Spring 2020 **PHYSICS 116 PRACTICE FINAL EXAM** Seat No.____

SOLUTION

Last Name (Print): ______________________ First Name (Print): _____________________

Honor Pledge: *All work presented here is my own.*

Signature: ______________________________ Student ID: _________________________

READ THIS ENTIRE PAGE NOW

Do <u>not</u> open the exam until told to do so.

You will have <u>120 minutes</u> to complete the examination.

<u>NO</u> CELL PHONES, TEXT MSG, etc. ALLOWED AT ANY TIME.

Before the exam begins:

- Print and sign your name, and write your student ID number in the spaces above.

During the exam

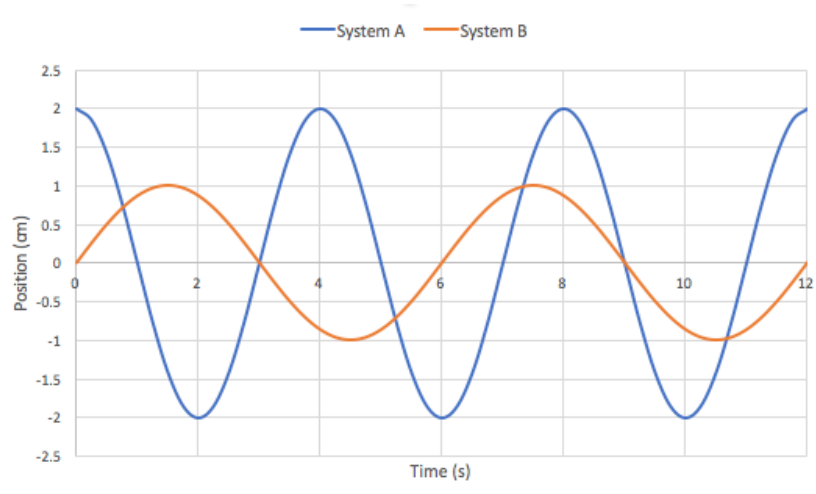
- When the exam begins, print your name and student ID number on the top of each page. Do this first when you are told to open your exam.
- If you are confused about a question, raise your hand and ask for an explanation.
- If you cannot do one part of a problem, move on to the next part.
- This is a closed book examination. All equations and constants are provided.
- You may use a calculator, but not a computer, or other internet connected devices (smart-phones, iPads, etc.).
- Clearly circle your answer choice. Make no stray marks. If you must erase, erase completely.

End of exam:

- Out of respect to other students, please remain seated for the last 10 minutes of the exam. At the end of the exam, please remain seated until all exams have been collected.

Name ____ Student ID: ________________ Score: ________
Last First

1. [7 pts] The two curves in the figure at right are for two horizontal mass-spring systems. If both systems have the same mass, what is the ratio k_A/k_B of their spring constants?



A) 1.20

B) 1.50

C) 2.00

D) 2.25

E) 3.00

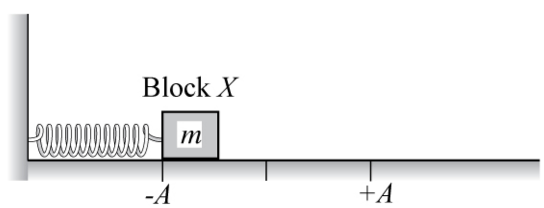
$$T_A = 2\pi\sqrt{\frac{m}{k_A}}$$

$$k_A = 4\pi^2\frac{m}{T_A^2}$$

$$k_B = 4\pi^2\frac{m}{T_B^2}$$

$$\frac{k_A}{k_B} = \frac{4\pi^2 m}{T_A^2}\frac{T_B^2}{4\pi^2 m} = \frac{T_B^2}{T_A^2} = \frac{(6\text{ s})^2}{(4\text{ s})^2} = 2.25$$

2. [6 pts] Block X of mass m is attached to an ideal-horizontal spring. The system oscillates on a frictionless surface with an amplitude A. Block Y of mass $2m$ is attached to an identical ideal-horizontal spring. It is known that the maximum kinetic energy of block X is equal to that for block Y.
Is the amplitude of block Y's motion *greater than*, *less than*, or *equal to* A (the amplitude of block X)?



A) Greater than

B) Less than

C) Equal to

D) Not enough information to answer.

The maximum kinetic energy of a block-mass system is equal to the maximum potential energy. The maximum potential energy is a function of the spring constant and the amplitude, $U_{max} = \frac{1}{2}kA^2$.

Since both blocks are attached to the same spring (same spring constant) and have the same maximum kinetic energy, both block's must also have the same amplitude of motion.

Name ______________________________ Student ID: ______________ Score: _______
Last First

3. [6 pts] An object in simple harmonic motion has amplitude 4.0 cm and frequency 6.0 Hz, and at $t = 0$ s it is at a position of $x = 4.0$ cm. At what time will the object be at x = 1.80 cm?

   A) 0.029 s

   B) 0.042 s

   C) 0.061 s

   D) 0.092 s

   E) 0.15 s

$$x(t) = Acos(2\pi ft)$$

$$2\pi ft = cos^{-1}\left(\frac{x(t)}{A}\right)$$

$$t = \frac{cos^{-1}\left(\frac{x(t)}{A}\right)}{2\pi f} = \frac{cos^{-1}\left(\frac{1.80 \text{ cm}}{4.0 \text{ cm}}\right)}{2\pi(6.0 \text{ Hz})} = 0.029 \text{ Hz}$$

4. [6 pts] The amplitude of an oscillator decreases to 46.8% of its initial value in 10.0 s. What is the value of the damping time constant, τ? $A = A_0 e^{-t/\tau}$

   A) 9.41 s

   B) 10.1 s

   C) 11.8 s

   D) 12.6 s

   E) 13.2 s

$$A = A_0 e^{-t/\tau}$$

$$e^{-t/\tau} = \frac{A}{A_0}$$

$$ln\left(e^{-t/\tau}\right) = ln\left(\frac{A}{A_0}\right)$$

$$\frac{-t}{\tau} ln(e) = ln\left(\frac{A}{A_0}\right)$$

$$\frac{-t}{\tau} = ln\left(\frac{A}{A_0}\right)$$

$$\tau = \frac{-t}{ln\left(\frac{A}{A_0}\right)} = \frac{-10.0 \text{ s}}{ln(0.468)} = 13.2 \text{ s}$$

5. [6 pts] The wave speed on a string is 150 m/s when the tension is 75.0 N. What tension will give a speed of 180 m/s?

A) 95.1 N

B) 82.2 N

C) 90.0 N

D) 108 N

E) 87.3 N

$$v = \sqrt{\frac{T}{\mu}} \qquad \mu = \frac{T}{v^2} \qquad \mu_{150} = \mu_{180} \qquad \frac{T_{150}}{v_{150}^2} = \frac{T_{180}}{v_{180}^2} \qquad T_{180} = \frac{T_{150} v_{180}^2}{v_{150}^2}$$

$$T_{180} = \frac{T_{150} v_{180}^2}{v_{150}^2} = \frac{(75.0\text{ N})(180\text{ m/s})^2}{(150\text{ m/s})^2} = 108\text{ N}$$

6. [7 pts] A whistle you use to call your hunting dog has a frequency of 20.5 kHz, but your dog is ignoring it. You suspect the whistle may not be working, but you can't hear sounds above 20 kHz. To test it, you ask a friend to blow the whistle, then you hop on your bicycle. In which direction should you ride (toward or away from your friend) and at what minimum speed to know if the whistle is working? $v_{sound-air} = 343\text{ m/s}$

A) 9.41 m/s toward your friend

B) 10.1 m/s toward your friend

C) 7.34 m/s away from your friend

D) 8.36 m/s away from your friend

E) 9.21 m/s away from your friend

You want to hear a lower frequency so you should cycle away from your friend. For a moving object, we find the perceived frequency as follows:

$$f' = \left(1 - \frac{v_{bike}}{v}\right) f$$

$$\frac{f'}{f} = 1 - \frac{v_{bike}}{v}$$

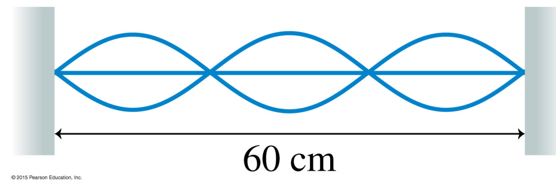
$$\frac{v_{bike}}{v} = 1 - \frac{f'}{f}$$

$$v_{bike} = \left(1 - \frac{f'}{f}\right) v = \left(1 - \frac{20 \times 10^3\text{ Hz}}{20.5 \times 10^4\text{ Hz}}\right) 343\text{ m/s} = 8.36\text{ m/s} = 19\text{ mph}$$

Name ______________________________ Student ID: ____________ Score: ______

Last   First

7. [6 pts] The figure at right shows a standing wave oscillating at 100 Hz on a string. What is the wave speed?



A) 60 m/s

B) 120 m/s

C) 20 m/s

D) 40 m/s

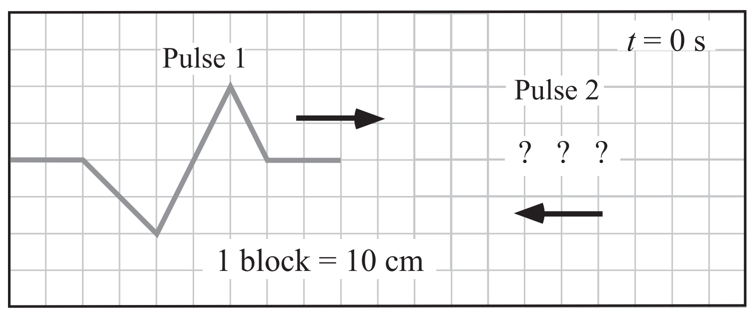
E) 100 m/s

There are three nodes so the value of n is 3.

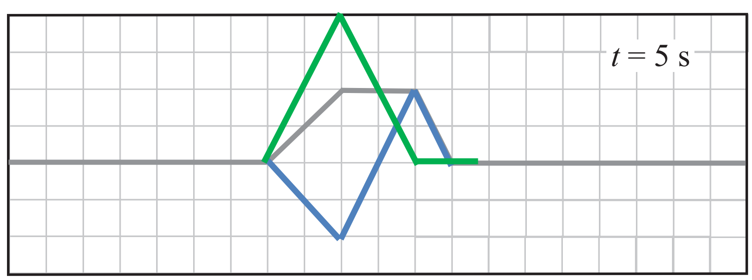
$$f_m = m\frac{v}{2L}$$

$$v = \frac{f_m 2L}{m} = \frac{(100\text{ Hz})2(0.60\text{ m})}{3} = 40\text{ m/s}$$

8. [6 pts] Two pulses move towards each other with speed 10 cm/s. Each block is 10 cm wide. The top figure at right shows the shape and location of pulse 1 at time $t = 0$. Pulse 2 is not shown.



The shape of the entire spring at $t = 5$ s is shown in the bottom figure at right.



Which of the following choices describe the leading edge to trailing edge distance and the amplitude of pulse 2?

A) 20 cm, 60 cm

B) 30 cm, 50 cm

C) 40 cm, 40 cm

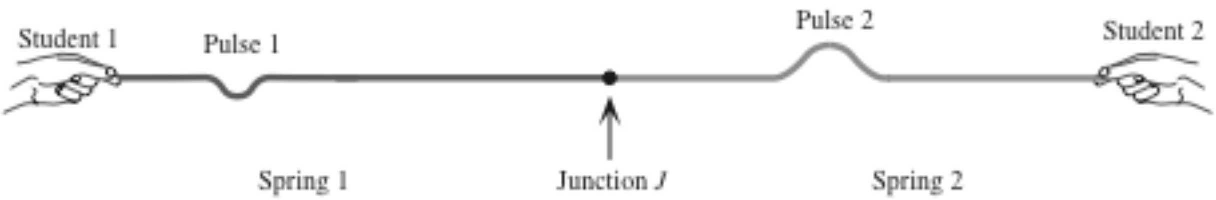
D) 20 cm, 40 cm

E) 50 cm, 70 cm

The blue pulse is pulse 1 at t = 5 and the green pulse is pulse 2 at t = 5.

Name ______________________________ Student ID: ____________ Score: _______
Last First

9. [6 pts] The top-view diagram below shows two different springs connected at junction *J*. Student 1 holds the left end of spring 1, and student 2 holds the right end of spring 2. Student 1 and student 2 each begin to generate a single pulse at exactly the same time by moving the end of the springs back and forth. The shapes of the two springs are shown a short time later, ***before any reflections have occurred***. It is noted that pulse 2 propagates twice as fast as pulse 1, and the width of pulse 2 is twice as large as pulse 1.



Is μ_1, the linear mass density of spring 1 *greater than, less than,* or *equal to* μ_2, the linear mass density of spring 2? Explain. If there is not enough information provided to determine the relative linear mass densities, state the additional information needed to answer.

A) Greater than

B) Less than

C) Equal to

D) Not enough information.

We are told that the pulses are created at the same time. This means that the leading edges of each pulse are created at the same time. We can see from the diagram, that the leading edge of pulse 1 has not traveled as far as the leading edge of pulse 2 in the same time interval. The tension in both springs is the same so the speed of each pulse is inversely proportional to the square root of the linear mass density. Since pulse 1 moves at a slower speed, the linear mass density of spring 1 must be greater than that of spring 2.

10. [6 pts] Two slits with a separation of 8.5×10^{-5} m create an interference pattern on a screen 2.3 m away. If the tenth bright fringe from the central fringe is a linear distance of 12 cm from the central fringe, what is the wavelength of light used in the experiment?

A. 420 nm	B. 440 nm	C. 490 nm	D. 570 nm	E. 660 nm

$$y_m = L\tan\theta_m$$

$$\theta_m = \tan^{-1}\left(\frac{y_m}{L}\right)$$

$$\theta_{10} = \tan^{-1}\left(\frac{0.12\text{ m}}{2.3\text{ m}}\right) = 0.0521\text{ rad} = 2.99°$$

$$d\sin\theta_m = m\lambda$$

$$\lambda = \frac{d\sin\theta_m}{m} = \frac{(8.5 \times 10^{-5}\text{ m})\sin(2.99°)}{10} = 4.42 \times 10^{-7}\text{ m} = 442\text{ nm}$$

Name ______________________________ Student ID: ______________ Score: _______
Last First

11. [6 pts] A lab technician uses laser light with a wavelength of 670 nm to test a diffraction grating. When the grating is 40.0 cm from the screen, the first order maxima appear 6.00 cm from the center of the pattern. How many lines per millimeter does this grating have?

A) 155

B) 179

C) 200

D) 221

E) 249

$$y_m = Ltan\theta_m$$

$$\theta_m = tan^{-1}\left(\frac{y_m}{L}\right)$$

$$\theta_1 = tan^{-1}\left(\frac{0.06\text{ m}}{0.40\text{ m}}\right) = 0.149\text{ rad} = 8.53°$$

$$dsin\theta_m = m\lambda$$

$$d = \frac{m\lambda}{sin\theta_m} = \frac{(670 \times 10^{-9}\text{ m})}{sin(8.53°)} = 4.52 \times 10^{-6}\text{ m}$$

$$N = \frac{0.001\text{ m}}{d} = \frac{0.001\text{ m}}{4.52 \times 10^{-6}\text{ m}} = 221$$

12. [7 pts] A laboratory dish, 20.0 cm in diameter, is half filled with water (n = 1.33). An oil drop (n = 1.45) of volume V is dropped from a pipette onto the surface of the water, forming a thin film of oil on the top surface of the water. When white light is incident on the thin film, it is known that the reflection of 600 nm light is suppressed. What is the minimum volume of the oil drop?

A) 5.51 x 10^{-9} m^3

B) 6.50 x 10^{-9} m^3

C) 6.92 x 10^{-9} m^3

D) 7.42 x 10^{-9} m^3

E) 8.14 x 10^{-9} m^3

Wave 1 will undergo a $\lambda/2$ phase shift but wave 2 will not. Thus the condition for destructive interference is: $2nt = m\lambda$

$$t = \frac{m\lambda}{2n} = \frac{(1)(600 \times 10^{-9}\text{ m})}{2(1.45)} = 2.07 \times 10^{-7}\text{ m}$$

$$V = \pi r^2 t = \pi(0.1\text{ m})^2(2.07 \times 10^{-7}\text{ m}) = 6.5 \times 10^{-9}\text{ m}^3$$

Name ______________________________ Student ID: ____________ Score: ______
Last First

13. [6 pts] You need to use a 24-cm-focal-length lens to produce an inverted image twice the height of an object. At what distance from the object should the lens be placed?

A) 0.55 m	B) 0.36 m	C) 0.85 m	D) 0.63 m	E) 0.72 m

Inverted images produced by convex lenses (positive focal lengths) are real images.

$$m = -\frac{s'}{s} = -2$$

$$-s' = -2s \qquad s' = 2s$$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} \qquad \frac{1}{f} = \frac{1}{s} + \frac{1}{2s}$$

$$\frac{1}{f} = \frac{2}{2s} + \frac{1}{2s} = \frac{3}{2s}$$

$$s = \frac{3}{2}f = \frac{3}{2}(24\text{ cm}) = 36\text{ cm} = 0.36\text{ m}$$

14. [6 pts] A 10-cm candle is 60 cm from a concave mirror with a focal length of 20 cm. Determine the size and orientation of the image?

A) 2.5 cm and upright

B) 2.5 cm and inverted

C) 5.0 cm and upright

D) 5.0 cm and inverted

E) 7.5 cm and inverted

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

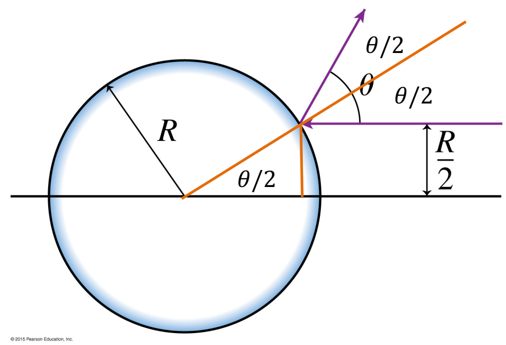
$$s' = \left(\frac{1}{f} - \frac{1}{s}\right)^{-1} = \left(\frac{1}{20\text{ cm}} - \frac{1}{60\text{ cm}}\right)^{-1} = 30\text{ cm}$$

$$m = -\frac{s'}{s} = -\frac{30\text{ cm}}{60\text{ cm}} = -0.5$$

$$m = \frac{h'}{h} = -0.5 \qquad h' = h(-0.5) = 10\text{ cm}(-0.5) = -5\text{ cm}$$

Name ______________________________ Student ID: ____________ Score: _______
Last First

15. [7 pts] The figure at right shows a light ray incident on a polished metal cylinder. At what angle θ will the ray be reflected?



A) 25.0°

B) 40.0°

C) 50.0°

D) 60.0°

E) 70.0°

$$sin\left(\frac{\theta}{2}\right) = \frac{R/2}{R} = \frac{1}{2}$$

$$\frac{\theta}{2} = sin^{-1}\left(\frac{1}{2}\right) = 30°$$

$$\theta = 2(30°) = 60°$$

16. [6 pts] Sanjay has hyperopia/farsightedness. The near point of his left eye has increased to 150 cm from his eye. What prescription lens will restore his near point to 25 cm from his eye?

A) 3.7 diopters

B) 3.5 diopters

C) 3.3 diopters

D) 3.1 diopters

E) 2.9 diopters

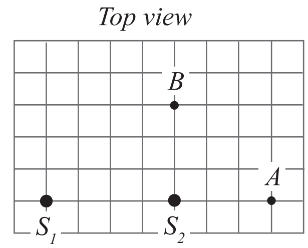
$$P_{naked\ eye} = \frac{1}{1.50\text{ m}} + \frac{1}{s'} = 0.67\text{ D} + \frac{1}{s'}$$

$$P_{ideal} = \frac{1}{0.25\text{ m}} + \frac{1}{s'} = 4\text{ D} + \frac{1}{s'}$$

To achieve the ideal power, Sanjay needs to wear glasses with a power of 3.3 diopters (4 D – 0.67 D).

Name ____________________________________ Student ID: _______________ Score: _______
Last First

Two point sources, S_1 and S_2 are shown in the top-view diagram at right. The sources are in phase and produce periodic circular waves of wavelength λ. The grid spacing in the diagram is 1 meter. (*Note:* Ignore the change in amplitude of the waves from the point sources as the distance from the point source changes.)



Grid spacing = 1m

17. [6 pts] For which of the following wavelengths would point *A* be a point of *maximum constructive interference?*

A) $\lambda = 2$ m

B) $\lambda = 3$ m

C) $\lambda = 5$ m

D) All of the above

E) None of the above

We can determine the path length difference to point A as follows:

$$\Delta r_A = r_{s_1 \to A} - r_{s_2 \to A} = 7\text{ m} - 3\text{ m} = 4\text{ m}$$

Destructive interference occurs when:

$$\Delta r = m\lambda$$

The path length difference of 4 m is equal to 2λ *when* $\lambda = 2\ m$*, so this suits the above condition. The path length difference of 4 m is equal to* 1.33λ *when* $\lambda = 3\ m$*, so this cannot be correct. The path length difference of 4 m is equal to* 0.8λ *when* $\lambda = 5\ m$*, so this also cannot be correct.*

18. [6 pts] For which of the following wavelengths would point *B* be a point of *complete destructive interference?*

A) $\lambda = 4$ m

B) $\lambda = 4.5$ m

C) $\lambda = 5$ m

D) All of the above

E) None of the above

We can determine the path length difference to point B as follows:

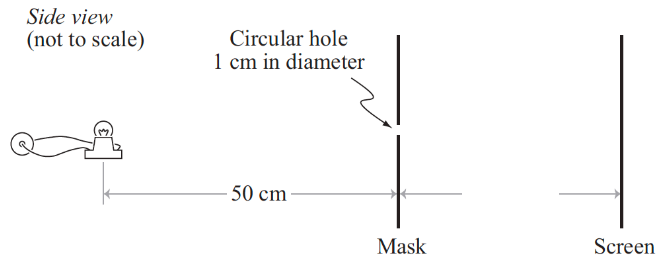
$$\Delta r_A = r_{s_1 \to B} - r_{s_2 \to B} = 5\text{ m} - 3\text{ m} = 2\text{ m}$$

Destructive interference occurs when:

$$\Delta r = \left(m + \frac{1}{2}\right)\lambda$$

The path length difference of 2 m is equal to $\lambda/2$ *when* $\lambda = 4$ m*, so this suits the above condition. The path length difference of 2 m is equal to* 0.44λ *when* $\lambda = 4.5$ m*, so this cannot be correct. The path length difference of 2 m is equal to* 0.4λ *when* $\lambda = 5$ m*, so this also cannot be correct.*

19. [6 pts] A small bulb light bulb is placed 50 cm in front of mask with a circular aperture with a diameter of 1.0 cm. The bulb is horizontally aligned with the center of the hole, and can be treated as a point source of light. If the height of the image on the screen is 2.20 cm, what is the distance between the mask and the screen? *Figure not drawn to scale.*



A) 30 cm	B) 40 cm	C) 50 cm	D) 60 cm	E) 70 cm

We can use similar triangles to solve for the height of the aperture. (B = bulb, M = mask, S = screen).

$$\frac{d_{mask}}{L_{B\ to\ M}} = \frac{h_{image}}{L_{B\ to\ M} + L_{M\ to\ S}}$$

$$L_{B\ to\ M} + L_{M\ to\ S} = \frac{(h_{image})(L_{B\ to\ M})}{d_{mask}}$$

$$L_{M\ to\ S} = \frac{(h_{image})(L_{B\ to\ M})}{d_{mask}} - L_{B\ to\ M} = L_{B\ to\ M}\left(\frac{(h_{image})}{d_{mask}} - 1\right)$$

$$L_{screen} = (50\text{ cm})\left(\frac{2.20\text{ cm}}{1\text{ cm}} - 1\right) = 60\text{ cm}$$

20. [6 pts] Light of frequency 9.95×10^{14} Hz ejects electrons from the surface of silver. If the maximum kinetic energy of the ejected electrons is 0.180×10^{-19} J, what is the work function of silver?

A) 1.85 eV

B) 2.49 eV

C) 3.15 eV

D) 4.01 eV

E) 4.87 eV

$$K_{max} = E_{elec} - E_0$$

$$E_0 = E_{elec} - K_{max} = E_{photon} - K_{max} = hf - K_{max}$$

$$E_0 = (4.14 \times 10^{-15}\text{ eV.s})(9.95 \times 10^{14}\text{ Hz}) - \frac{(0.180 \times 10^{-19}\text{ J})}{\left(1.6 \times 10^{-19}\frac{\text{J}}{\text{eV}}\right)} = 4.01\text{ eV}$$

21. [7 pts] In a photoelectric-effect experiment, electrons are emitted from a metal surface with a maximum kinetic energy of 2.8 eV. When the wavelength of the light is increased by 50%, the maximum kinetic energy decreases to 1.1 eV. What is the work function of the metal surface?

A) 1.2 eV	B) 1.7 eV	C) 2.3 eV	D) 2.6 eV	E) 3.1 eV

$$K_{max,1} = E_{elec} - E_0 = E_{photon,1} - E_0 = \frac{hc}{\lambda_1} - E_0 = 2.8 \text{ eV}$$

$$K_{max,2} = E_{elec} - E_0 = E_{photon,2} - E_0 = \frac{hc}{1.5\lambda_1} - E_0 = 1.1 \text{ eV}$$

$$E_0 = \frac{hc}{\lambda_1} - 2.8 \text{ eV}$$

$$\frac{hc}{1.5\lambda_1} - E_0 = 1.1 \text{ eV} \qquad \frac{hc}{1.5\lambda_1} - \frac{hc}{\lambda_1} + 2.8 \text{ eV} = 1.1 \text{ eV}$$

$$\frac{hc}{\lambda_1}\left(\frac{1}{1.5} - \frac{1}{1}\right) = -1.7 \text{ eV}$$

$$\lambda_1 = \frac{hc(-1/3)}{-1.7 \text{ eV}} = \frac{1242 \text{ eV.nm}(-1/3)}{-1.7 \text{ eV}} = 243.5 \text{ nm}$$

$$E_0 = \frac{hc}{\lambda_1} - 2.8 \text{ eV} = \frac{1242 \text{ eV.nm}}{243.5 \text{ nm}} - 2.8 \text{ eV} = 2.3 \text{ eV}$$

22. [6 pts] Through what potential difference must an electron be accelerated from rest to have a de Broglie wavelength of 500 nm? $m_{electron} = 9.11 \times 10^{-31}$ kg

A) 6.0 μV	B) 50.0 μV	C) 2.5 mV	D) 15.0 mV	E) 1.2 V

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34} \text{ J.s}}{(9.11 \times 10^{-31} \text{ kg})(500 \times 10^{-9} \text{ m})} = 1455 \text{ m/s}$$

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(9.11 \times 10^{-31} \text{ kg})(1455 \text{ m/s})^2 = 9.64 \times 10^{-25} \text{ J} = 6.02 \times 10^{-6} \text{ eV}$$

$$\Delta V q = -\Delta K$$

$$\Delta V = \frac{-\Delta K}{q} = \frac{-\Delta K}{-e} = \frac{\Delta K}{e} = \frac{9.64 \times 10^{-25} \text{ J}}{1.6 \times 10^{-19} \text{ C}} = 6.02 \times 10^{-6} \text{ V}$$

Name ________________________________ Student ID: _____________ Score: _______
Last First

23. [6 pts] A 2.55 eV photon is emitted from a hydrogen atom. What are the Balmer formula *n* and *m* values corresponding to this emission?

A) $m = 1, n = 5$

B) $m = 1, n = 3$

C) $m = 2, n = 3$

D) $m = 2, n = 4$

E) $m = 2, n = 5$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{1242\ \text{eV.nm}}{2.55\ \text{eV}} = 487\ \text{nm}$$

Since the wavelength is in the visible region we can rule out choices with m = 1. Transitions to the ground state result in ultraviolet photons.

$$\lambda = \frac{91.1\ \text{nm}}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)}$$

$$\left(\frac{1}{m^2} - \frac{1}{n^2}\right) = \frac{91.1\ \text{nm}}{\lambda} = \frac{91.1\ \text{nm}}{487\ \text{nm}} = 0.187$$

$$\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 0.139$$

$$\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 0.187$$

$$\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 0.21$$

Name ______________________________ Student ID: _____________ Score: _______
Last First

24. [6 pts] Consider the following three transitions in a hydrogen atom: (A) $n_i = 5$, $n_f = 2$; (B) $n_i = 7$, $n_f = 2$; (C) $n_i = 7$, $n_f = 6$. Each transition results in the emission of a photon. Rank the transitions in order of decreasing wavelength of the emitted photon.

A) C > A > B

B) B > C > A

C) B > A > C

D) C > B > A

E) A > B > C

$$\lambda = \frac{91.1 \text{ nm}}{\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)}$$

$$\lambda_A = \frac{91.1 \text{ nm}}{\left(\frac{1}{2^2} - \frac{1}{5^2}\right)} = 434 \text{ nm}$$

$$\lambda_B = \frac{91.1 \text{ nm}}{\left(\frac{1}{2^2} - \frac{1}{7^2}\right)} = 397 \text{ nm}$$

$$\lambda_A = \frac{91.1 \text{ nm}}{\left(\frac{1}{6^2} - \frac{1}{7^2}\right)} = 12360 \text{ nm}$$

25. [6 pts] Apply the Bohr model to a triply ionized beryllium atom ($B^{3+}, Z = 4$). Find the ionization energy required to remove the final electron in B^{3+}.

A) 110 eV	B) 140 eV	C) 165 eV	D) 189 eV	E) 218 eV

$$E_n = (-13.6 \text{ eV})\frac{Z^2}{n^2}$$

$$E_1 = (-13.6 \text{ eV})\frac{4^2}{1^2} = 218 \text{ eV}$$

Name ____________________________________ Student ID: _______________ Score: _______
Last First

26. [7 pts] An ionized atom has only a single electron. The $n = 6$ Bohr orbit of this electron has a radius 2.721×10^{-10} m. Find the total energy E of its $n = 3$ Bohr orbit.

A) -58.3 eV	B) -61.3 eV	C) -74.0 eV	D) -81.4 eV	E) -88.4 eV

$$r_n = \frac{a_B}{Z} = 0.0529\ \text{nm}\frac{n^2}{Z}$$

$$Z = 0.0529\ \text{nm}\frac{n^2}{r_n}$$

$$Z = 0.0529\ \text{nm}\frac{6^2}{2.721\ \times\ 10^{-10}\ \text{m}} = 7$$

$$E_n = (-13.6\ \text{eV})\frac{Z^2}{n^2}$$

$$E_8 = (-13.6\ \text{eV})\frac{7^2}{3^2} = -74\ \text{eV}$$

27. [6 pts] Identify the daughter nucleus when $^{212}_{83}\text{Bi}$ undergoes alpha decay.

A) $^{208}_{83}\text{Bi}$

B) $^{216}_{87}\text{Fr}$

C) $^{208}_{81}\text{Tl}$

D) $^{216}_{83}\text{Bi}$

E) $^{208}_{81}\text{Bi}$

$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + \alpha + energy$$

$$^{212}_{83}\text{Bi} \rightarrow {}^{208}_{81}\text{Tl} + \alpha + energy$$

28. [6 pts] The number of radioactive nuclei in a particular sample decreases over a period of 18 days to one-sixteenth the original number. What is the half-life of these nuclei?

A) 0.50 days	B) 1.5 days	C) 2.5 days	D) 3.5 days	E) 4.5 days

$$N = N_0 e^{-t/\tau} = N_0 e^{-t\ln 2/t_{1/2}}$$

$$\frac{N}{N_0} = e^{-t\ln 2/t_{1/2}}$$

$$\ln\left(\frac{N}{N_0}\right) = \frac{-t\ln 2}{t_{1/2}}$$

$$t_{1/2} = \frac{-t\ln 2}{\ln\left(\frac{N}{N_0}\right)} = \frac{-(18\text{ days})\ln 2}{\ln\left(\frac{1}{16}\right)} = 4.5\ days$$

29. [6 pts] A drug prepared for a patient is tagged with ${}^{99}_{43}Tc$, which has a half-life of 6.05 hours. How many ${}^{99}_{43}Tc$ are required to give an activity of 1.50 μCi?

A) 1.7 x 10^9	B) 1.1 x 10^7	C) 2.1 x 10^{12}	D) 2.8x10^9	E) 3.2x10^8

$$1\text{ Ci} = 3.7 \times 10^{10}\text{ Bq} = 3.7 \times 10^{10}\text{ decays/s}$$

$$1.50\ \mu\text{Ci} = (1.5 \times 10^{-6})3.7 \times 10^{10}\text{ Bq} = 5.55 \times 10^4\text{ Bq}$$

$$R = \frac{N}{\tau} = \frac{0.693N}{t_{1/2}}$$

$$N = \frac{Rt_{1/2}}{0.693} = \frac{(5.55 \times 10^4\text{ Bq})(6.05\text{ hr})(3600\text{ s/hr})}{0.693} = 1.74 \times 10^9$$

Name ____ Student ID: ________________ Score: ________
Last First

30. [6 pts] Calculate the average binding energy per nucleon of ${}^{64}_{30}Zn$. (Mass of ${}^{64}_{30}Zn$ = 63.929145)
m_{Hydrogen} =1.007825 u m_{neutron} =1.008665 u

A) 0.600 MeV	B) 8.74 MeV	C) 12.1 MeV	D) 559 MeV	E) 653 MeV

$$A = N + Z$$

$$N = A - Z = 64 - 30 = 34$$

$$B = \left(Z_{m_H} + N_{m_n} - m_{atom}\right) \times (931.49\ \text{MeV/u})$$

$$B = \left((30)(1.007825\ \text{u}) + (34)(1.008665\ \text{u}) - 63.929145\ \text{u}\right) \times (931.49\ \text{MeV/u})$$

$$B = 559\ \text{MeV}$$

$$\frac{B}{A} = \frac{559\ \text{MeV}}{64\ \text{nucleons}} = 8.74\ \text{MeV/nucleon}$$

31. [6 pts] A patient undergoes radiation therapy for cancer receives a 225-rad dose of radiation. Assuming the cancerous growth has a mass of 0.17 kg, calculate how much energy it absorbs?

A) 0.15 J	B) 0.24 J	C) 0.38 J	D) 0.49 J	E) 0.55 J

$$1\ \text{rad} = 0.01\ \text{Gy} = 0.01\ \text{J/kg}$$

$$225\ \text{rad} = (225)0.01\ \text{Gy} = 2.25\ \text{J/kg}$$

$$Radiation\ dose = \frac{Energy}{mass}$$

$$Energy = (mass)(radiation\ dose) = (0.17\ \text{kg})(2.25\ \text{J/kg}) = 0.38\ \text{J}$$

Name ______________________________________ Student ID: ________________ Score: ________
Last First

32. [7 pts] As part of a treatment program, a patient ingests a radioactive pharmaceutical containing ${}^{32}_{15}P$, which emits β particles with an RBE of 1. The half-life of ${}^{32}_{15}P$ is 14.28 days, and the initial activity of the medication is 1.34 MBq. If each beta particle has an energy of 705 keV, what is the dose equivalent, assuming the radiation is absorbed by 125 g of tissue over a period of 7 days?

A) 15 rem	B) 33 rem	C) 47 rem	D) 62 rem	E) 85 rem

$\text{dose equivalent in Sv} = \text{dose in Gy} \times \text{RBE}$

$1 \text{ rem} = 0.01 \text{ SV}$

To determine the dose equivalent, we first need to find the dose in Gray. And in order to find the dose in Gray, we need to find the number of β particles absorbed over the 7days. The initial number of radioactive particles can be found as follows:

$$R = \frac{N}{\tau} = \frac{0.693N}{t_{1/2}}$$

$$N = R\tau = \frac{Rt_{1/2}}{0.693} = \frac{(1.34 \times 10^6 \text{ Bq})(14.28 \text{ days})(86400 \text{ s/day})}{0.693} = 2.39 \times 10^{12} \text{ particles}$$

The number of particles that remain after seven days is determined as follows:

$$N = N_0 e^{-t/\tau}$$

$$N = (2.39 \times 10^{12})e^{-7 \text{ days}/14.28\, days/ln2} = 1.70 \times 10^{12} \text{ particles}$$

The number of particles that have decayed is determined as follows:

$$N_{decay} = 2.39 \times 10^{12} \text{ particles} - 1.70 \times 10^{12} \text{ particles} = 6.87 \times 10^{11} \text{ particles}$$

Each one of these beta particles has an energy of 705 keV (1.13 x 10^{-13} J). The total energy absorbed is thus:

$$E_{total} = (6.87 \times 10^{11} \text{ particles})(1.13 \times 10^{-13} \text{ J/particle}) = 0.0775 \text{ J}$$

The dose in Gray is therefore:

$$Radiation\ dose = \frac{0.0775 \text{ J}}{0.125 \text{ kg}} = 0.62 \text{ Gy}$$

$\text{dose equivalent in Sv} = \text{dose in Gy} \times \text{RBE} = 0.62 \text{ Gy} \times 1 = 0.62 \text{ Sv}$

$1 \text{ rem} = 0.01 \text{ Sv} \qquad 1 \text{ Sv} = 100 \text{ rem}$

$0.62 \text{ Sv} = (0.62)100 \text{ rem} = 62 \text{ rem}$