

Midterm Test (Test 2) - PHYS102 - Solution

Part I: Extended Clicker Quiz

Problem 1

Which of the following ideas for heating your house is the most efficient **and** consistent with all known laws of Physics? (Efficiency is maximum if you use the minimum amount of **primary** energy – the kind you have to pay for! - for the same heating effect)

- A. I turn all electric lights and appliances on.
- B. I use natural gas to heat the air inside my house (either directly through forced air or using a water circuit with radiators).
- C. I use a electricity-operated heat pump (a type of refrigerator) that cools the air around my house and exhausts heat into my house.**
- D. I use the temperature difference between my house and the surrounding air to run a (perfect) heat engine which in turn runs a heat pump as in C) above.

Problem 2

A curious boy extends the length of the pendulum in his grandfather's clock from 1 meter to 1.2 meter. What will he observe once he sets it back in motion?

- A. The clock will stop working altogether.
- B. The clock will be ticking (and running) faster than before.
- C. The clock will be running slow.**
- D. The clock will work just the same as before – the length of the pendulum has no effect.

Problem 3

A man and a little girl both sing a long, single-pitch note (one after the other, and at different pitches). When the man sings, a nearby window pane is vibrating quite a bit, but it is vibrating not at all when the girl sings. Why? (pick the most likely/best explanation)

- A. The man sings a little bit louder
- B. The man's sound is traveling faster than the girl's
- C. The man is singing at a higher frequency than the girl
- D. The man's frequency is in resonance with the window pane's own frequency, while the girl's frequency is far off resonance**

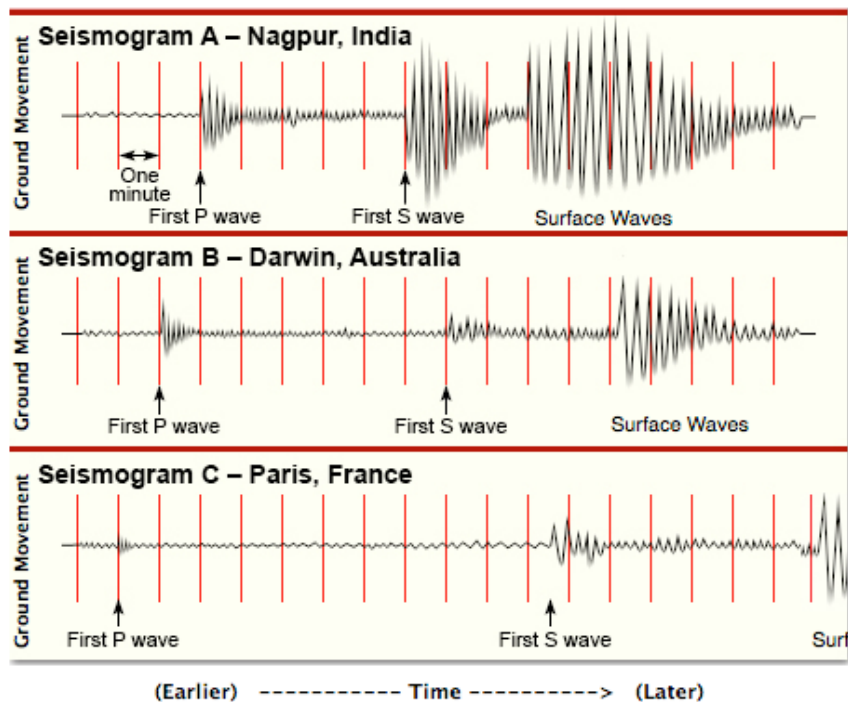
Problem 4

Seismograms record earth movements on a scrolling roll of paper. Earthquakes generate three types of waves (called P-, S-, and surface waves). P waves are fastest and so arrive first at seismic stations around the world. S-waves are slower and surface waves are slowest.

After an earthquake, scientists at (A) Nagpur, India; (B) Darwin, Australia; and (C) Paris, France record the interval between P- and S-waves but neglect to note actual times.

Which city is closest to the source of the Earthquake?

- A. Nagpur
- B. Darwin
- C. Paris
- D. You can't tell anything about the earthquake location without knowing actual times.



Problem 5

Water waves are rolling across a 90 m wide pond, with a wave velocity of 15 m/s. Every $T = 2$ seconds, a new wave maximum reaches the shore. How many complete wave oscillations (peak and trough) can you see on the pond at any given time?

$f = 1/T = 0.5 \text{ Hz}$; $\lambda = v_{\text{wave}}/f = 30 \text{ m} \Rightarrow$ I can see **3** complete waves (peak and trough)

Problem 6

True or False: The same pond from Problem 5 can support a standing wave of a frequency as low as $f = 1/12 \text{ Hz}$? (Assume the water is “fixed in place” on both shores.)

Enter “T” or “F” on your clicker! **T**: $\lambda = v_{\text{wave}}/f = 180 \text{ m} = 2L$

Problem 7

Your (AM) radio is receiving the same broadcast from 2 different antennas at the same time, both emitting the same frequency radio waves. While you are walking around with your radio, the signal sometimes becomes louder, sometimes fades away completely, only to reappear again after a while. What's going on? (Pick the most likely scenario!)

- A. You are moving between spots where the 2 radio waves are in constructive interference and other spots where they are in destructive interference.**
- B. Your batteries are going dead.
- C. This is due to the Doppler effect
- D. One of the 2 antennas has an intermittent connection that turns it off every now and then.

Problem 8

A copper wire coil is lying directly on top of a second, identical one (with the same orientation), but without any direct electrical contact between the two. The first coil carries a rising current that produces an increasing magnetic field which also passes through the second coil. The second coil forms a closed circuit (its ends are connected to each other).

Which of the following statements is NOT correct?

- A. The second coil will not react in any way to the field produced by the first one.**
- B. There will be an electric field along the direction of the wire of the second coil.
- C. The second coil will carry a current also, at least for a while.
- D. The second coil will produce a magnetic field also, in the opposite direction.
- E. The second coil will experience a force pushing it away from the first one.

Part II: Word Problems

Problem 9

Air at normal room temperature (293 K) and normal atmospheric pressure (101,000 Pa) is enclosed in a thermally well-insulated cylinder with an airtight piston. Describe in detail (at least 1-2 paragraphs) what happens when you quickly push the piston into the cylinder so that the same amount of air is now confined to only half its initial volume. Make sure you discuss what happens to the pressure, temperature and internal energy of the air (be as quantitative as possible). Where does any change in internal energy come from? Make sure you include enough details about what's going on and quote the *relevant laws and equations* of Physics to support your statements!

Solution: As I compress the air, two things happen simultaneously: I reduce the volume it can occupy, and at the same time I am doing work on it, increasing its internal energy: $\Delta E_{\text{internal}} = P(-\Delta V)$ according to the Formula Sheet. (There is no heat loss since the cylinder is well insulated; so the internal energy can only **increase** given that $-\Delta V$ is positive – the volume **shrinks**).

According to the Formula Sheet, $E_{\text{internal}} = \frac{3}{2} nRT$ for an ideal gas (like air at normal conditions). Increasing internal energy means the temperature must increase, as well – the air in the cylinder gets hot. Finally, the ideal gas equation, $PV = nRT$, tells us that when the temperature T goes up and the amount of air (n) stays the same, the product of pressure P and volume V must increase. However, the volume actually **decreases**, so the pressure must increase dramatically, more than to twice the original value!

Problem 10 (extra credit)

How are sound waves and light waves different from each other? List and describe at least 4 “features” that distinguish between the two. (1 Paragraph)

Solution:

The most fundamental difference is that in the case of sound waves, it is the medium that oscillates (in density or pressure), while in the case of light waves, the oscillations are those of the electric and magnetic field, which can exist anywhere (including a vacuum). Hence, light waves can travel through empty space, but sound waves can not. In addition, light waves ordinarily travel much faster than sound waves, and have much shorter wave lengths (and waaayyy higher frequencies) than typical sound waves. Light waves are transverse (the electric and magnetic fields oscillate perpendicular to the direction of propagation) while sound waves are longitudinal. Therefore, light waves can be polarized and sound waves cannot. Finally, we humans detect sound waves with our ears and light waves with our eyes!