# Announcements

- Exam Thursday, 7-9pm. No class Thursday morning. **Pick up an Exam Info sheet from the front or back of the room.**
- Optional review session tonight at 8:30 pm, here in Olin 268.
- Last year's exam is available on the Solutions page.
- Graded group exercise in problem session tomorrow.
- Graded activity in problem session on Friday.
- Open Lab will run from Monday to Thursday of next week (April 20–23). Hours posted on the Lab Info page.
    - This is your last chance to make up missed labs!
    - You will also be able to prepare for the practicum which takes place the week after.

# Physics & Astronomy Speaker Series

## JASON YBARRA

Director of the West Virginia Polytechnic University Observatory and Planetarium
Professor of Physics, WVU

## From Archives to Astrophysics: Reviving Historical Data for Modern Discovery

**Thurs April 16th at noon in OLIN 268**

This talk explores the history of astronomy, not only as context for the human role in scientific discovery, but also as a valuable source of long-term data that can inform modern astrophysical research. I will highlight recent projects that draw on major astronomical discoveries made in 17th century Europe.

Pizza will be provided. Bring your own water bottle

# What Will You Be Tested On?

- PHYS 212 exams are not evaluating if you are "good at math" or "good at physics". This exam will test your mastery of the material covered in Unit 3 of PHYS 212.
- This includes:
  - Lectures 15-21
  - Problem Session (assigned problems)
  - Previous PHYS 211/212 content used in this unit
- We thoroughly check our exams to eliminate bias with respect to race, gender, or culture.

## You're allowed one 3×5 index card for Unit 3. Things you might put on it:

- Fundamental equations
- Basic derivatives and integrals: $x^n$, $e^x$, $\sin x$, $\cos x$, and product rule and chain rule.
- Prefixes: you should know nano, micro, milli, centi, kilo, mega, and giga.
- Examples. How to show a wavefunction is a solution to Schrödinger's equation.
- You do NOT need to put on your card Schrödinger's equation or the spin relations from Table 5.1 (e.g., $|{+x}\rangle = \frac{1}{\sqrt{2}}|{+z}\rangle + \frac{1}{\sqrt{2}}|{-z}\rangle$). These will be provided.

You are also allowed to bring your two sheets from the two previous exams.

**PHYS 212 Third Exam** **Name** ________________________
**April 16, 2026** **P. S. Instructor:** ______________
**P. S. Time:** _______

**Show all work for full credit! Answers must have correct units. For all problems (except multiple choice questions) start with either (a) a generally applicable equation, or (b) a sentence explaining your approach.**

**The work for each problem should appear on the same page as the problem for full consideration.**

**All smart devices (phones, watches, glasses, etc.) have to be packed away during the exam. If your cell phone is out, we will have to confiscate your exam.**

$k = 8.99 \times 10^9\,\mathrm{N{\cdot}m^2/C^2}$ $k_B = 1.38 \times 10^{-23}\,\mathrm{J/K} = 8.62 \times 10^{-5}\,\mathrm{eV/K}$

$h = 6.63 \times 10^{-34}\,\mathrm{J{\cdot}s} = 4.14 \times 10^{-15}\,\mathrm{eV{\cdot}s}$ $\hbar = 1.06 \times 10^{-34}\,\mathrm{J{\cdot}s} = 6.59 \times 10^{-16}\,\mathrm{eV{\cdot}s}$

$hc = 1240\,\mathrm{eV{\cdot}nm}$ $\hbar c = 197\,\mathrm{eV{\cdot}nm}$

$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$ $m_e c^2 = 0.511\,\mathrm{MeV}$ $1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

$m_p = 1.67{\times}10^{-27}\,\mathrm{kg}$ $m_p c^2 = 938\,\mathrm{MeV}$ $\mu_p = 1.41{\times}10^{-26}\,\mathrm{J/T}$ $\mu_e = 9.28{\times}10^{-24}\,\mathrm{J/T}$

$c = 3.00 \times 10^8\,\mathrm{m/s}$ Hydrogen: $E_1 = -13.6\,\mathrm{eV}$

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + U(x)\psi(x) = E\psi(x)$$

$$-\frac{\hbar^2}{2mr^2}\left[\frac{\partial}{\partial r}\left(r^2\frac{\partial\psi}{\partial r}\right) + \frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial\psi}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2\psi}{\partial\phi^2}\right] + U\psi = E\psi$$

$$|{+z}\rangle = \frac{1}{\sqrt{2}}|{+x}\rangle + \frac{1}{\sqrt{2}}|{-x}\rangle \qquad |{-z}\rangle = \frac{1}{\sqrt{2}}|{+x}\rangle - \frac{1}{\sqrt{2}}|{-x}\rangle$$

$$|{+z}\rangle = \frac{1}{\sqrt{2}}|{+y}\rangle + \frac{1}{\sqrt{2}}|{-y}\rangle \qquad |{-z}\rangle = -i\frac{1}{\sqrt{2}}|{+y}\rangle + i\frac{1}{\sqrt{2}}|{-y}\rangle$$

$$|{+x}\rangle = \frac{1}{\sqrt{2}}|{+z}\rangle + \frac{1}{\sqrt{2}}|{-z}\rangle \qquad |{-x}\rangle = \frac{1}{\sqrt{2}}|{+z}\rangle - \frac{1}{\sqrt{2}}|{-z}\rangle$$

$$|{+y}\rangle = \frac{1}{\sqrt{2}}|{+z}\rangle + i\frac{1}{\sqrt{2}}|{-z}\rangle \qquad |{-y}\rangle = \frac{1}{\sqrt{2}}|{+z}\rangle - i\frac{1}{\sqrt{2}}|{-z}\rangle$$

$$|{\uparrow}\rangle = b_+|{\nearrow}\rangle + b_-|{\swarrow}\rangle \qquad |{\downarrow}\rangle = b_-|{\nearrow}\rangle - b_+|{\swarrow}\rangle$$

$$b_+ = \sqrt{\frac{1+\cos\theta}{2}} \qquad b_- = \sqrt{\frac{1-\cos\theta}{2}}$$

# Don’t take shortcuts!

- Show all work. We grade the process and not the answer, so you need to communicate your approach.

- Generally applicable equations such as $E_{\text{ph}} = hc/\lambda$ can be used without explanation. Starting with $E_{\text{ph}} = 2\mu_p B$ is not valid.

- If using a specialized equation that is valid only for a particular situation, you must state the assumptions. For example,

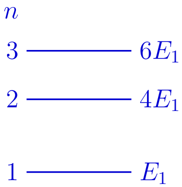
  $$\text{Infinite square well:} \qquad E_n = \frac{h^2 n^2}{8mL^2}$$

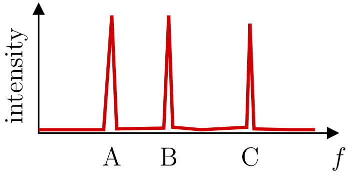
  is only valid for an infinite square well potential, and $E_n = -13.6\,\text{eV}/n^2$ is only valid for hydrogen.

- You may use either SI units or eV units, unless the problem specifies which should be used. Be careful not to mix units!

# Lecture 21 — Concept Test 1

An electron is in a system with three discrete energy levels. The spectrum of light emitted by this system is shown in red.

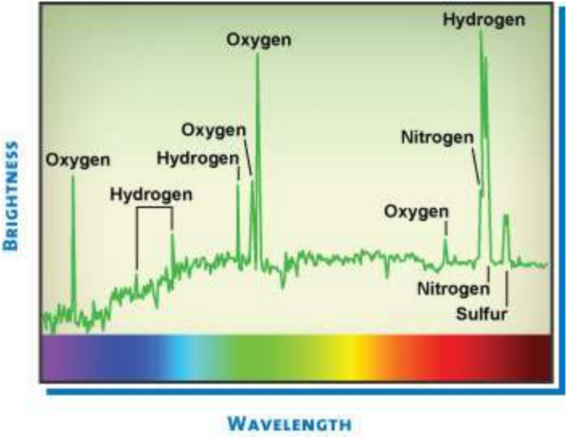




How do these frequencies of light correspond to the energy diagram?

1. **A:** $n = 1$, **B:** $n = 2$, **C:** $n = 3$
2. **A:** $n = 3$, **B:** $n = 2$, **C:** $n = 1$
3. **A:** $3 \to 2$, **B:** $3 \to 1$, **C:** $2 \to 1$
4. **A:** $3 \to 2$, **B:** $2 \to 1$, **C:** $3 \to 1$
5. **A:** $3 \to 1$, **B:** $2 \to 1$, **C:** $3 \to 2$
6. **A:** $3 \to 1$, **B:** $3 \to 2$, **C:** $2 \to 1$

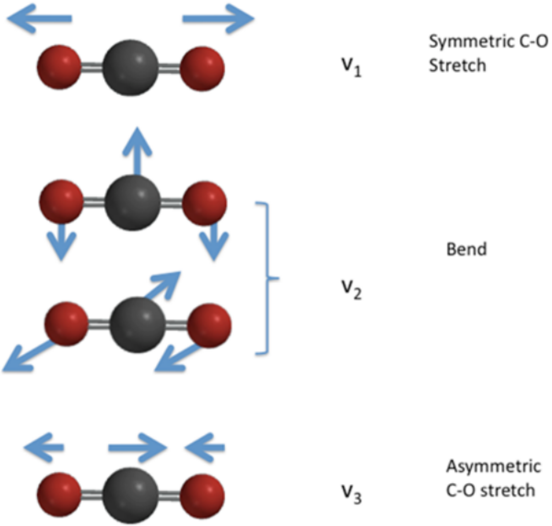
# Atomic and Molecular Spectra

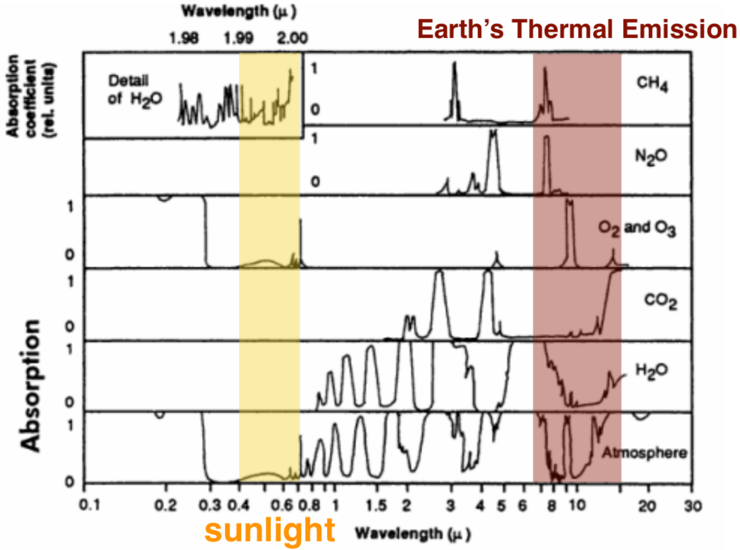


Can determine what is in a sample by looking for peaks corresponding to known atoms or molecules.

# Molecules also have vibrational energy levels

$CO_2$:





**Earth's Thermal Emission**

**sunlight**

**Figure 5-2.** Absorption spectra for $CH_4$, $NO_2$, $O_2$, $O_3$, $CO_2$, and $H_2O$, and of the atmosphere. (From R. G. Fleagle and J. A. Businger [2006] after J. H. Howard [519] and R. M. Goody and G. D. Robinson [514])

# Lecture 21 — Concept Test 2

When I shine a certain light on the beach ball, it fluoresces, glowing green. What can you say about the light source that I used?

1. it is a green light source
2. it has a shorter wavelength than green
3. it has a longer wavelength than green
4. it is a very powerful light source
5. it is a very weak light source

# Lecture 21 — Concept Test 3

The following state describes a pair of particles:

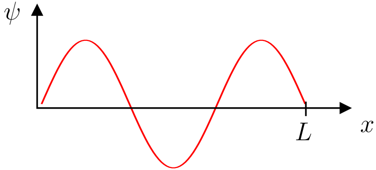
$$|\psi\rangle = 0.6\,|\uparrow\downarrow\rangle - 0.8\,|\downarrow\uparrow\rangle$$

Which type(s) of particles could this state describe?

1. identical fermions
2. identical bosons or an electron-positron pair
3. an electron-positron pair
4. identical bosons
5. identical fermions or an electron-positron pair
6. any pair of particles

# Lecture 21 — Concept Test 4

For the infinite square well wavefunction shown in the plot, what is the probability that the particle will be found in the region $0 < x < 2L/3$?



**1.** $0$

**2.** $1/3$

**3.** $1/2$

**4.** $2/3$

**5.** $3/4$

**6.** not enough info

# Lecture 21 — Concept Test 5

You are testing a possible solution to Schrödinger's Equation. You take the test solution, substitute it into the equation, taking derivatives when needed, and you simplify as much as is possible.

For each of the following cases, determine whether

**1.** this could be a solution or **2.** this could not be a solution.

**(a)** $B\sin(kx) + 3 = E\sin(kx)$

**(b)** $Cx^2 + 3 - 2x^2 = E$

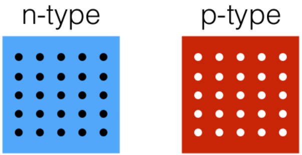
**(c)** $D + 6x^2 - 3 = E$

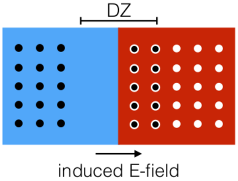
# Lecture 21 — Concept Test 6

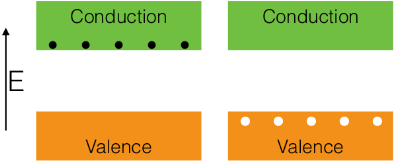
Which of the following $(n, \ell, m_\ell, m_s)$ values represent valid states for an electron in a hydrogen atom? Choose all that are valid.

1. $(0, 0, 0, 0)$
2. $(1, 0, 0, 0)$
3. $(2, 0, 0, \frac{1}{2})$
4. $(2, 0, 1, -\frac{1}{2})$
5. $(2, 1, 0, -\frac{1}{2})$
6. $(3, 2, 0, \frac{1}{2})$

# Doped semiconductors







🟦 electron
🟥 hole

# Lecture 21 — Concept Test 7

How could shining light on this diode make it able to conduct electricity?

1. Shining light causes electrons to leave the surface of the semiconductor, just like the photoelectric effect.
2. Shining light with a photon energy greater than or equal to the band gap energy will excite photons from the valence band into the conduction band.
3. Shining light will induce an electric field that will shrink the depletion zone.
4. Shining light will create enough thermal motion that $k_B T$ is comparable to the band gap energy, which will excite photons from the valence band into the conduction band.
5. Shining light is not able to make this diode conduct.