Name: ______________________

Student ID number: ______________________

Oral interview time (see below): ______________________

Discussion section: ______________

MIDTERM 1
PHYSICS 1B, SPRING 2020

APRIL 24, 2020

READ THE FOLLOWING CAREFULLY:

- ▷ Open book. Calculators will not be needed. Make sure that you work independently on the exam, i.e., no discussion with others.
- ▷ Oral interview time: choose a time period of 20 minutes between 11:59AM and 11:59PM on April 25 (Pacific Time) for possible oral interview (via the zoom office hour link). A random sample of students will be selected and be notified via email by 11:59AM on April 25 (Pacific Time). If all of the work on your submission is your own, you will have nothing to worry about.
- ▷ For non-response in the field of oral interview time, I may assess a score penalty.
- ▷ Make sure to submit your exam packet via GradeScope by 9AM April 25, Pacific Time. **No credit will be given for late submissions**.
- ▷ To submit your exam, you have the following two options: (a) Download the PDF from CCLE, print out the PDF, write your solutions in the space provided on the exam packet, scan your packet using a smart phone scanning app such as Adobe Scan, upload your scan to Gradescope. (b) View the PDF on CCLE, write your solutions to all of the problems on loose-leaf, lined or blank paper **in precisely the locations you would have written your responses if that paper were the exam packet**. Scan and upload your packet of solutions to Gradescope.
- ▷ For every option above, **you must make sure that your submission has exactly the same number of pages as the posted exam PDF (including this page)**.
- ▷ **You must justify your answers to each question**. Simply giving the correct answer without proper justification (can be brief) will not result in full credit.
- ▷ Mistakes in grading: If you find a mistake in the grading of your exam, alert the instructor within one week of the exams being returned.

[1.] **Short answer conceptual questions**. Provide *concise* answers to the questions below; you should write enough to explain your answer, but an essay is not required (most can be answered in 2 – 3 sentences).

(a) (8 pts) I have a tuning fork that when struck sounds a perfect middle C (261 Hz). I have an organ pipe, open on both ends whose fundamental frequency is also middle C; when I strike the tuning fork, I can hear the pipe resonate with the sound waves from the fork. I now close off one end of the organ pipe; the fork no longer resonates with the pipe (this makes me sad). A friend, trying to cheer me up, suggests that I could make the fork emit sound waves that again resonate with the tube by running (perhaps very fast) with the fork in hand. Will that work, and if so why and how should I run with the fork?

That will work. The fundamental frequency of an open pipe is $f_1 = \frac{v}{2L}$. If we close one end of the pipe, its fundamental frequency will become $f_1 = \frac{v}{4L}$. If we want the fork and the pipe to resonate, we need to double the fundamental frequency of the closed pipe. We can do this by doubling the wave speed. If I run toward the pipe with the fork at the speed of sound, the wave speed produced by the fork relative to the pipe will be doubled, so the pipe will have the same fundamental frequency as the fork, and they will resonate.

(b) (10 pts) **(i)** Give two reasons why the intensity of sound waves from a point source decreases with distance. **(ii)** Why do cheerleaders use megaphones at sporting events (the non-electric kind, see the image below)? If the cheerleader yells at me in the same way with or without the megaphone (that is, the power used in generating the waves is the same in both cases), why would I hear her better with the megaphone than without?

(i) The intensity of sound is the power of sound per unit area. As distance increases, the area that receives the energy also increases, so the power per unit area decreases.

Also, some of the sound energy gets transformed into other types of energy, such as heat. So the farther away from the source, the more energy gets transformed, and the smaller the intensity will be.

(ii) The megaphone prevents the sound wave from propagating in all directions, so more energy is transferred in the desired direction. So the intensity of sound at the same distance is greater than that without the megaphone.

(c) (8 pts) **(i)** I hold a big stone and stand on a boat. The boat is floating on a pond. If I drop the stone into the pond and the stone sinks, will the level of the pond rise, fall, or not change? Explain. **(ii)** If all icebergs (made of pure ice) floating on the sea melt due to global warming, will the sea level rise, fall, or not change? Explain. Note that the mass densities has the relation $\rho_{\text{sea}} > \rho_{\text{water}} > \rho_{\text{ice}}$.

(i) The level of the pond will fall.
Let the mass of stone be m and mass of me be M. Before I drop the stone, the buoyancy force is equal to the gravitational force of me and the stone, so $B = (m+M)g$. Because $B = \rho V g$, $V = \frac{m+M}{\rho}$. After I drop the stone, the buoyancy force of the stone will be smaller than mg, because there will be a normal force on the stone by the pond floor. $B_{stone} < mg$, so $V_{stone} < \frac{m}{\rho}$. The buoyancy force on me is Mg, $V_{me} = \frac{M}{\rho}$. $V_{me} + V_{stone} < V$, so the level of the pond will fall.

(ii) $B_{ice} = m_{ice} g = \rho_{ice} V_{ice} g$, and $B_{ice} = \rho_{sea} V_{sea} g$, so V_{sea} displaced by the ice is $\frac{\rho_{ice} V_{ice}}{\rho_{sea}} = \frac{m_{ice}}{\rho_{sea}}$. After it melts The volume of water will become $\frac{m_{water}}{\rho_{water}}$. Because $m_{ice} = m_{water}$, $V_{water} = \frac{m_{ice}}{\rho_{water}} > \frac{m_{ice}}{\rho_{sea}}$. So the volume of fluid in the sea will increase, and sea level will rise.

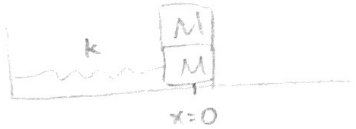
(d) (10 pts) Two blocks of mass M are stacked one on top of the other, with the lower block attached to a horizontal spring with spring constant k (on a frictionless surface). The two masses are put into oscillation with amplitude A (about $x = 0$), which is low enough such that the two masses do not slip relative to one another. If the top block is removed at the instant the masses reach $x = 0$, what happens to the oscillation (comment on changes to frequency and amplitude). Explain.

At $x=0$, the mechanical energy of the system is all kinetic energy, so $E = \frac{1}{2}(2M)v^2$. The original amplitude A satisfies $\frac{1}{2}kA^2 = \frac{1}{2}(2M)v^2$. After one block is removed, $E_{x=0} = \frac{1}{2}Mv^2$, and $\frac{1}{2}kA'^2 = \frac{1}{2}Mv^2$. So $A' = \frac{A}{\sqrt{2}}$.

Because $\omega = \sqrt{\frac{k}{m}}$, when m is reduced to a half, $\omega' = \sqrt{2}\omega$.

$f = \frac{\omega}{2\pi}$, so $f' = \sqrt{2} f$.

So frequency increases by $\sqrt{2}$, amplitude decrease by $\frac{1}{\sqrt{2}}$.



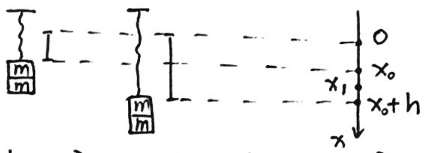
$\frac{1}{2}(2M)v^2 = \frac{1}{2}kx^2$

$\frac{1}{2}Mv^2 = \frac{1}{2}kx'^2$

$x' = \frac{x}{\sqrt{2}}$

[2.] (32 pts) A spring of unknown spring constant is hung from the ceiling; a block of mass m is attached to the bottom of the spring (gravity acts downward, you can assume the acceleration due to gravity is g). I find the mass and spring hanging in equilibrium. I now attach a second block of mass m to the first and then release the two blocks. I see that the two blocks fall a distance h before stopping momentarily.

(a) What is the amplitude of the resulting oscillation?



x_0 : the displacement before attaching the second mass

$$\frac{1}{2}kx_0^2 + 2mgh = \frac{1}{2}k(x_0+h)^2$$

$$2mg = \frac{1}{2}kh + kx_0$$

$$x_0 = \frac{mg}{k}$$

$$\therefore \; mg = \frac{1}{2}kh$$

$$k = \frac{2mg}{h}$$

Let the new equilibrium be x_1

$$x_1 = \frac{2mg}{k} = \frac{2mg}{(2mg/h)} = h$$

$$A = (x_0 + h) - x_1$$

$$= \frac{mg}{2mg/h} + h - h = \frac{h}{2}$$

So the amplitude of oscillation is $\frac{h}{2}$

(b) What is the frequency of the resulting oscillation? (Note that you don't know the spring constant k (but you can figure out what it must be). You must write this answer in terms of the given quantities).

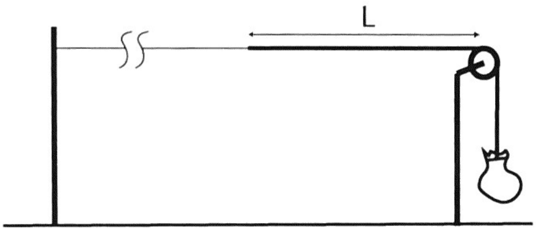
From part (a) we get $k = \frac{2mg}{h}$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{2mg/h}{m}} = \sqrt{\frac{2g}{h}}$

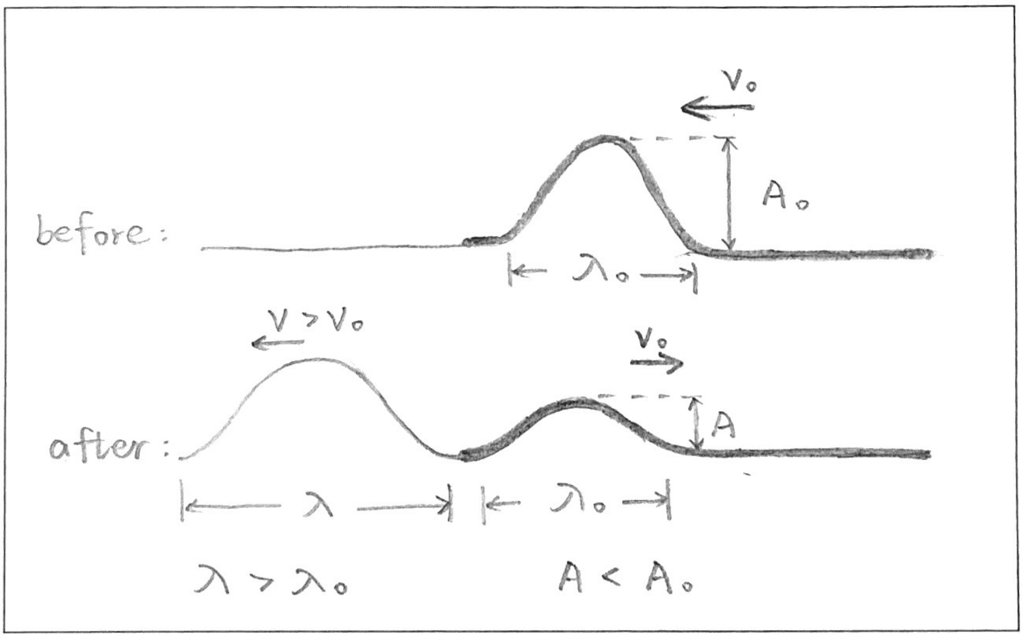
$\therefore f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{2g}{h}}$

So the frequency of the resulting oscillation is $\frac{1}{2\pi}\sqrt{\frac{2g}{h}}$

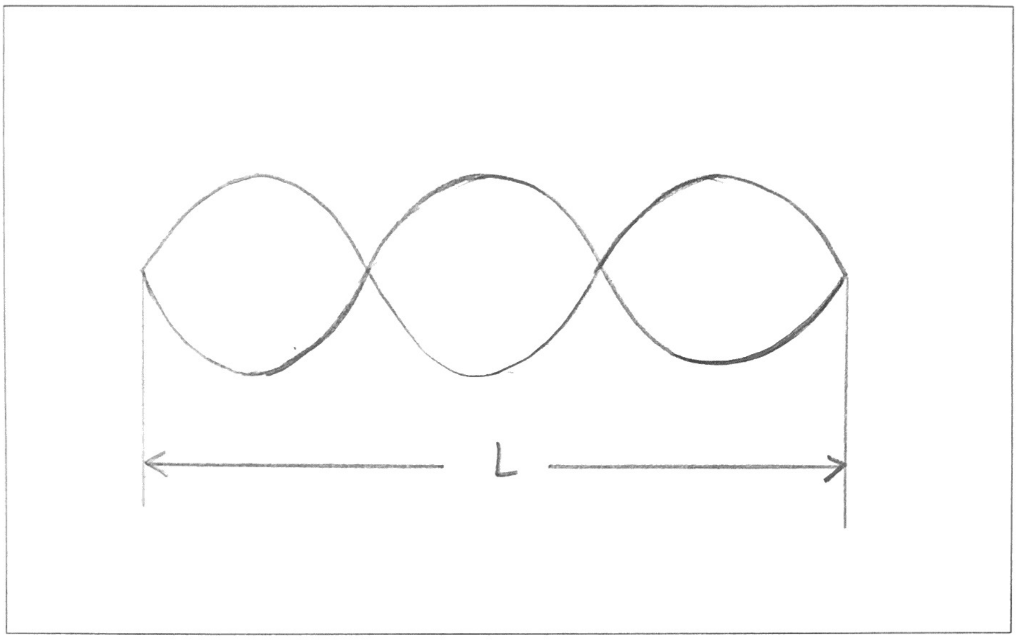
[3.] (32 pts) A composite string is made up of a short length of heavy string (μ_1) and a very very long length of much lighter string ($\mu_2 \ll \mu_1$). The light end of the string is attached to a pole very far away. The string is held under tension by passing the heavy end over a pulley and attaching it to a bag full of sand. The heavy segment of the string has length L (between the pulley and the knot between the two strings).



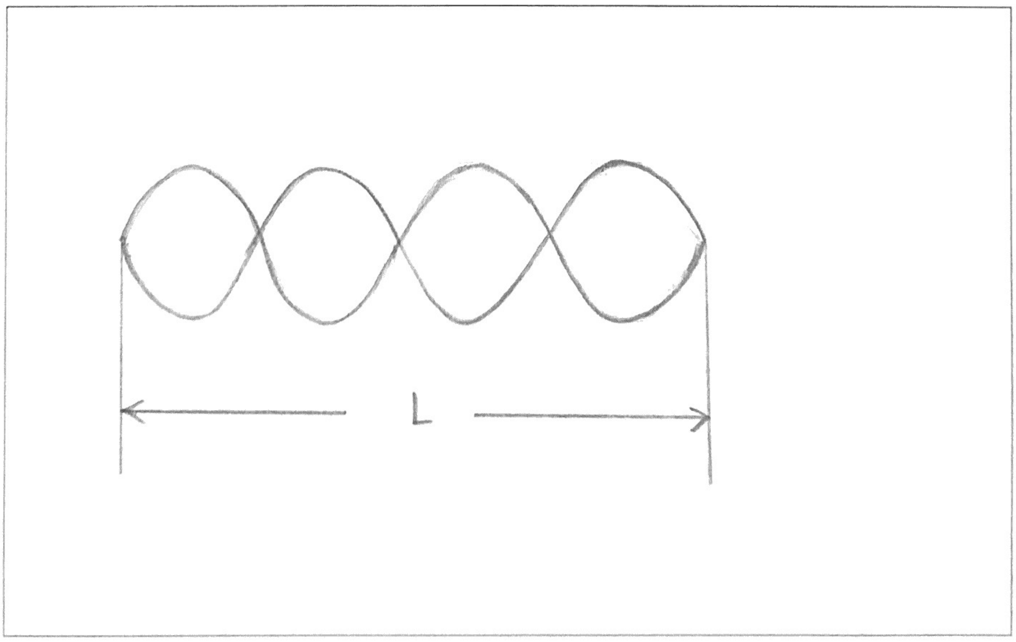
(a) I pluck the end of the string by the pulley, launching an upright pulse that travels to the left starting on the heavy string. When the pulse encounters the knot between the light and heavy string, I see a transmitted and reflected pulse. Draw the reflected and transmitted pulses, clearly indicating any differences in: spatial size, amplitude, and polarization (upright or inverted).



(b) I now excite the string sinusoidally in time by gently shaking the pulley up and down; the frequency I excite the string at is variable. I start at a very low frequency and slowly turn up the frequency. As I do this, I see standing waves appear on the heavy portion of the rope. I turn the frequency up until I have found the third such standing wave. Draw the pattern that this standing wave makes on the heavy rope.



(c) I now leave the frequency of excitation fixed (the third standing wave is being excited) and then I cut a small hole in the bottom of the sand bag so that sand starts slowly trickling out, lowering the mass of the sand bag. At first, my exciting frequency goes out of resonance, and I do not see a standing wave on the heavy part of the string. After a short while later however, I see a new standing wave excited on the string. Draw this standing wave.



(d) What is the fractional change in the mass of the sandbag at that instant ($m_{\text{new}}/m_{\text{old}}$)?

$\lambda_1 = \frac{2}{3}L$

$\lambda_2 = \frac{1}{2}L$

$\frac{\lambda_1}{\lambda_2} = \frac{4}{3}$

$\frac{v_1}{v_2} = \frac{\lambda_1 f}{\lambda_2 f} = \frac{4}{3}$

$v = \sqrt{\frac{T}{\mu}}$, $T = v^2\mu$

$\frac{T_1}{T_2} = \frac{v_1^2\mu}{v_2^2\mu} = \frac{16}{9}$

$\because T_1 = m_{old}\, g$

$T_2 = m_{new}\, g$

$\therefore \frac{m_{new}}{m_{old}} = \frac{T_2}{T_1} = \frac{9}{16}$