

UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Astrophysics I (ASTR 691) — Prof. Crossfield — Fall 2026

In-Class Problems 10 [28 pts]

You may use your OoMA Sheet, your handwritten notes, and a scientific or graphing calculator – and you may work in a group. As always, be sure to: show your work, circle or highlight your final answer, list units, use the appropriate number of significant figures, and write your name.

1. **Molecular Vibrational Spectra** Consider the humble Carbon Monoxide (CO) molecule.
 - 2 pts Calculate the reduced mass, μ , assuming (i) a molecule composed of ^{12}C and ^{16}O , and (ii) a molecule composed of ^{13}C and ^{16}O (the next-most-common isotopologue).
 - 2 pts Assuming the CO ‘spring constant’ $k \approx 1800 \text{ N/m}$, what is the fundamental frequency ν_0 (i) for ^{12}CO ? (i) for ^{13}CO ?
 - 4 pts What is the energy change (ΔE) and associated photon wavelength (λ) of each of these two molecules (i) for vibrational quantum number $\ell : 1 \rightarrow 0$? (ii) for $\ell : 2 \rightarrow 0$? (iii) for $\ell : 0 \rightarrow 3$?
 - 6 pts Sketch, roughly to scale, an energy diagram for a molecule of ^{12}CO for $\ell = 0, 1, 2, 3, 4$. Show and label the transitions whose ΔE you just calculated.
2. **Molecular Rotational Spectra** Consider again the humble Carbon Monoxide (CO) molecule.
 - 4 pts Assuming the ^{12}CO moment of inertia is $I \approx 1.5 \times 10^{-46} \text{ kg }^2\text{m}$, what is the energy change (ΔE) and associated photon wavelength (λ) (i) for rotational quantum number $J : 1 \rightarrow 0$? (ii) for $J : 2 \rightarrow 1$? (iii) for $J : 0 \rightarrow 2$?
 - 6 pts Sketch an energy diagram for a molecule of ^{12}CO , for $J = 0, 1, 2, 3, 4$. Show and label the transitions whose ΔE you just calculated.
3. At which wavelengths would you expect rotational spectra to be most often observed? what about vibrational spectra? [4 pts]