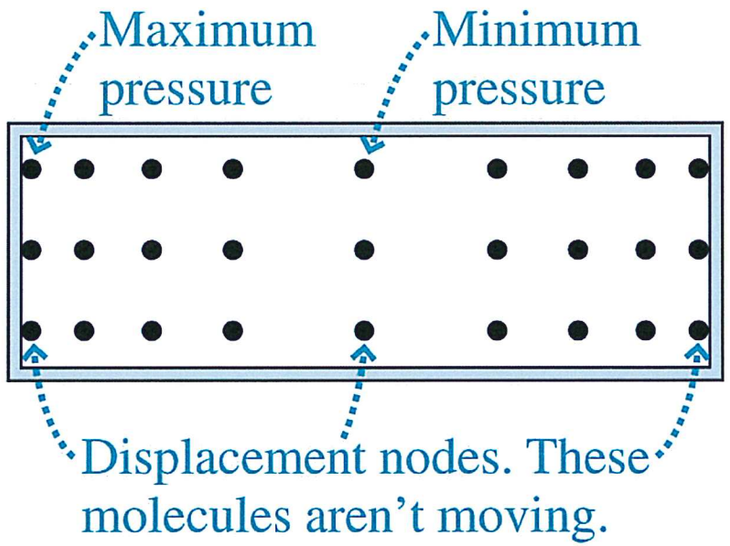
Standing Sound Waves

$t = T/4$

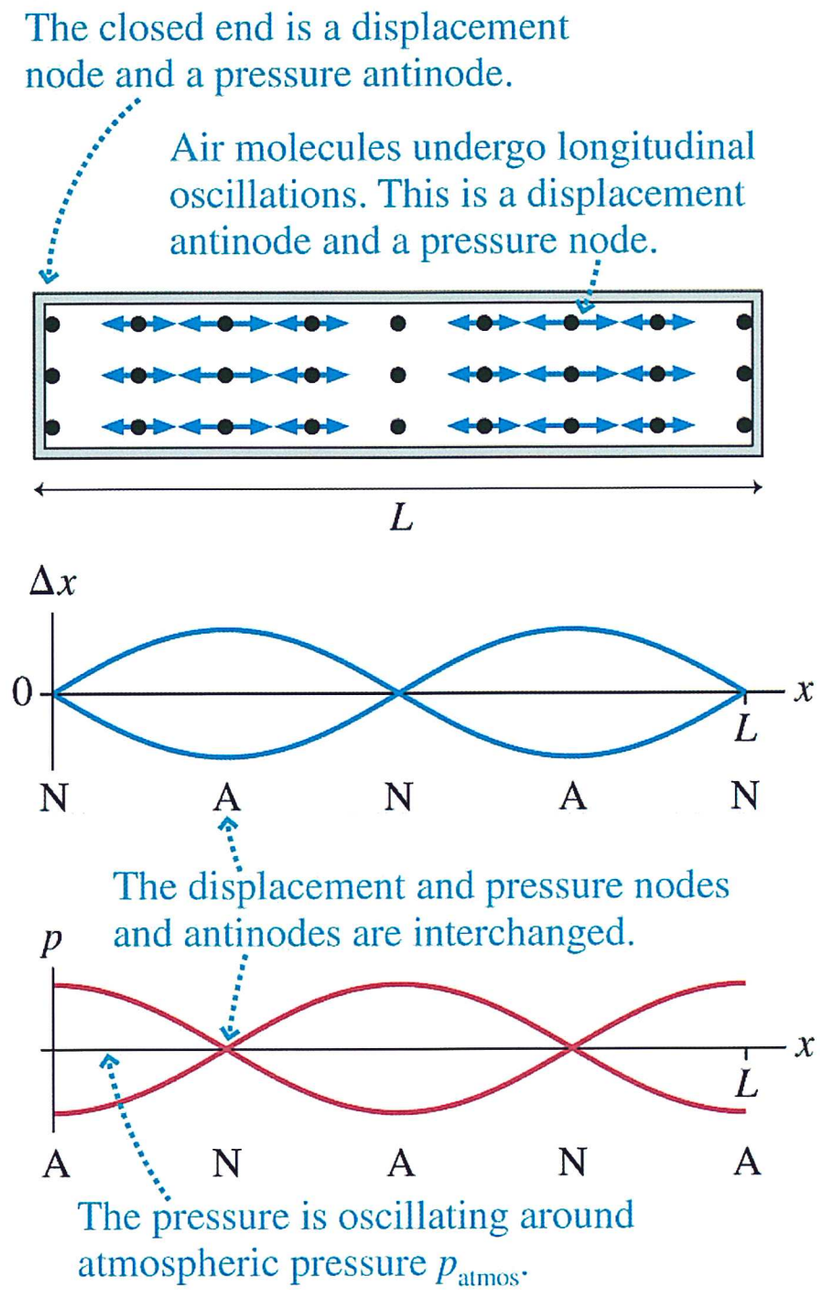


$t = T/2$



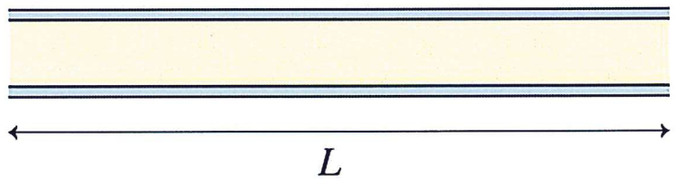


- Displacement Δx and pressure graphs for the $m = 2$ mode of standing sound waves in a closed-closed tube.
- The nodes and antinodes of the pressure wave are interchanged with those of the displacement wave.

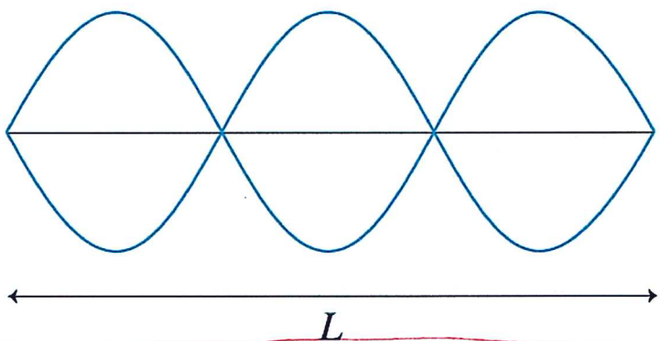


Learning Catalytics Discussion Question

An open-open tube of air has length L. Which is the displacement graph of the $m = 3$ standing wave in this tube?



A.



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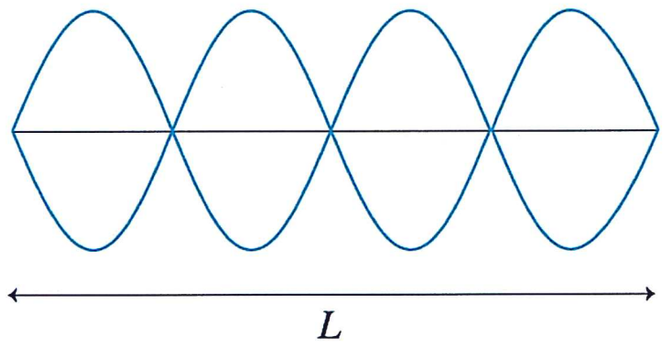
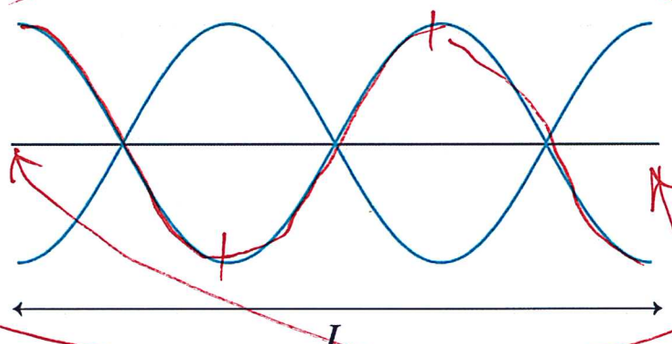


B.



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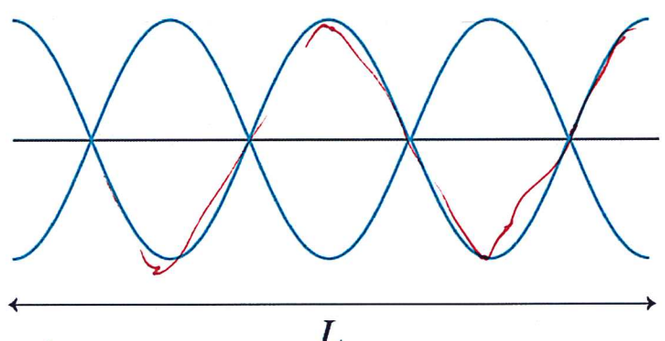
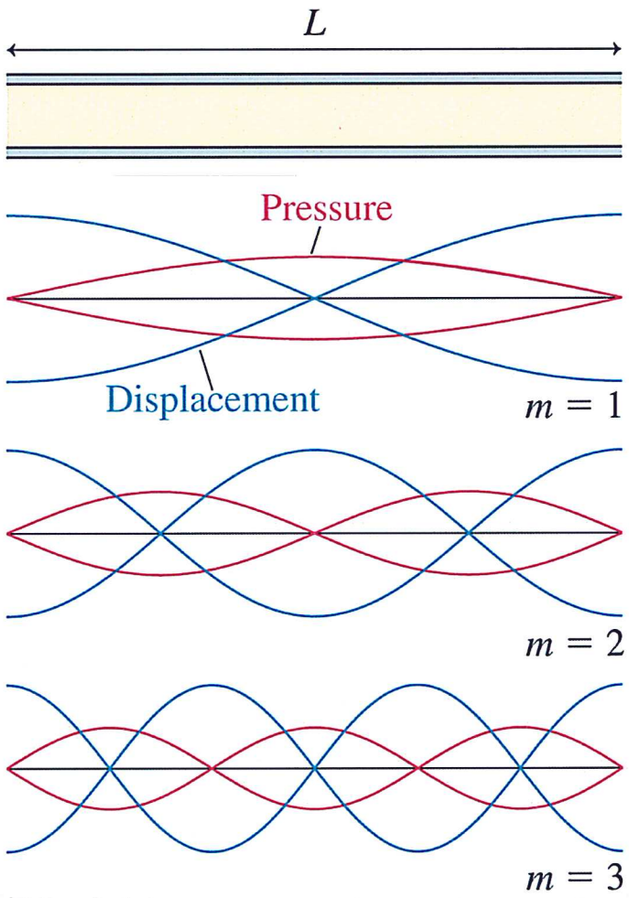


$L = \frac{3}{2}$ wavelengths. $m = 3$

antinodes of Δx at open ends.

Open-open



$v_{sound} = 343\ m/s$

$$f_1 = \frac{v_{sound}}{2L}$$

$$\begin{cases} \lambda_m = \dfrac{2L}{m} \\ f_m = m\dfrac{v}{2L} = mf_1 \end{cases} \qquad m = 1, 2, 3, 4, \ldots$$

(open-open or closed-closed tube)

Example from a past test

A metal pipe, open at both ends, can create a standing wave in the second harmonic with a frequency of 483 Hz. What is the length of the pipe?

$m = 2$

$f_2 = 483$

$L = ?$

Use: $f_m = \frac{m v}{2L}$ for open-open

$v = 343 \text{ m/s}$

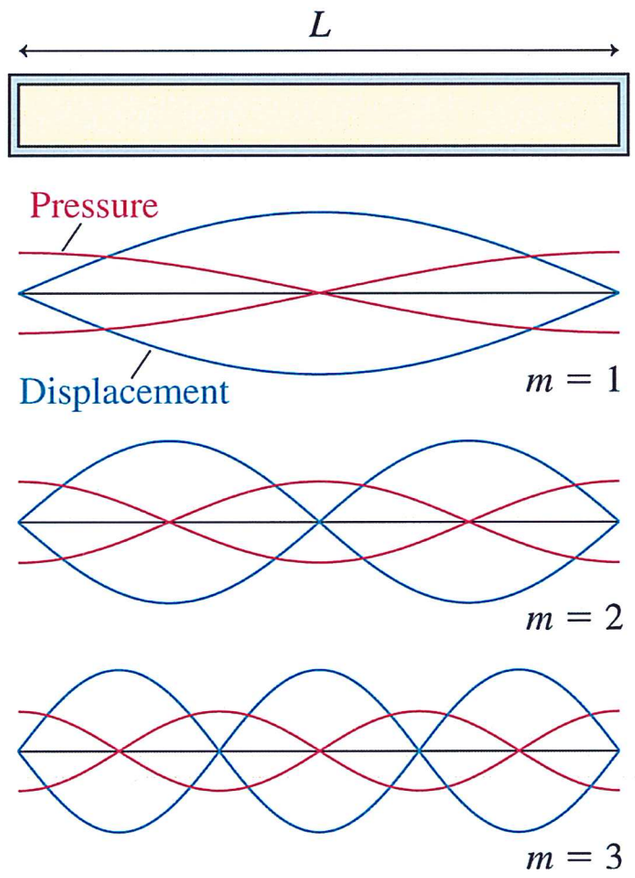
Solve for L:

$$L = \frac{m v}{2 f_m}$$

$$= \frac{2(343)}{2(483)}$$

$$L = 0.71 \text{ m}$$

Closed-closed



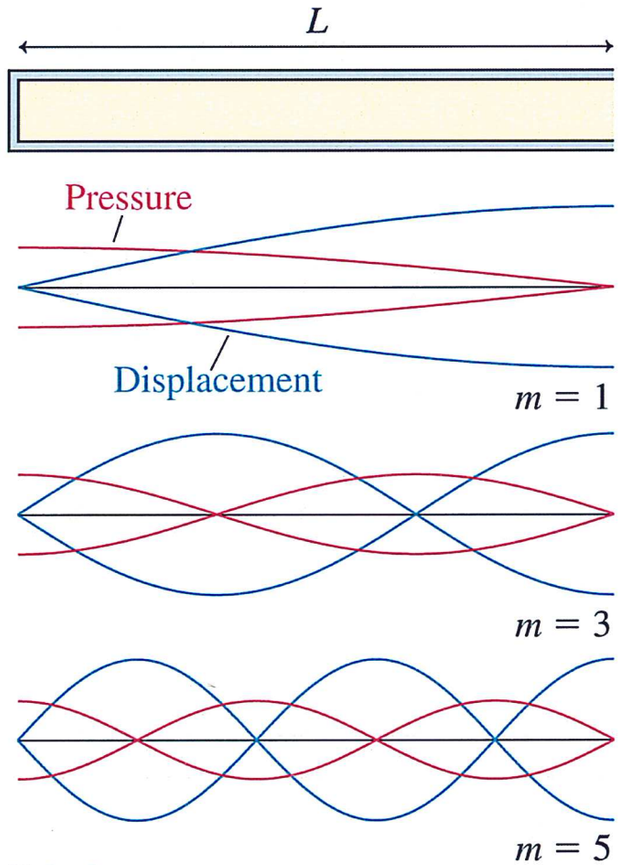
same eq. as open-open.

$$f_1 = \frac{v_{sound}}{2L}$$

$$\begin{cases} \lambda_m = \dfrac{2L}{m} \\ f_m = m\dfrac{v}{2L} = mf_1 \end{cases} \qquad m = 1, 2, 3, 4, \ldots$$

(open-open or closed-closed tube)

Open-closed



$\frac{1}{4}\lambda = L$ for fundamental.

$\frac{3}{4}\lambda = L$

$$\lambda_m = \frac{4L}{m}$$

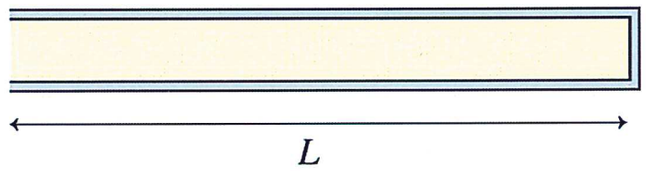
$$f_m = m\frac{v}{4L} = mf_1$$

$m = 1, 3, 5, 7, \ldots$

(open-closed tube)

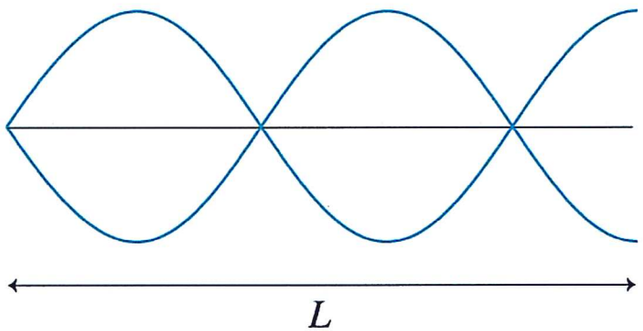
Learning Catalytics Discussion Question

An open-closed tube of air of length L has the closed end on the right. Which is the displacement graph of the $m = 3$ standing wave in this tube?



ox graphs.

A.



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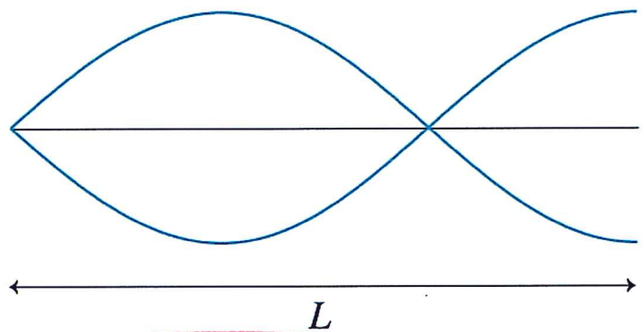

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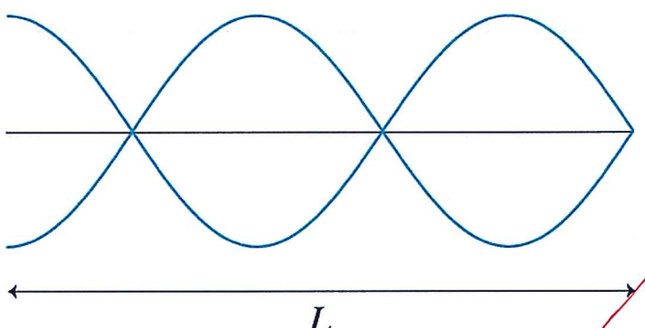

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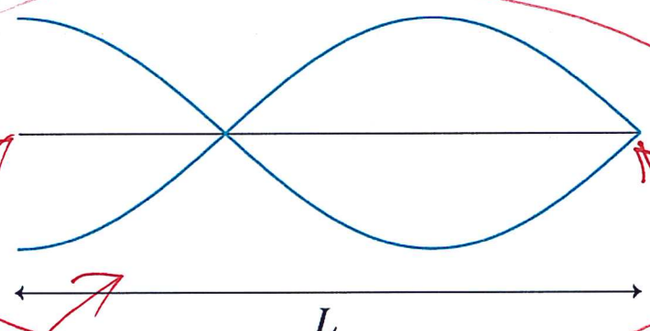
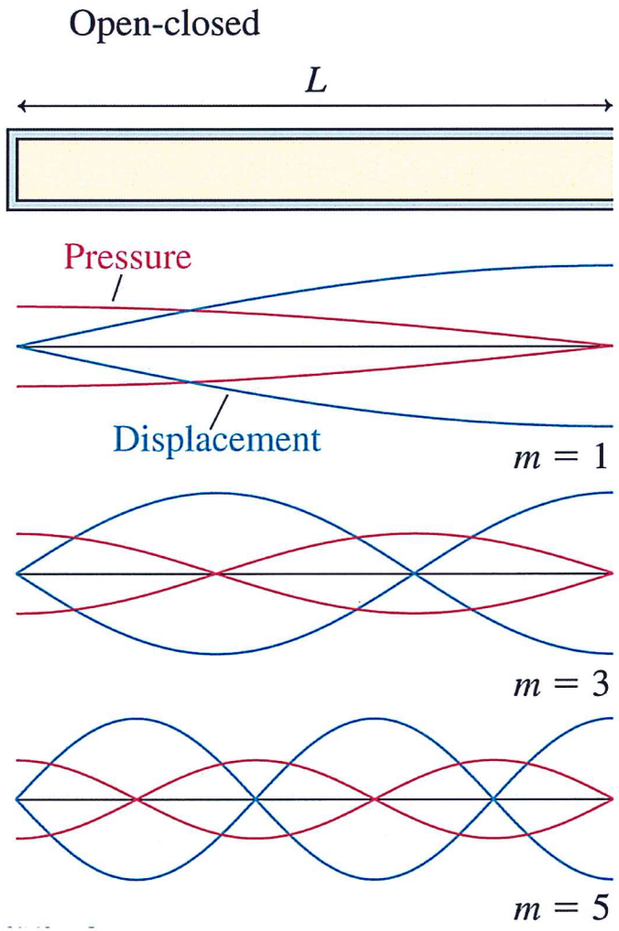


antinode at open end.

$\frac{3}{4}$ of wavelength

node at closed



open - closed

$$f_1 = \frac{v_{sound}}{4L}$$

$$\begin{cases} \lambda_m = \dfrac{4L}{m} \\ f_m = m\dfrac{v}{4L} = mf_1 \end{cases} \qquad m = 1, 3, 5, 7, \ldots \text{ (open-closed tube)}$$

Musical Instruments

- With a wind instrument, blowing into the mouthpiece creates a standing sound wave inside a tube of air.
- The player changes the notes by using her fingers to cover holes or open valves, changing the length of the tube and thus its fundamental frequency:

$$f_1 = \frac{v}{2L}$$ for an open-open tube instrument, such as a flute

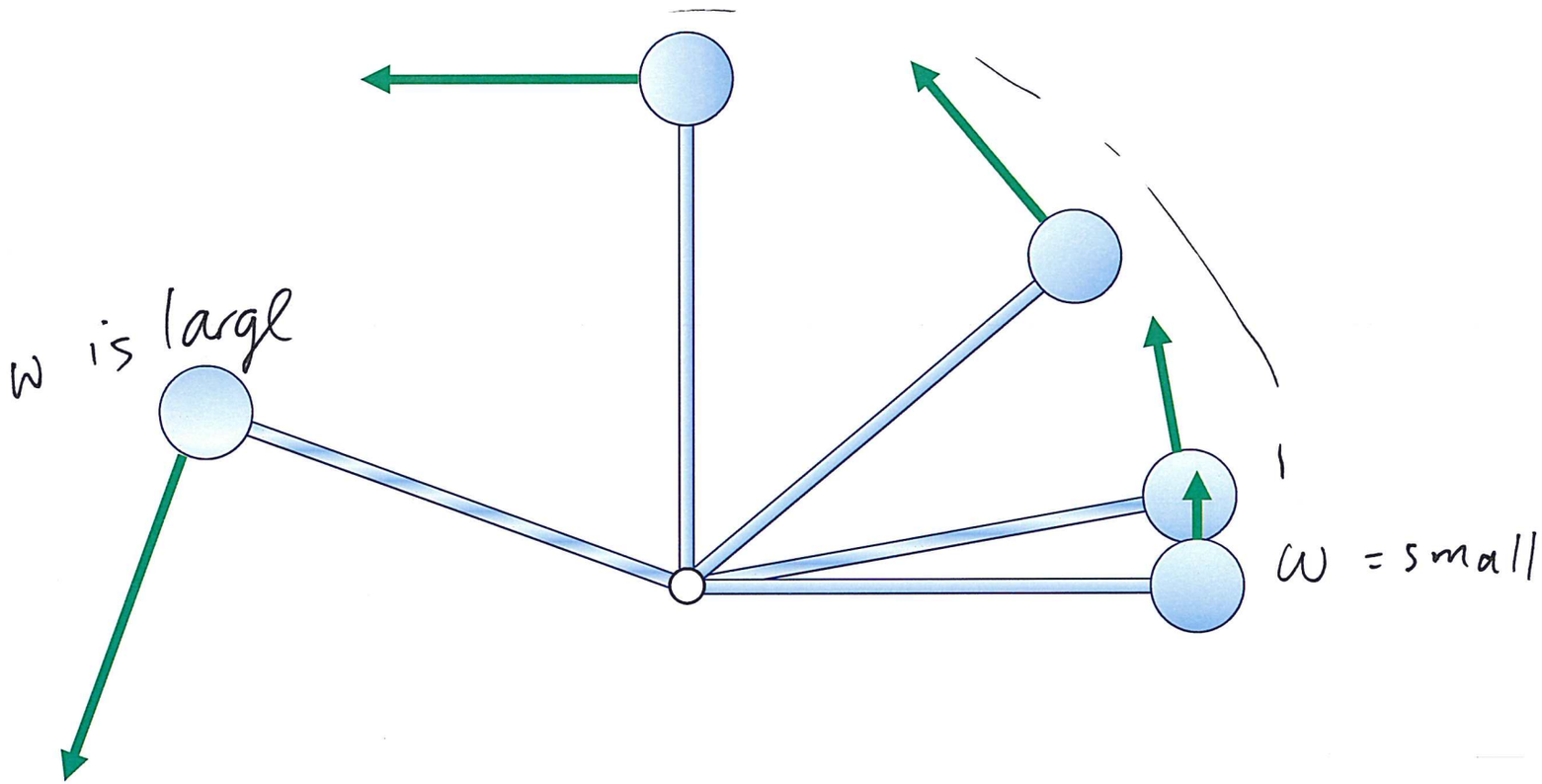
$$f_1 = \frac{v}{4L}$$ for an open-closed tube instrument, such as a clarinet

- In both of these equations, v is the speed of sound in the air *inside* the tube.
- Overblowing wind instruments can sometimes produce higher harmonics such as $f_2 = 2f_1$ and $f_3 = 3f_1$.

Review: Angular Acceleration

- Angular acceleration α is the rate of change of angular velocity.

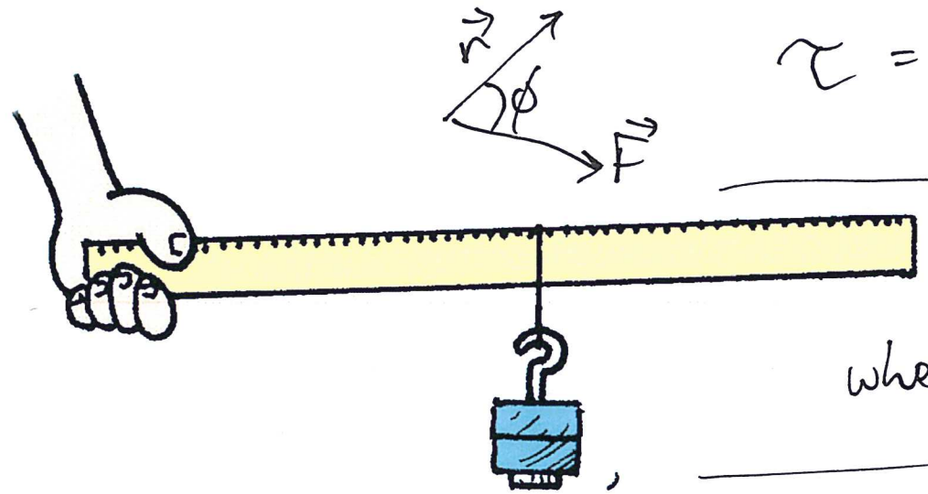
$$\text{Average: } \bar{\alpha} = \frac{\Delta\omega}{\Delta t} \qquad \text{Instantaneous: } \alpha = \frac{d\omega}{dt}$$



Review: Torque

- The equation for Torque is

$$\vec{\tau} \equiv \vec{r} \times \vec{F}$$



3 mathematically equivalent ways of calculating torque.

$\tau = r F \sin\phi$

,, $\tau = F \ell$

where ℓ = lever arm.

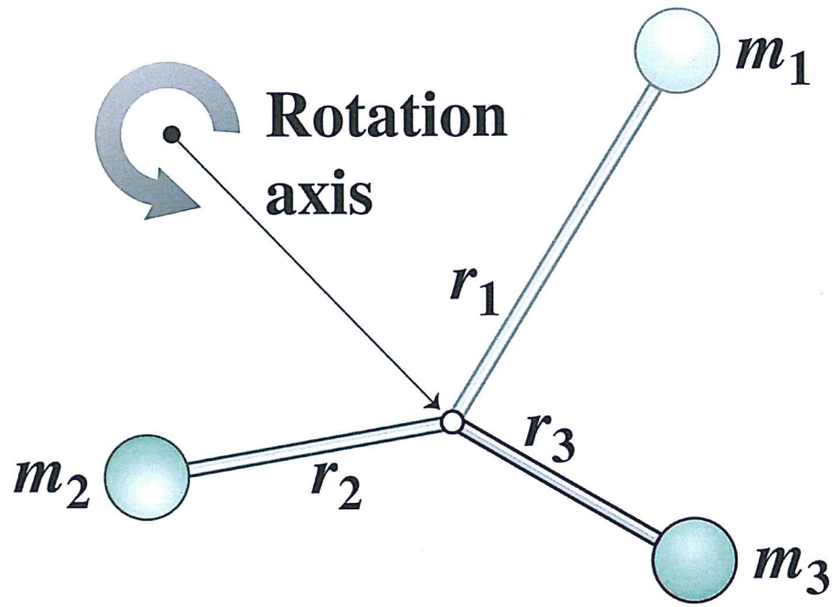
, $\tau = F_\perp r$

$F_\perp$ = component of $\vec{F}$ perpendicular to $\vec{r}$

Review: Rotational Inertia

- For a system of discrete masses, the rotational inertia is the sum of the rotational inertias of the individual masses:

$$I = \sum m_i r_i^2$$



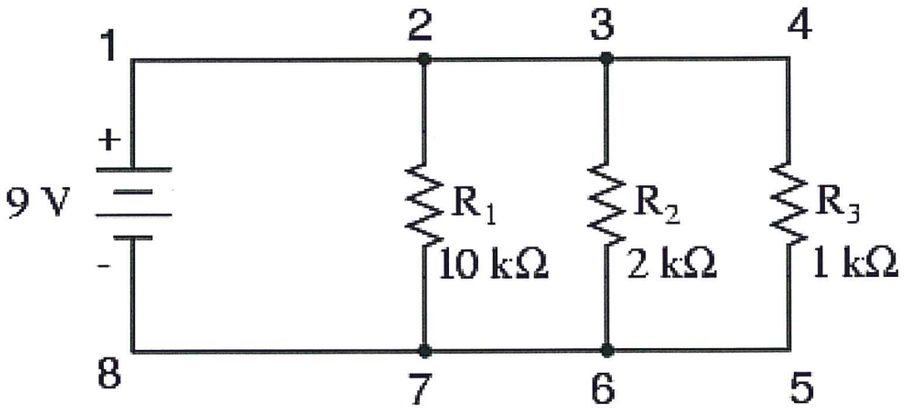
Newton's Second Law for Rotation:

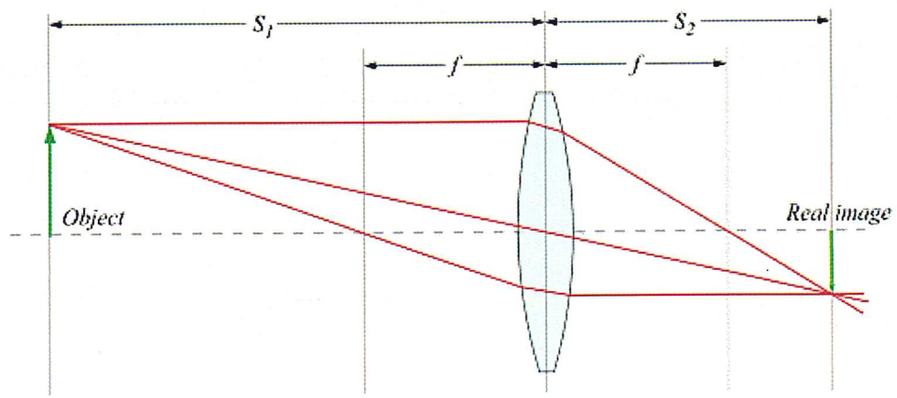
$$\alpha = \frac{\tau_{net}}{I}$$

Preview: PHY132H1S

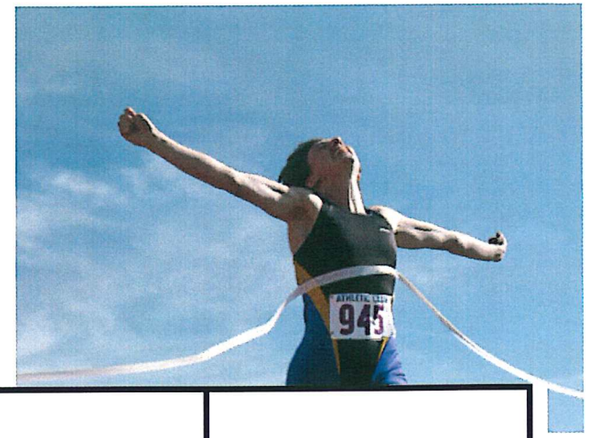
- **Professor Andrew Meyertholen**

- Electric Charges
- Electric Field
- Electric Circuits
- Magnetism
- Electromagnetic Induction
- Optics
- Einstein's Theory of Relativity





The last thing in PHY131 you have to do: The Final Exam



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- EX is Central Exams Facility, 255 McCaul St. (just south of College St.)

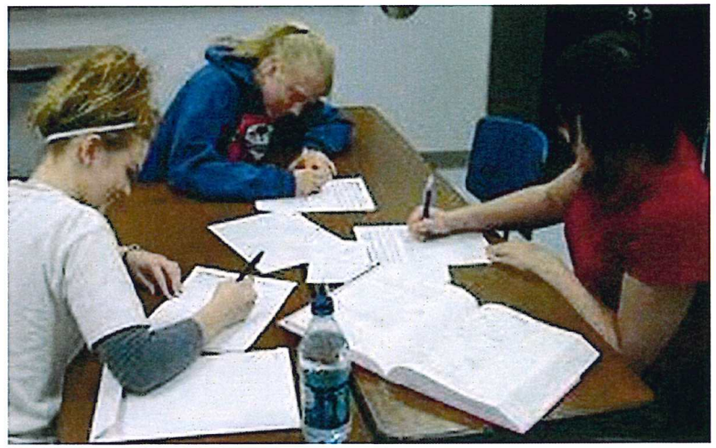
What to expect

- 2 hours – starts at 9:**00**, not 9:10!
- 12 multiple choice questions worth 2 points each (24 points total)
- 3 long-answer problems worth 6 points each for which you must show your work (18 points total).
- Final exam is out of 42 points.
- The exam includes questions from the **entire** course, covering every chapter from 1-14, plus what was learned in the Practicals.
- Slightly more of the weight of the exam is based on the material that has not been tested yet (Chs.10-14).

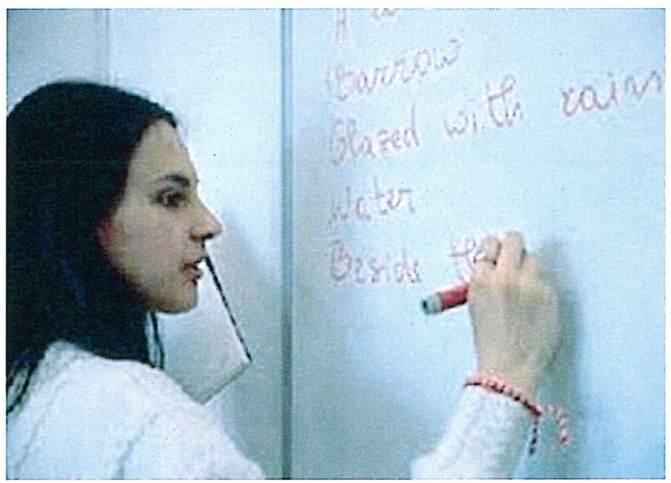
Suggested Study Plan

1. Review **reading** and **lecture notes** and **Practicals Activities** for the entire course.
2. Work through the **MasteringPhysics Homeworks 1-11**. Make sure you can do these problems on paper.
3. Work through all **suggested end-of-chapter exercises**, and then **problems**.
4. Work through all the **Practice Problems** from the first hours of **Practicals**.
5. After you have done the above, if you have time, try some past exams or past midterms.

Study Groups – working with Peers

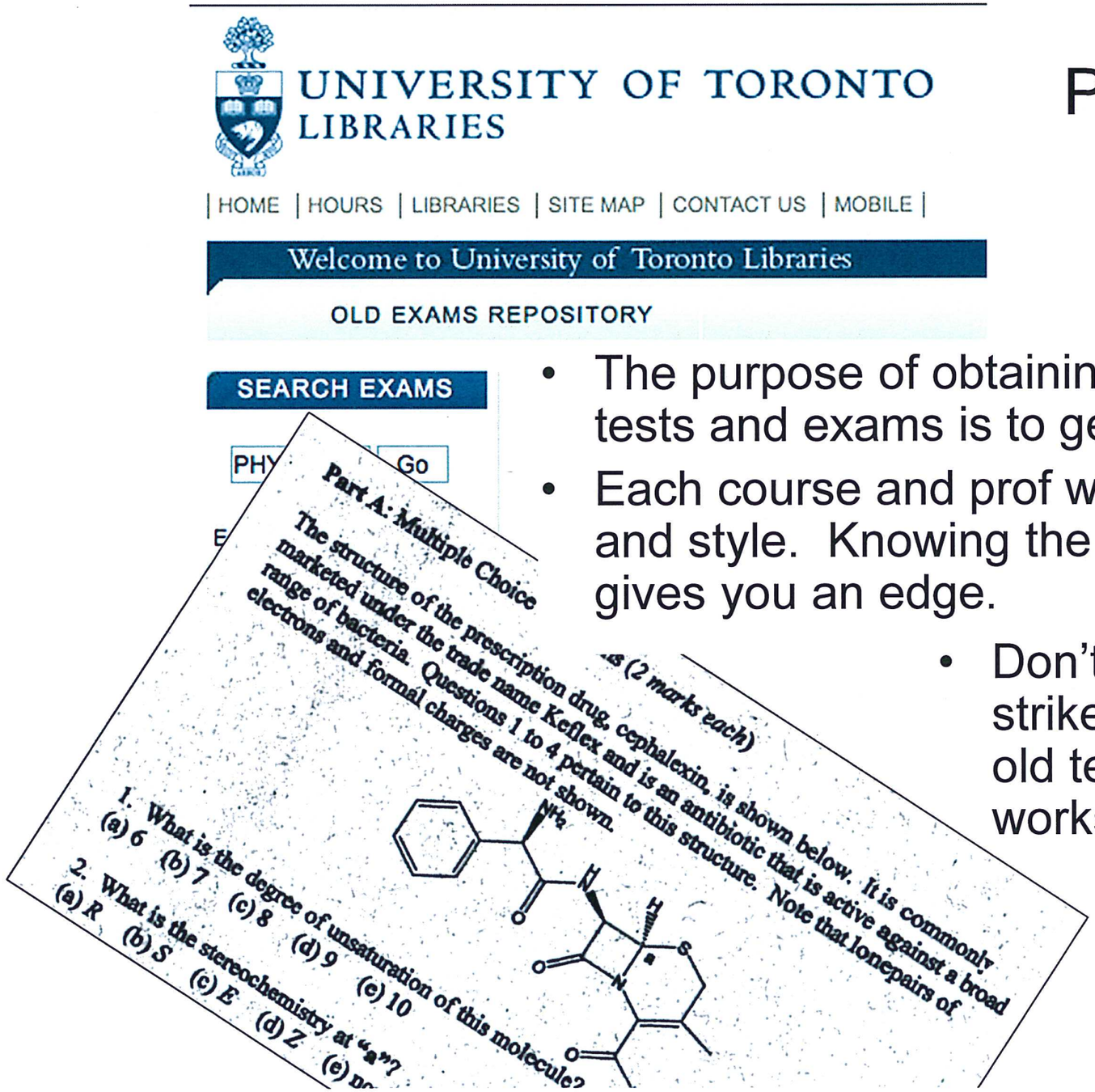


- Find student (students) in class that you work well with on MasteringPhysics, end-of-chapter suggested problems, and past tests.



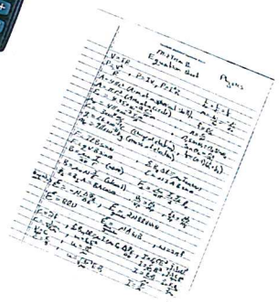
- ***The best way to learn is to teach!*** If you can't explain to someone else what you have done, you haven't really understood it! (This is harder than you think!)

Past Tests and Exams

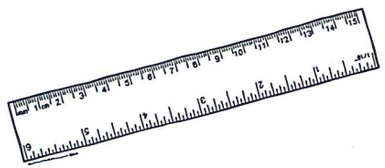


- The purpose of obtaining and going through old tests and exams is to get to know “the system”.
- Each course and prof will have a certain pattern and style. Knowing the pattern in advance gives you an edge.
  - Don’t count on lightning to strike twice – memorizing old test questions rarely works!

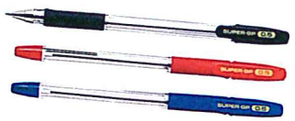
Aids Allowed on the Final Exam

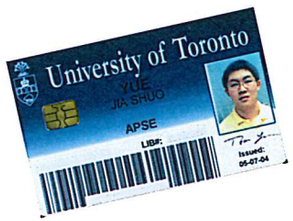


- Any calculator without communication capability.
- Aid sheet: one single, original, handwritten 8 1/2 × 11 inch sheet of paper, which may be written on both sides.
- A ruler.



- A **paper** copy of an English translation dictionary.
- Also:





During the Exam

- Exam begins at **9:00am SHARP**!!! Seating will begin at 8:50am, pens hit paper at 9:00.
- This exam is run by the faculty, not the physics department, so be extra careful about the rules.
- Skim over the entire exam from front to back **before** you begin. Look for problems that you have confidence to solve first.
- If you start a problem but can't finish it, leave it, make a mark on the edge of the paper beside it, and come back to it after you have solved all the easy problems.
- Quite snacks or drinks are allowed, and recommended by me.

Tuesday Dec. 12 after 6:00pm, you **must**:

Relax, watch Netflix, then go to bed.

- The evening before a test is NOT the best time to study (it is just the most popular)
- Don't worry – you have been studying since the 1st week of classes!
- You need to **relax** and get your mind **physically** ready to focus on Wednesday at 9:00am.

See you at the final!

- The faculty runs a final exam for this course on Wednesday Dec.13 at 9:00am. See you there!
- Professor Wilson and I will be giving back-to-back "Exam Jam" lectures tomorrow (Friday) from 1:00-3:00pm in SS2117. I have posted a hand-out for Exam Jam on my slides, and I will post any written notes from Exam Jam on the portal after Friday.
- Please email me (jharlow@physics.utoronto.ca) with any questions. Keep in touch! It's been a really fun course for me!

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