Astronomy 101 Exam 3 Form Dkey

Name: ______________________________

- This exam form is for you to keep. Circle your answers on it for your records; all you will turn in this time is the Scantron.
- If you fill out your Scantron in pen and make a mistake, ask us for a new form. It is better if you use pencil so you can erase.
- Exam time: one hour and twenty minutes
- Please put bags under your seats to allow proctors to move around the room.
- You may use only pencils and pens for this exam; **no cellphones, calculators, or smartwatches** are allowed.
- If you have a question, raise your hand, and a proctor will assist you.
- You may use a single-sided 8.5x11 inch page of notes you wrote yourself
- Do not attempt to communicate with anyone other than teaching staff during the exam

This exam is printed in color. If you have limited color vision, and would like a description of what color things are, please ask us for help.

Good luck!

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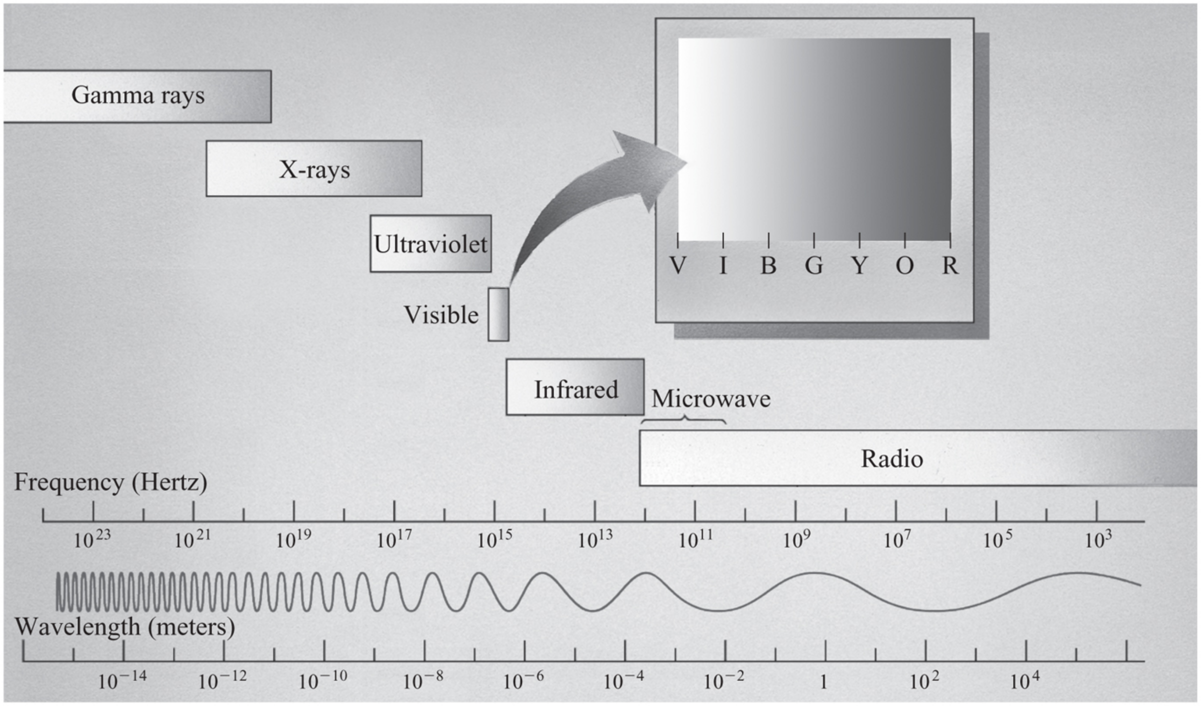
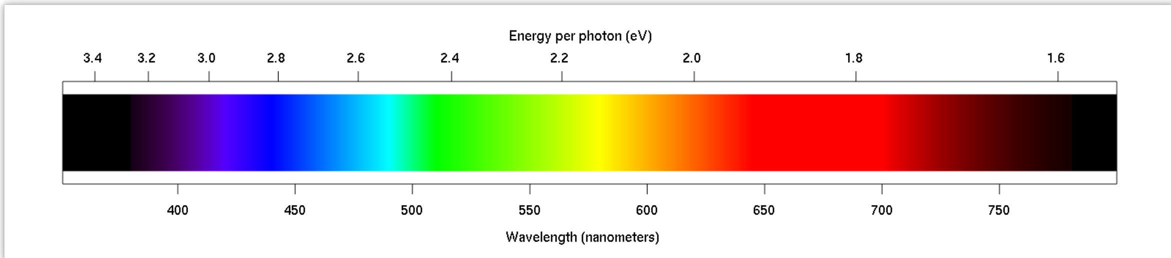
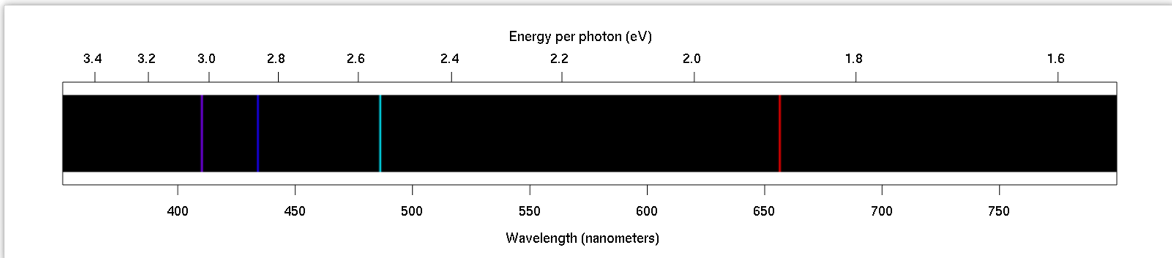
Reference



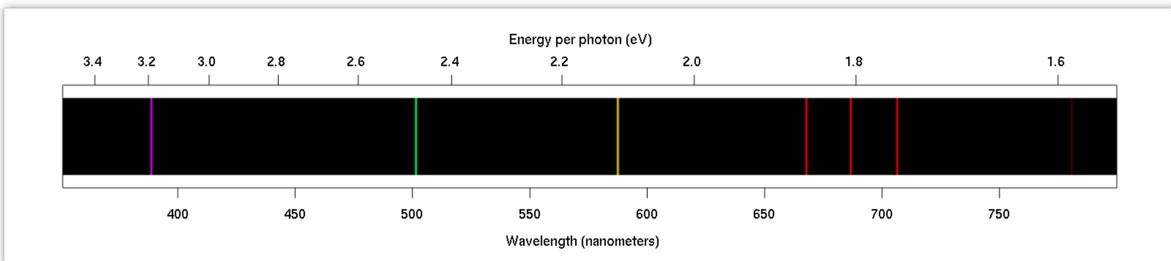
Gamma rays
X-rays
Ultraviolet
Visible
V I B G Y O R
Infrared
Microwave
Radio
Frequency (Hertz)
10^{23} 10^{21} 10^{19} 10^{17} 10^{15} 10^{13} 10^{11} 10^{9} 10^{7} 10^{5} 10^{3}
Wavelength (meters)
10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2} 10^{4}



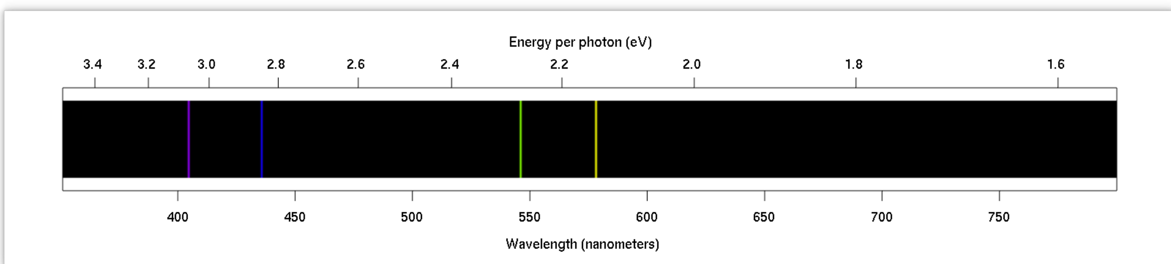
Visible light



Hydrogen



Helium



Mercury

`(Question formid)`

1. What form is your exam?

   (A) Form A
   (B) Form B
   (C) Form C
   (D) Form D
   (E) Form E

`(Question calculate-lines)`

2. A hypothetical element Syracusium has energy levels of 0 eV, 5 eV, 7 eV, and 7.5 eV. If you put a diffuse gas of this element in a tube and run electric current through it, what sort of light will come out?

   (A) Visible and infrared photons of a wide range of energies, depending on its temperature
   (B) Photons of energies 5 eV, 2 eV, and 2.5 eV
   (C) Photons of all energies up to 7.5 eV
   (D) **Photons of energies 0.5 eV, 2 eV, 2.5 eV, 5 eV, 7 eV, and 7.5 eV**
   (E) Photons of energies 0.5 eV, 5 eV, 7 eV, and 7.5 eV

   All possible transitions will happen. There are six different results from subtracting the energy levels given: 7.5-7 = 0.5, 7.5-5 = 2.5, 7.5-0 = 7.5, 7-5 = 2, 7-0 = 7, and 5-0 = 5.

`(Question frequency-wavelength)`

3. Amateur radio ("ham") signals can have very long wavelengths around a hundred meters. Which of the following is true about these radio signals?

   (A) They have large amounts of energy per photon

   (B) They pose a significant danger to human health because their wavelengths are so long

   (C) They are generated by producing energy-level transitions in molecules between energy levels that are about 0.1 eV apart

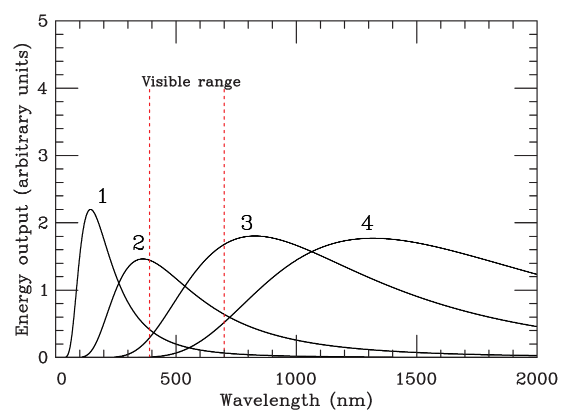
   (D) **They have very low frequencies**

   (E) They are transmitted at very low power

   Long wavelengths correspond to low frequencies and low energy per photon. This makes them not very dangerous to human health since the photons do not have enough energy to cause chemical change. They can be transmitted at quite high power, though – don't confuse the energy per photon with the total amount of energy of all the photons together.

`(Question highest-temperature)`

4. Here are spectral curves from four different objects.

   Which one of the spectra shown to the right would come from an object with the highest temperature?

   (A) **Spectrum 1**

   (B) Spectrum 2

   (C) Spectrum 3

   (D) Spectrum 4

   (E) You can't tell temperature from these, only wavelength

   Spectrum 1 has its peak at the shortest wavelength, and thus corresponds to the highest temperature.

`(Question human-blackbody)`

5. Look back at the four spectral curves shown in the previous question.

   Which of these corresponds to the thermal radiation emitted by a person?

   (A) Spectrum 1
   (B) Spectrum 2
   (C) Spectrum 3
   (D) Spectrum 4
   (E) **None of these correspond to the spectrum that a person produces**

   All of the spectra shown emit a significant amount of visible light. Since we don't see people glowing, none of these can be correct.

`(Question stardust)`

6. Where do the elements like carbon, oxygen, iron, and silicon around us come from?

   (A) **They were created in the core of a star which has since exploded in a supernova**
   (B) They are created in the core of the Sun
   (C) They are created when the solar wind interacts with Earth's atmosphere
   (D) They were created in the Big Bang
   (E) None of the above

   The Sun is fusing hydrogen into helium. Heavier elements were produced by the parent star, massive enough to go further up the fusion chain. When that star exploded, they were released into space.

`(Question star-no-dark-lines)`

7. You observe a star that is slightly smaller than the Sun. However, when looking at it through a spectroscope, you see far fewer dark lines than in the Sun's spectrum.

   What can you conclude about this star?

   (A) This star does not have planets orbiting it
   (B) This star is fusing helium into carbon in its core
   (C) This star is much hotter than the Sun
   (D) This star is much cooler than the Sun
   (E) **This star does not have many different elements in its atmosphere**

   Since the dark lines (absorption lines) are caused by different chemical elements in a star's atmosphere, a star lacking them doesn't have that many different elements in its atmosphere.

`(Question fusion-power)`

8. Why don't humans use nuclear fusion, as in the Sun, as an energy source on Earth? *(Thanks to Ben Rabin for the question!)*

   (A) Because there is nothing on Earth that is suitable fuel for nuclear fusion; only stars have the needed raw materials
   (B) Because nuclear fusion is an inefficient energy source and doesn't produce much energy per ton of fuel
   (C) **Because it requires temperatures of millions of degrees to produce, and containing these temperatures is a difficult engineering challenge**
   (D) Because nuclear fusion produces highly radioactive byproducts that are difficult to store safely

   It takes a tremendous amount of heat and pressure to stick hydrogen atoms together to make helium – millions of degrees. On Earth, other than in a few extremely exotic research machines that use far more power than they produce via fusion, the only way to achieve these temperatures and pressures is inside a detonating nuclear bomb... not exactly a good thing to put in a power plant!

`(Question star-know-temperature)`

9. How can astronomers best determine the temperature of stars near us in the Milky Way?
   - (A) By examining them with a thermal camera similar to the ones we used in class/lab
   - (B) By looking at the location of the thin dark lines that appear in their spectra
   - (C) **By looking at the peak wavelength at which they emit light (or, equivalently, their color)**
   - (D) By looking at the location of the thin bright lines that appear in their spectra
   - (E) None of the above would allow us to measure the temperature of a star

   The peak wavelength of thermal radiation tells you the temperature.

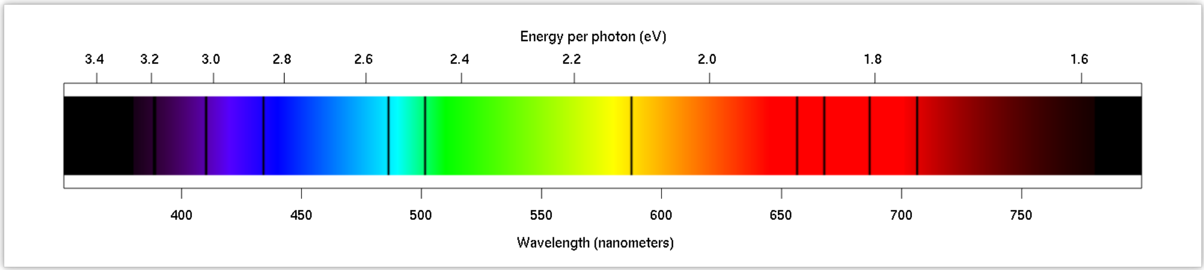
`(Question star-know-composition)`

10. How can astronomers best determine what chemical elements are present in the outer layer of stars?
    - (A) By determining their age, and thus the elements they are producing with nuclear fusion
    - (B) By examining the amount of light they produce in total
    - (C) By examining the energies of the neutrinos produced in nuclear reactions in their core
    - (D) By examining the peak wavelength at which they emit light (equivalently, their color)
    - (E) **By examining the locations of the thin dark lines that appear in their spectra**

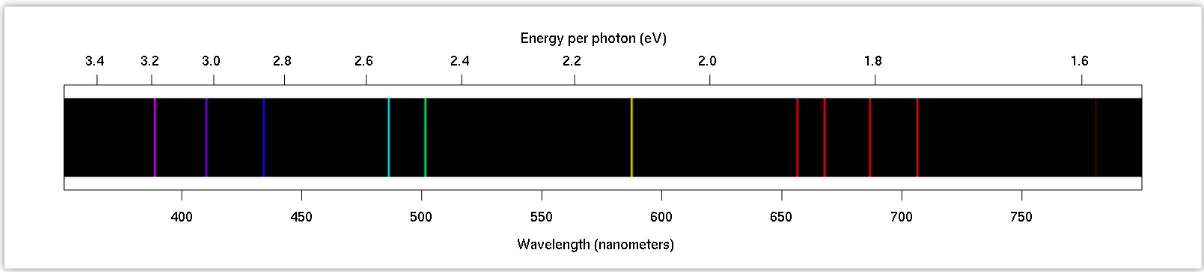
(Question stellar-atmosphere)

11. Which of the following spectra would you expect to see if you were looking at a star with only hydrogen and helium in its atmosphere? *(Consult the reference spectra provided to you with your exam.)*

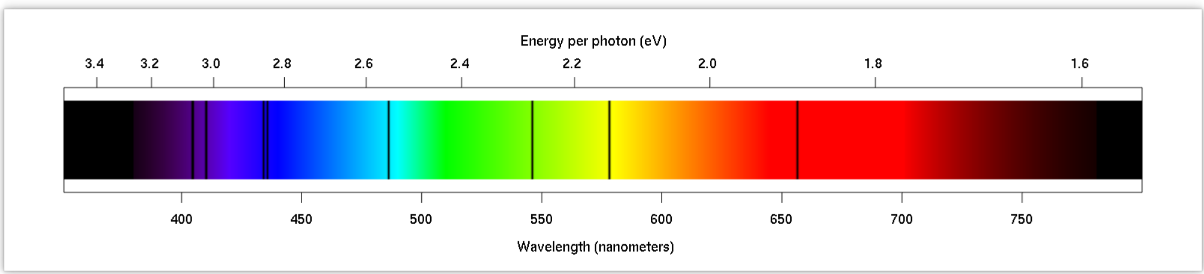
(A)



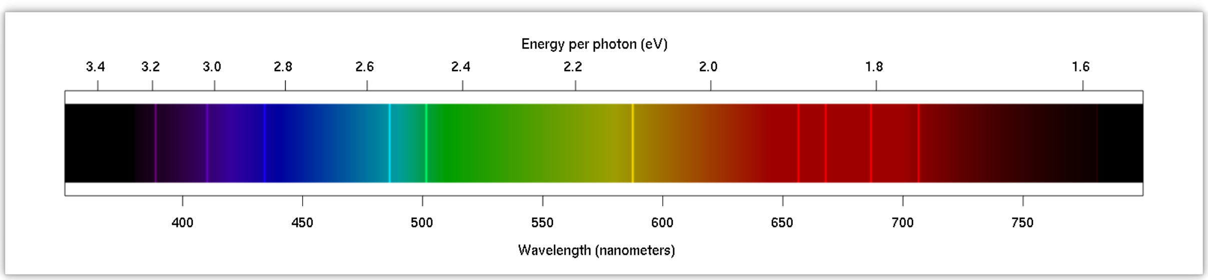
(B)



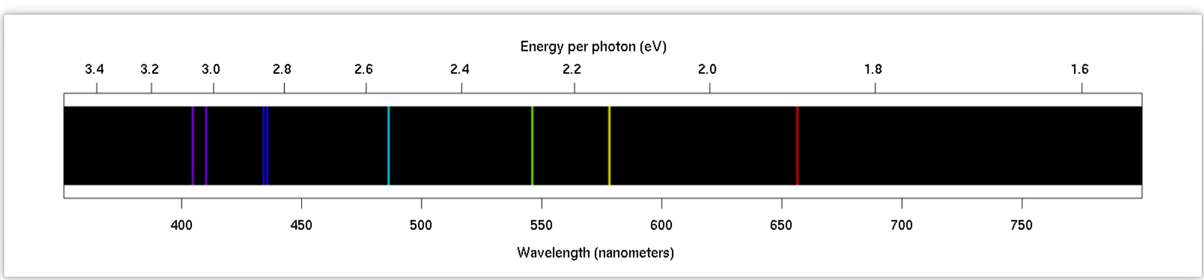
(C)



(D)



(E)



The program I wrote to generate exams doesn't let me readily indicate the correct spectrum, but it's the one with dark lines corresponding to the hydrogen+helium spectra.

(Question snowman)

12. You decide to make the best of the Syracuse weather, and build a snowman in the Quad that is about the same size as you and stand next to it.

    Which statement is true?

    (A) Neither of you is emitting light

    (B) Both you and the snowman are emitting infrared light; the light coming from you is more intense and has longer wavelength than the light coming from the snowman.

    (C) **Both you and the snowman are emitting infrared light; the light coming from you is more intense and has shorter wavelength than the light coming from the snowman.**

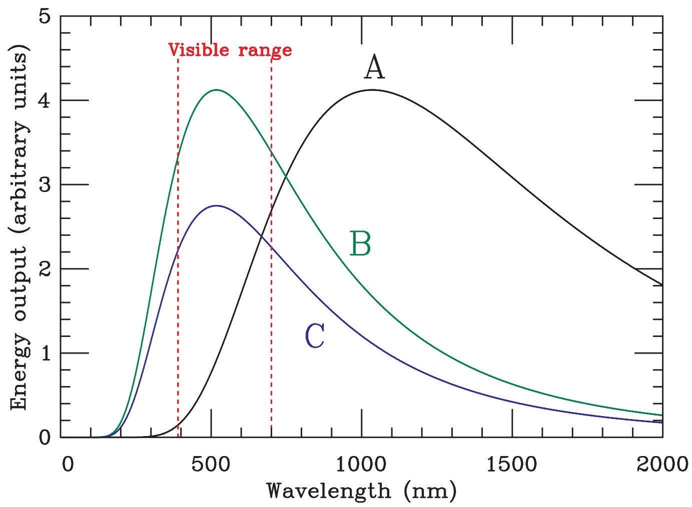
    (D) You are emitting infrared light, and the snowman is emitting ultraviolet light

    (E) You are emitting infrared light, but the snowman is not emitting light

    The snowman is probably around freezing, 273 K; you are around 300 K. Both of these correspond to infrared light; since you are warmer than the snowman, your infrared light will be a little more intense and a little shorter wavelength.

(Question three-spectra-1)

13. You observe three stars (A, B, and C) that are all the same distance away. The shapes of spectra are shown in the following graph:



The next three questions will all reference this graph.

Of these three stars, what can you conclude about their *temperatures*?

(A) Star A and B are the same temperature; star C is cooler

(B) Star B and C are the same temperature; star A is warmer

(C) Star A and B are the same temperature; star C is warmer

(D) **Star B and C are the same temperature; star A is cooler**

(E) You can't determine their temperatures from only this information

Star A, since its peak emission is at longer wavelengths, is cooler.

(Question three-spectra-2)

14. In the previous question, you saw spectral curves for three stars. Which statement is true about their *color*, as viewed by a human observer?

(A) **Stars B and C would look white; star A would look red**

(B) Stars A and B would look red; star C would look blue

(C) Stars B and C would look white; star A would not be visible since we cannot see infrared light

(D) Star A would look red; star B would look blue; star C would look white

Stars B and C peak in the middle of the visible range and emit visible light that is balanced throughout that range; they would thus look white (like the Sun). Star A emits much more red light (long end of visible) than blue (short end of visible), and so would look red.

(Question three-spectra-3)

15. Referencing again the spectral curves of these three stars, what can you conclude about their *sizes*?

    (A) Star A is larger than stars B and C, which are the same size

    (B) Star B is larger than stars A and C; you can't tell whether star A is larger than star C from these data

    (C) **Star A is larger than star B, and both are larger than star C**

    (D) Stars A and B are the same size; both are larger than star C

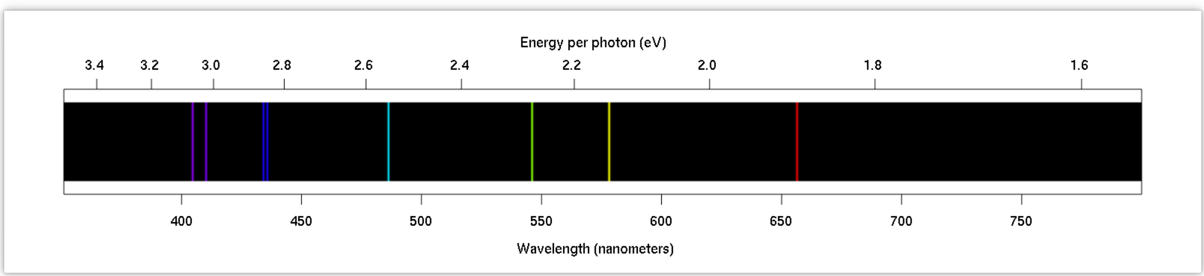
    (E) You can't conclude anything about their sizes from these data

    Normally, larger objects emit more light, and hotter objects emit more light. Since Star A emits as much light as Star B, but is cooler, it must be bigger to compensate. Stars B and C are the same temperature since their spectra peak at the same wavelength, but since star C emits less light, it must be smaller.

(Question broken-bulb)

16. A mixup has happened in a fluorescent light factory with the gas supply. They now have lots of unlabeled gas discharge tubes. Even worse, some of them may contain mixtures of several different gases.

    You are sent in with a spectrometer and a set of reference spectra (included with your exam) to figure out which is which. You see the following spectrum from the first tube you look at:



    What is in this tube? Consult the reference spectra provided with your exam. *(I wrote this question first and then saw that Andrew wrote a very similar one, so he gets credit!)*

    (A) Helium and mercury

    (B) Only mercury

    (C) **Hydrogen and mercury**

    (D) Hydrogen and helium

    (E) Another element not listed here

    The lines shown here are a combination of the lines from hydrogen and mercury.

(Question mwb)

17. The leftover radiation from the Big Bang looks like the thermal radiation coming from an object with a temperature of around 3 K. (For reference, room temperature is around 300 K, incandescent light bulbs are around 3000 K, and the Sun is around 5700 K.)

    What type of light is this radiation?

    (A) **Microwaves**
    (B) Visible light
    (C) Infrared
    (D) Ultraviolet
    (E) Gravitational waves

    Infrared is only a little longer wavelength/less energy per photon than visible. We need something two thousand times longer wavelength/lower energy per photon than visible light – not infrared, but microwave, past infrared on the spectrum.

(Question radiation-threat)

18. What property of x-rays makes them more dangerous to human health than microwaves?

    (A) X-rays have longer wavelength than microwaves
    (B) X-rays travel much faster than microwaves
    (C) X-ray sources (like an x-ray imaging machine) produce much more total energy than microwave sources (like a microwave oven)
    (D) X-rays cause atoms that they interact with to become radioactive and to decay later
    (E) **X-ray photons have much more energy than microwave photons**

    X-ray photons have energies of hundreds or more eV, enough to ionize atoms and change the chemical structure of molecules. Even a small number of x-ray photons can cause lasting change to DNA. Microwaves, regardless of their intensity, do not have enough energy to do this.

(Question ground-state-unable)

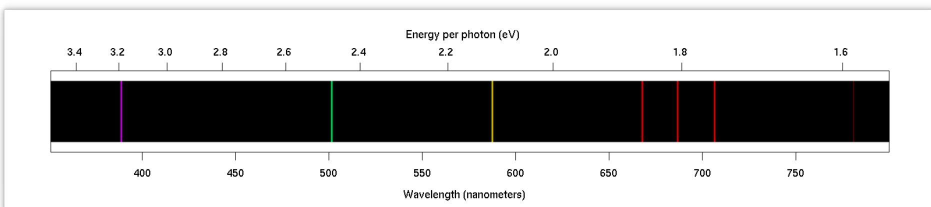
19. An atom in its ground state is unable to do which of the following?

    (A) It is unable to gain energy by absorbing light
    (B) It is unable to absorb light via electron transitions to another energy level
    (C) **It is unable to emit light via electron transitions to another energy level**
    (D) It is unable to emit thermal radiation
    (E) An atom in its ground state can do all four of the above

    An atom in its ground state has no more energy to give away, and so it can't emit light by transitioning downward.

(Question what-source-1)

20. What sort of object would produce a spectrum that looks like this?

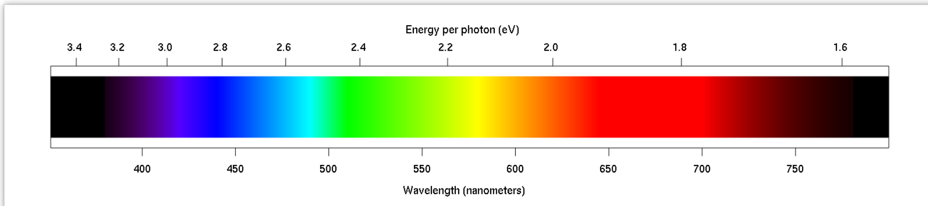


    (A) **A diffuse gas in an electrified tube, such as the ones you used in lab**
    (B) A hot object heated to thousands of degrees
    (C) Reflected light from the wall of a room that was lit by a mixture of incandescent and fluorescent lamps
    (D) A hot object heated to thousands of degrees, seen through the atmosphere of a planet or star
    (E) None of the above

    This is an emission spectrum: a few thin bright lines. (It's helium, but that doesn't matter for this problem.)

(Question what-source-2)

21. What sort of object would produce a spectrum that looks like this?



(A) Reflected light from the wall of a room that was lit by a mixture of incandescent and fluorescent lamps

(B) A diffuse gas in an electrified tube, such as the ones you used in lab

(C) **A hot object heated to thousands of degrees**

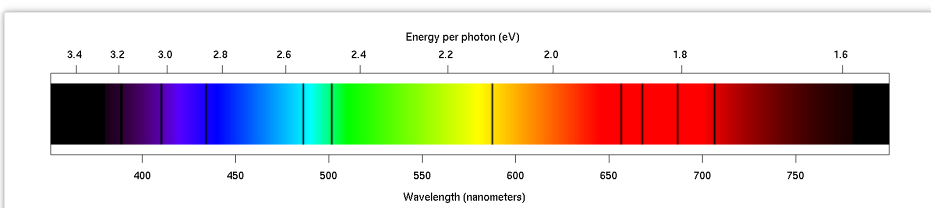
(D) A hot object heated to thousands of degrees, seen through the atmosphere of a planet or star

(E) None of the above

This is a continuous spectrum without features: a thermal radiation spectrum. It contains a lot of visible light, so it is thousands of degrees.

(Question what-source-3)

22. What sort of object would produce a spectrum that looks like this?



(A) A hot object heated to thousands of degrees

(B) A diffuse gas in an electrified tube, such as the ones you used in lab

(C) **A hot object heated to thousands of degrees, seen through the atmosphere of a planet or star**

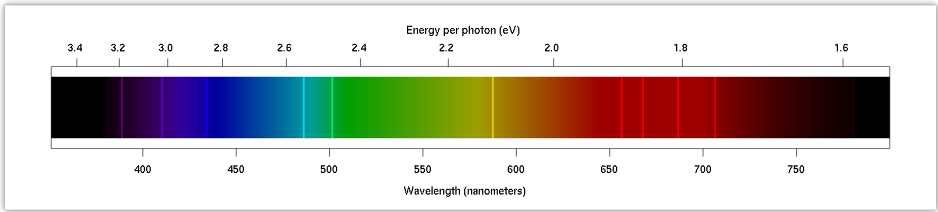
(D) Reflected light from the wall of a room that was lit by a mixture of incandescent and fluorescent lamps

(E) None of the above

This is an absorption spectrum: a continuous spectrum from a hot object with some dark lines that correspond to wavelengths absorbed by gas in the way, as from the atmosphere of a star.

(Question what-source-4)

23. What sort of object would produce a spectrum that looks like this?



(A) A hot object heated to thousands of degrees

(B) **Reflected light from the wall of a room that was lit by a mixture of incandescent and fluorescent lamps**

(C) A diffuse gas in an electrified tube, such as the ones you used in lab

(D) A hot object heated to thousands of degrees, seen through the atmosphere of a planet or star

(E) None of the above

This shows a continuous spectrum plus an emission spectrum. You'd see this if you saw light from a mix of fluorescent light bulbs (thin bright lines) and incandescent light bulbs (continuous spectrum)

(Question MeV)

24. Atomic nuclei have energy levels just like electrons do.
In particular, the isotope technetium-99 has its the following as its first two energy levels:

- $n = 1$: 0 eV
- $n = 2$: 140,000 eV

If nuclear physicists want to study the light associated with this transition, they need to look for...

(A) Infrared

(B) **Gamma rays**

(C) Radio waves

(D) Visible light

(E) Ultraviolet light

Gamma rays have the highest energy per photon of any type of light. Ultraviolet light is only a little higher energy/shorter wavelength than visible, but gamma rays are hundreds of thousands of times higher – what we're looking for here.

`(Question red-star)`

25. How could you determine the temperature of the Moon by measuring the spectrum of moonlight? Imagine that you are using the Hubble Space Telescope, so there is no interference from Earth's atmosphere. *(Inspired by a question suggested by Mingkun; thanks!)*

    Hint: the temperature of the part of the Moon facing Earth is a few hundred Kelvin.

    (A) By examining the thin bright lines that occur in its spectrum

    (B) By examining the thin dark lines that occur in its spectrum

    (C) **By examining much longer wavelengths that it emits, around ten times the wavelength of visible light. (This could be done regardless of the Moon's phase.)**

    (D) By waiting for a full moon, and examining the wavelengths of visible light that constitute moonlight

    (E) There's no way to measure the temperature of the Moon since it doesn't produce its own light, only reflects the Sun's light

    The visible part of moonlight is reflected light from the Sun. That will tell us the temperature of the Sun, not the Moon. To get the temperature of the Moon, we need to see its own thermal radiation. Since the Moon is a few hundred Kelvin, we will need to look at the infrared light it produces. You could do this during a new moon, since you specifically don't care about the light that's reflected from the Sun.

`(Question blacklight)`

26. Suppose that a particular element has its first four energy levels of 0 eV, 3 eV, 5.2 eV, and 7 eV. You have a sample of this element at room temperature, so almost all of its atoms are initially in their ground state.

    If you illuminate it with ultraviolet light whose photons have 5.2 eV of energy while looking at it with a handheld spectroscope, what will you see? *(Reference the mapping of photon energy to color included with your exam.)*

    (A) **One bright blue/violet line and one bright yellow/green line**

    (B) Nothing, because you can't see ultraviolet light of that energy

    (C) One bright blue/violet line

    (D) One bright blue/violet line, one bright yellow/green line, and one bright red line

    (E) A continuous band of color, like a rainbow

    The atoms will absorb the 5.2 eV photons and transition to the third energy level. In transitioning back to the ground state, they will make two jumps of 2.2 eV (yellow-green) and 3 eV (blue/violet).

`(Question element-2)`

27. You take this same element with energy levels of 0 eV, 3 eV, 5.2 eV, and 7 eV, vaporize it and make a diffuse gas, and put it in an electrified emission tube that tears the electrons completely away from the nucleus.

    As they transition back down to the ground state, they will emit light. If you examine this light using a computer spectrometer that can see wavelengths of light outside the visible range, what will you see? *(The visible range is from 1.6-3.2 eV.)*

    (A) A continuous band of wavelengths extending from the ultraviolet to the visible range

    (B) Three lines in the visible range

    (C) Three lines in the ultraviolet, one line in the visible range, and two lines in the infrared

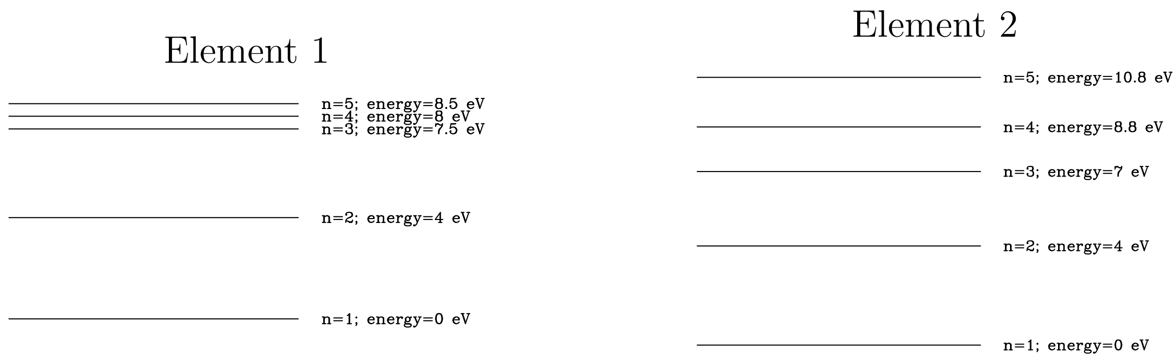
    (D) One line in the visible range and two lines in the ultraviolet

    (E) **Three lines in the ultraviolet and three lines in the visible range**

    Here you will see all possible transitions, corresponding to all differences between energy levels. Three of them have energies greater than 3.2 eV and are thus in the ultraviolet; three of them have energies between 1.6 and 3.2 eV and are visible.

(Question light-bulb-suitability)

28. You are put in charge of designing a new sort of fluorescent light bulb, and have to choose what sort of gas to put inside. A chemist presents you with two options.



Are either of these gases suitable for use by humans? *(The visible range is 1.6 eV - 3.2 eV.)*

(A) **Element 2 is suitable, but Element 1 is not**

(B) Both elements are suitable to use in a fluorescent light bulb

(C) Neither element is suitable to use in a fluorescent light bulb

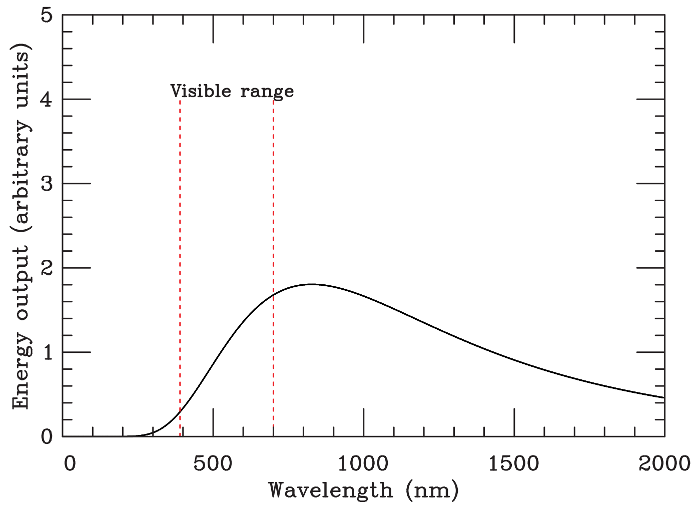
(D) Element 1 is suitable, but Element 2 is not

(E) Either element could be suitable, depending on the temperature that they are heated to

Element 1 has no transitions in the visible range, but Element 2 does. Thus, Element 2 is suitable for making a fluorescent lightbulb that produces light that humans can see.

(Question chunk)

29. Consider the spectral curve below, showing the light given off by a chunk of carbon heated to 3500 K.



What type of light does this object primarily emit?

(A) Ultraviolet light
(B) **Infrared light**
(C) X-rays
(D) Visible light
(E) Gamma rays

Looking at the area under the curve, it is primarily in the infrared, longer wavelengths than visible light. (The peak emission is also in the infrared.)

Scratch Paper

Scratch Paper

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