

Homework Assignment #3 – due via Moodle at 11:59 pm on Friday, Mar. 6, 2026
[Ungraded Prob. 2b revised 3/5/26]

Instructions, notes, and hints:

Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work. You may make reasonable assumptions and approximations to compensate for missing information, if any.

The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

Graded Problems:

1. This problem is purely mathematical in nature, but it is meant to give you practice working with exponents. We will be working with exponents extensively over the next week or two and occasionally over the rest of the semester. Make sure that you know how to use the calculator functions that correspond to these mathematical operations. Calculate the results of the following mathematical expressions:

- a. 4^3
- b. $4^{1/2}$
- c. $(4^{1/2})^4$
- d. $2^{2.5}$

2. Referring to Fig. 5.10 in the textbook (Rossing, et al., 3rd ed.), find the approximate critical bandwidth for the following center frequencies:

- a. 50 Hz
- b. 900 Hz
- c. 7,000 Hz

3. According to the table included next to the graph in Fig. 5.10 of the textbook, the critical bandwidth at a center frequency of 1,000 Hz is 150 Hz. Any group of tones heard within the range of frequencies specified by the critical bandwidth would excite the same group of nerves along the basilar membrane of the cochlea. Find the upper and lower frequency limits of the critical band centered at 1,000 Hz.
4. A certain composite sound is made up of partials at the frequencies 720 Hz, 900 Hz, 1,080 Hz, and 1,260 Hz. Find the perceived pitch that a listener would be likely to experience.

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5. Refer to Fig. 7.2 in the textbook (Rossing, et al., 3rd ed.). Show that the just noticeable difference (jnd) in frequency perception is roughly 1/30 of the critical bandwidth at the frequencies 200 Hz, 1,000 Hz, and 5,000 Hz.
6. Fig. 7.4 in the textbook gives the required minimum time duration of a tone as a function of the tone's frequency for a human to deduce its pitch. The time duration is indicated by the solid curve, and it is compared to the duration of two cycles (two periods) of the tone, which is indicated by the dashed curve. Confirm that that the dashed curve is roughly correct at the frequencies 100 Hz and 500 Hz. Compare your answers to the exposure time required to identify the pitches at the same two frequencies; express your comparison as a ratio of the required exposure time to the length of two cycles.
7. Find the first three partials above the fundamental in the Fourier series representation of a square wave with a fundamental frequency of 520 Hz. (See Sec. 7.10 of the textbook.)
8. Suppose that two tones with frequencies of 500 Hz and 508 Hz are generated simultaneously by a sound source. Find the frequency of the "fused" (average) tone and the beat frequency that are likely to be perceived by a human listener.

Ungraded Problems:

The following problems will not be graded, but you should attempt to solve them on your own and then check the solutions. Do not give up too quickly if you struggle with one or more of them. Move on to a different problem and then return to the difficult one after a few hours.

The first three problems are purely mathematical in nature, but they are meant to give you more practice working with scientific notation (composite values using powers of 10) and logarithms. Make sure that you know how to use the corresponding calculator functions.

1. Calculate the results of the following mathematical expressions:

a. $(2.3 \times 10^8)(4.0 \times 10^{-5})$

b. $\frac{2.2 \times 10^3}{2.5 \times 10^{-5}}$

c. $(4.40 \times 10^3) + (2.7 \times 10^2)$

d. $(4.40 \times 10^3) - (2.7 \times 10^2)$

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2. **[Part b revised 3/5/26]** Calculate the results of the following mathematical expressions (all involve common logarithms, that is, base-10 logarithms):

a. $\log(8.0 \times 10^8)$

b. $\log\left(\frac{1}{8.0 \times 10^8}\right)$

3. Solve for the value of x in each of the following mathematical expressions (all involve common logarithms):

a. $\log(x) = 0.90$

b. $\log(x) = -0.90$

c. $\log(x) = 9.0$

d. $\log(x) = 2.3$

4. The pitch standards to which musical instruments are tuned have risen considerably over the past few centuries. In the time of George Frideric Handel, the musical note A above middle C was around 422 Hz. It is now 440 Hz. The change puts antique stringed instruments at risk of breakage because of the increased tension in their strings when tuned to modern standards. Referring to Sec. 4.3 in the textbook (Rossing, Moore, and Wheeler, 3rd, ed.), find the amount (the multiplying factor) by which the tension in a violin's A string must be increased to change the tuning from 422 Hz to 440 Hz. By the way, although a violin has four strings, the total tension (and therefore the net force experienced by the instrument's neck) roughly increases by a factor equal to the increase in the A string's tension alone. While the total increase in the tension measured in newtons depends on the number of strings, the *factor* by which the total tension increases is roughly independent of the number of strings. This difference in interpretation will be illustrated using an example in the problem solution. (Tension is the force transmitted through a string, so, like force, it is measured in newtons.)
5. Suppose that two tones with frequencies of 900 Hz and 1,210 Hz are generated simultaneously by a sound source. Refer to Fig. 5.10 in the textbook (Rossing, et al. 3rd ed.) to explain why a listener would most likely perceive the sound as two separate tones rather than a "rough" sound at a single frequency close to 1,055 Hz.