Name: ______________________ Student I.D.: ____________

Practice Exam 3A

Physics 100, Spring 2007

Wednesday, April 20, 2007

Useful Equations and Numbers

Acceleration due to gravity...
on Earth = 10 m/s^2
on Mars = 3.7 m/s^2
on the Moon = 1.6 m/s^2

$$(wave\ speed)\ =\ wavelength \times frequency$$

$$frequency = \frac{1}{period}$$

$$(deep\ water\ wave\ speed) = 1.25 \times \sqrt{wavelength} = 5/4 \times \sqrt{wavelength}$$

$$(shallow\ water\ wave\ speed) = 3 \times \sqrt{depth}$$

$$(force\ of\ gravity) = (mass) \times (acceleration\ due\ to\ gravity)$$

$$speed\ of\ light\ =\ 300,000,000\ m/s = 3 \times 10^8\ m/s$$

$$speed\ of\ sound\ in\ air = 340\ m/s$$

$$distance\ to\ origin_1 = \Delta time \times 5\ miles/second$$

$$distance\ to\ origin_2 = \Delta time \times \frac{1}{5}\ miles/second$$

$$(beat\ frequency) = |f_1 - f_2|$$

$1\ Hz = 1\ \frac{cycle}{sec} = \frac{1}{sec}$	$1\ km\ = 1,000\ m = 0.6\ miles$
$1\ MHz\ =\ 1,000,000\ Hz =\ 10^6\ Hz$	$1\ hour =\ 3,600\ seconds$
$1\ minute =\ 60\ seconds$	$1\ g\ =\ 10\ m/s^2$
$1\ m/s =\ 3.6\ km/hour$	$1\ Newton\ =\ 1\ \frac{kg\ m}{s^2}$
$1\ m\ =\ 3.2\ feet$	$1\ Joule\ =\ 10,000,000\ ergs$
$20\ m/s\ =\ 45\ mph$	$1\ mile/minute\ =\ 60\ mph$

DO NOT OPEN EXAM UNTIL INSTRUCTED TO DO SO!
TURN OFF YOUR CELL PHONE!

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Answer Key for Exam A

Section 1. **True/False (1 pts. each)**

Warm up!

False — Raleigh seismic waves are purely transverse waves.

False — When sound waves refract in the atmosphere, they tend to bend towards warmer air, where the molecules move faster.

True — A tsunami with a period of one hour and a (fixed) wavelength of 500 km will travel a distance of 1,000 km in two hours.

True — A wave moving with a *speed* of 10 m/s and a *period* of 4 seconds has a wavelength of 40 m.

False — A water wave cannot have a wavelength greater than the depth of the ocean.

True — When an airplane flies faster than the speed of sound in air, the sonic energy gets compressed into a cone called the shock wave.

False — Infra-red radiation is a type of electromagnetic wave that has a higher frequency than visible light.

False — Only sound waves with different frequencies can interfere.

True — Sound waves consist of alternating regions of compression and rarefaction of the medium they're traveling in.

False — Sound waves are a *combination* of transverse and longitudinal waves.

True — P-Wave seismic waves are purely longitudinal.

True — Even though the water at the bottom of the ocean is colder than the water at the top of the ocean, the speed of sound in really deep, cold ocean water is higher than shallower, warmer ocean water because it is under high pressure which compresses it.

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Section 2. **Multiple Choice (4 pts. each)**

Choose the single best answer unless instructed to do otherwise.
Hint: they're not all (C)!

1. If an ambulance begins accelerating away from you with its siren on, you will...
   - [(a)] hear the pitch of the siren decreasing due to the Doppler Effect.
   - (b) hear the pitch of the siren remaining the same since the ambulance is not moving at super-sonic speeds
   - (c) hear the pitch of the siren increasing due to the Doppler Effect.
   - (d) hear the pitch remain the same since you and the ambulance have a *negative* relative speed.

2. For a wave, the maximum displacement on either side of the equilibrium (midpoint) position is know as the...
   - (a) Period
   - [(b)] Amplitude
   - (c) Wavelength
   - (d) Domain
   - (e) Frequency

3. The distance between successive crests, troughs, or identical parts of a wave is known as the....
   - (a) Period
   - (b) Amplitude
   - (c) Domain
   - (d) Frequency
   - [(e)] Wavelength

4. The speed of a shallow water wave depends only on...
   - (a) the wavelength of the wave.
   - (b) the frequency of the wave.
   - [(c)] the depth of the water.
   - (d) the speed of sound in the water.

5. The second wave to arrive after an earthquake is...
   - (a) the Raleigh Wave.
   - (b) the Love Wave.
   - [(c)] the S-Wave.
   - (d) the P-Wave.
   - (e) *None of the above*

Section 3. **Short Answer Questions (8 pts. each)**

6. Shown below in Figure 1 is a cartoon representing the arrival of Raleigh seismic waves, whose crests are depicted as vertical black lines. The region of white background represents bedrock where Raleigh waves travel quickly. House B is built on bedrock. House A is built in the center of softer ground where the speed of the Raleigh waves is much slower. In the cartoon, the darker a region, the slower the wave.
(A) On figure 1, qualitatively draw what will happen to the waves as they travel from right to left. Use as your starting point the arrows already drawn on the leftmost crest and continue them towards the left up to at least House A (they may not hit House A, but you don't have to draw the lines past House A).
(B) How will the shaking of the ground round House A will compare to that around House B?

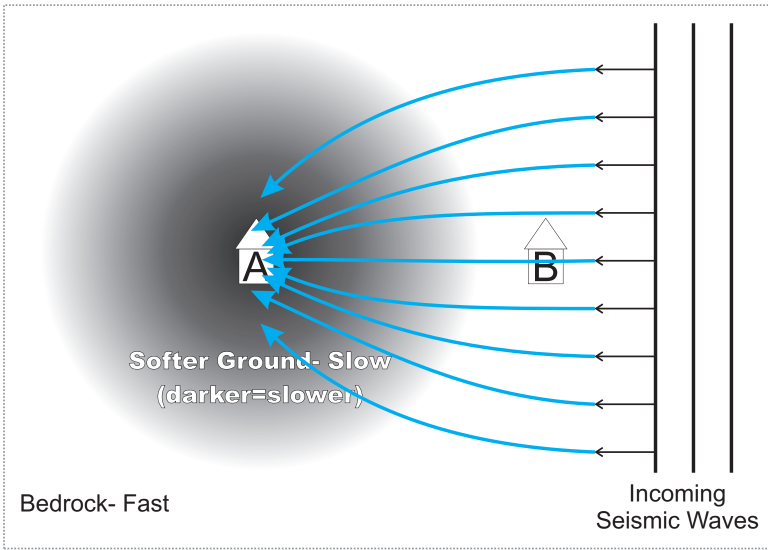

Figure 1: Raleigh seismic waves approach from the right in bedrock (white) and bend (refract) towards the region where they travel the slowest. House A has the seismic waves focused on it while House B does not, leading to bigger shaking for House A. See Question 6

Answer:

(A) See above figure. Since waves bend towards a medium in which they travel more slowly (refraction), the seismic waves get focused on House A.
(B) Since House A has all the seismic waves focused on it, it will experience more shaking, just as headlands jutting out into the ocean experience more wave action and eurovision than the protected coves.

7. The Sun is a very large thermonuclear explosion. Explain why we do not hear the sound coming from the Sun, even though we can see it.

   Answer: Sound has to be transmitted through a medium such as air, water, or steel. We do not hear anything from the Sun because there is nothing between the Earth and the Sun (well, not enough to matter).

8. A piano tuner has three tuning forks: one with a natural frequency of 440 Hz, one with a natural frequency of 442 Hz, and one with a natural frequency of 443 Hz. Using only two tuning forks at a time,
   (A) what is the highest beat frequency he could produce?
   (B) what is the lowest beat frequency he could produce?
   (C) what is the shortest beat period he could produce?

   Answer: Recall that the beat frequency is defined as $f_{beat} = |f_1 - f_2|$.
   (A) The highest beat frequency occurs when f_{beat} is as large as possible. In this case, it is 3 Hz: $f_{beat,max} = |443\ Hz - 440\ Hz| = 3\ Hz$.
   (B) The lowest beat frequency occurs when f_{beat} is as small as possible. In this case, it is 1 Hz: $f_{beat,max} = |443\ Hz - 442\ Hz| = 1\ Hz$.
   (C) The case of the shortest beat period is the same as the highest beat frequency, since the period is the inverse of the frequency ($T = \frac{1}{f}$). Thus the shortest beat period will be the inverse of the highest beat frequency, or $\frac{1}{3\ Hz} = \frac{1}{3}\ second$.

9. Shown below in Figure 2 is a depiction of the Earth and its atmosphere. Near the ground in Layer 1, the heat from absorbed sunlight warms the atmosphere. Above that, in Layer 2, the atmosphere is cold. Above that in Layer 3, we do not know what the relative temperature is. We do know that sound generated in Layer 2 can easily travel around the Earth so that a superhero flying in Layer 2 above the South Pole can hear an explosion that happened in Layer 2 above the North Pole.
   From this information, what can you say about the temperature of the atmosphere in Layer 3? **Explain your answer for full credit.**

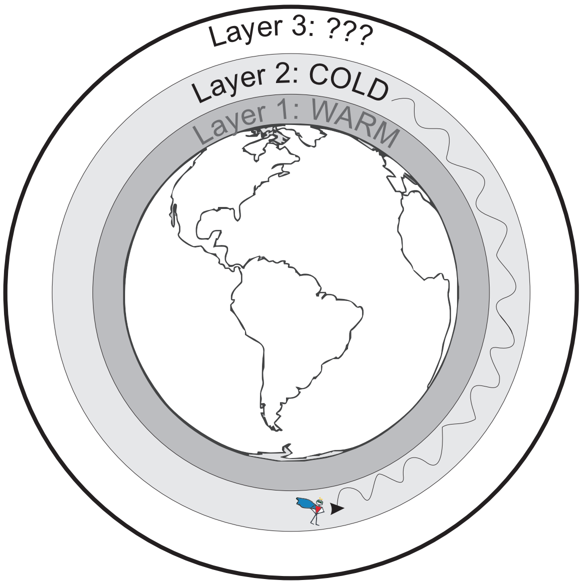

Figure 2: A cartoon of the Earth's atmosphere. The region near the ground is warm (Layer 1). Further up, it is cold (Layer 2). Above that, we don't know (Layer 3). However, sound generated in the cold layer above the North Pole easily makes it to a superhero in that same layer above the South Pole. See Question 9

Answer: If the sound is being refracted back into Layer 2 as it heads towards Layer 3, that must mean the speed of sound in Layer 2 is lower than the speed of sound in Layer 3. If the speed of sound in Layer 3 is higher than in Layer 2, Layer 3 must be hotter since sound travels faster in warmer air.

10. **(A)** A water wave with a wavelength of 3 m is traveling in water 6 m deep. What is its speed?
(B) A radio wave has a wavelength of 3 m traveling in the vacuum of space. What is its frequency?
(C) You see a bolt of lightning flash and first hear the thunder 10 seconds later. How far away did the lightning strike?
(D) You feel a small jolt in the ground and 3 seconds later you feel another jolt. A short time after that, your house really starts shaking. How far away did the earthquake happen?
(E) When struck, a tuning fork produces 300 Hz sound. How effective is this tuning fork at absorbing 250 Hz sound?

Answer:

(A) The water is twice as deep as the wavelength of the water wave, so it is 4 times as deep as $\frac{1}{2}$ wavelength. Thus the wave is traveling in deep water, and we must use the deep water wave speed equation:

$$\cancel{v = 1.25\sqrt{6}\ m/s = 2.2\ m/s}$$
$$v = 1.25\sqrt{3}\ m/s = 2.2\ m/s$$

⇒*Oops! There was a typo in the original solution! The '6' should have been a '3!'*

(B) The frequency is determined using our old friend: $v = \lambda \times f$. Solving for the frequency:

$$f = \frac{v}{\lambda} = \frac{3 \times 10^8\ m/s}{3\ m} = 1 \times 10^8\ Hz$$

(C) Use either the $distance = speed \times time$ equation, or the rule of thumb that for every 5 seconds between the lightning and beginning of the thunder, the lightning struck 1 mile away. Using the former:

$$distance = 340\ m/s \times 10\ s = 3,400\ m = 2.1\ miles$$

Using the latter: since it took 10 seconds, the lightning must have struck $10/5\ miles = 2\ miles$ away.

(D) The first jolt was the P-Wave, the second the S-Wave, and the third the L-Waves (Raleigh and Love). Using the rule of thumb that for every second of time between the arrival of the P-Wave and the S-Wave the earthquake happened 5 miles away, we know that the earthquake happened $3\ seconds \times 5\ miles/second = 15\ miles$ away.

(E) The tuning fork's natural frequency is 300 Hz, so it does not like to vibrate at anything other than 300 Hz. Therefore, it is not very effective at absorbing 250 Hz sound.