

Please use the boxes below to clearly print your name and UW NetID.  
Please write within the boxes.

<b>Printed Name</b>	
---------------------	--

*first*

*last*

<b>UW Net ID</b>	
------------------	--

*(part before @uw.edu)*

I certify that the work I shall submit is my own creation, not copied from any source.

Signature \_\_\_\_\_ Seat Number \_\_\_\_\_

---

---

Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

Do not open the exam until told to do so.

When prompted, clearly print the information required at the top of each page of this exam booklet.

For multi-select questions, you receive partial credit for each correct answer choice as long as you select none of the incorrect answer choices.

You can remove the equation sheet(s). Otherwise, keep the exam booklet intact. You will have 60 minutes to complete the examination.

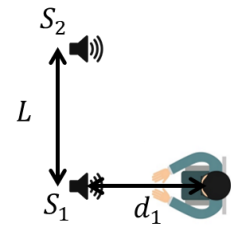
---

---



**I. Lecture multiple choice (60 points – 12 questions)**

- 1) (5 pts) A pair of in-phase stereo speakers,  $S_1$  and  $S_2$ , are separated by a distance  $L = 4.00$  m. As shown, you are sitting a distance  $d_1 = 3.00$  m directly in front of  $S_1$ . If the speakers play a constant note with frequency of 3430 Hz, do the sound waves from the speakers maximally constructively interfere, perfectly destructively interfere, or neither? Assume the speed of sound is 343m/s.

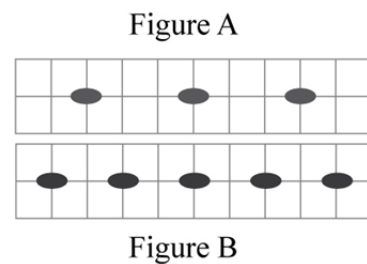


- A. Maximally constructively interfere
- B. Perfectly destructively interfere
- C. Neither
- D. Not enough information is given to determine.

- 2) (5 pts) A monochromatic light wave travels from water into oil. The wavelength of the light in water is 300 nm, and its wavelength in oil is 280 nm. The index of refraction of water is 1.33. What is the index of refraction of the oil?

- A. 0.933
- B. 1.07
- C. 1.24
- D. 1.43
- E. 1.93

- 3) (5 pts) Monochromatic light of wavelength  $\lambda$  illuminates a mask containing two narrow slits separated by a small distance  $d$ . The resulting interference pattern that is observed on a far screen located a distance  $L$  from the mask is shown in Figure A. Which of the following changes to the original experiment could produce the interference pattern shown in Figure B? You may assume the small-angle approximation applies.

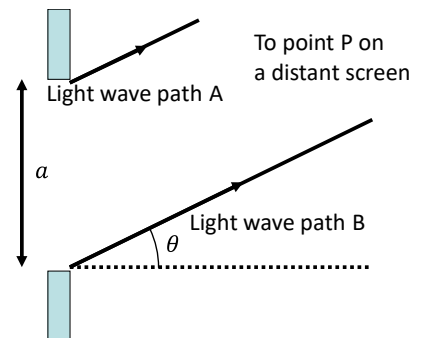


- A. Half the slit separation to  $\frac{d}{2}$  and triple the wavelength to  $3\lambda$
- B. Double the screen distance to  $2L$  and triple the wavelength to  $3\lambda$
- C. Double the screen distance to  $2L$  and triple the slit separation to  $3d$
- D. Half the slit separation to  $\frac{d}{2}$  and double the screen distance  $2L$
- E. Half the screen distance to  $\frac{d}{2}$  and triple the wavelength to  $3\lambda$

- 4) (5 pts) Monochromatic light illuminates a diffraction grating which has 900 lines per mm, producing an interference pattern on a distant screen. The grating is then replaced with another one that has 1800 lines per mm while all the other aspects of the set up remain unchanged. How would the positions of the bright and dark fringes on the screen change?
- A. They would be farther apart from each other.
  - B. They would be closer together.
  - C. They would remain the same.
  - D. The locations of the bright fringes would swap with the locations of the dark fringes.
  - E. The answer depends on the wavelength.

- 
- 5) (5 pts) An antireflective coating is applied to eyeglass lenses to minimize the reflection of stray light. The coating effectively reduces the reflection of light with a wavelength of 600 nm in air. The index of refraction of the coating is 1.50, and that of the lenses is 1.40. What is the minimum thickness of the coating?
- A. 100 nm
  - B. 107 nm
  - C. 200 nm
  - D. 214 nm
  - E. 400 nm

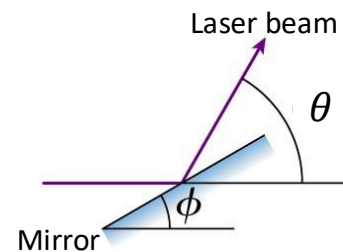
- 
- 6) (5 pts) Monochromatic light of wavelength  $\lambda$  illuminates a mask with narrow slit of width  $a$  and produces a diffraction pattern on a distant screen. Consider the two light wave paths, A and B, that originate from the edges of the slit and arrive at the same point on the screen, point P. If the path length difference of Path A and Path B is  $\lambda$ , is point P a bright fringe, dark fringe, or somewhere in between?



- A. Bright fringe
- B. Dark fringe
- C. Somewhere in between
- D. The answer depends on whether  $\frac{a}{\lambda}$  is an integer or a half-integer.
- E. The depends on whether  $\frac{\lambda}{a}$  is an integer or a half-integer.

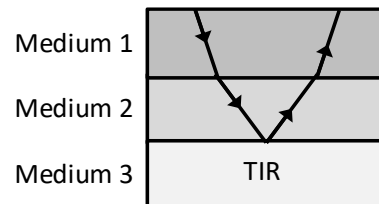
- 7) (5 pts) Two light bulbs are 2.0 m apart. From what distance can these lightbulbs be marginally resolved by a small telescope with a 4.0-cm-diameter objective lens? Assume that the lens is limited only by diffraction, and the wavelength of the light from the light bulbs is 600 nm.
- A. 55 km
  - B. 67 km
  - C. 110 km
  - D. 130 km
  - E. 2700 km

- 8) (5 pts) A plane mirror is tilted from horizontal by an angle  $\phi$ . A horizontal laser beam is deflected by the mirror by  $\theta = 50^\circ$ . What is the angle  $\phi$ ?



- A.  $17^\circ$
- B.  $20^\circ$
- C.  $25^\circ$
- D.  $30^\circ$
- E.  $65^\circ$

- 9) (5 pts) A laser beam refracts at the interface between media 1 and 2, and total internal reflection at the interface between media 2 and 3 as shown. Rank the speeds of light in media 1, 2, and 3 ( $v_1$ ,  $v_2$ , and  $v_3$ , respectively).



- A.  $v_1 < v_2 < v_3$
- B.  $v_3 < v_1 < v_2$
- C.  $v_1 < v_3 < v_2$
- D.  $v_2 < v_3 < v_1$
- E.  $v_3 < v_2 < v_1$

**Use the following scenario for the next two questions.**

An object is placed 3.0 m in front of a spherical mirror, and the image of the object is formed 1.2 m **behind** the mirror.

10) (5 pts) What is the focal length of the mirror?

- A. -2.0 m
- B. -0.83 m
- C. -0.50 m
- D. +1.2 m
- E. +1.8 m

11) (5 pts) Which of the following statements about the image is/are correct? **Select all that apply.**

- A. It is real.
- B. It is enlarged.
- C. It is inverted.
- D. None of the above choices are correct.

---

12) (5 pts) Two microscopes, A and B, have identical eyepieces and tube length, but the focal length of the objective lens of microscope A is twice as long as that of microscope B. Which microscope has a greater absolute value of angular magnification?

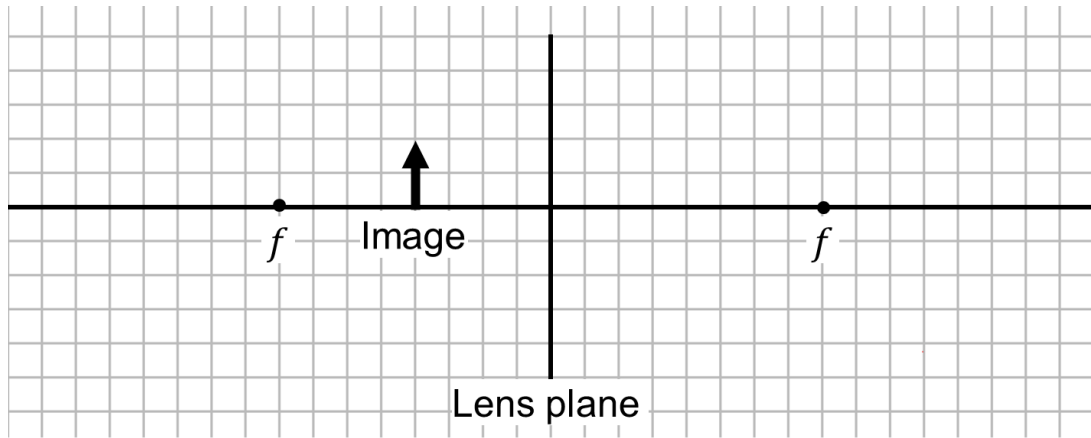
- A. Microscope A
- B. Microscope B
- C. Both microscopes have the same angular magnification.
- D. Not enough information is given to determine.

**Continue on the next page.**

**II. Lecture free response (20 points)**

Use the following scenario for the next two questions.

An object (not shown) is placed on the left side of a diverging lens, and the image of the object is formed as shown below.



13) (8 pts) On the diagram above, draw the three “special” rays to determine the location of the object. Clearly indicate the object as an arrow that indicates its orientation, size, and location.

14) (4 pts) Is this image a real image or a virtual image? Explain.

**Continue on the next page.**

**Use the following scenario for the next two questions.**

Suppose that when your eye is relaxed while trying to view distant objects, the focal length of your eye's lens  $f_{\text{eye}}$  is **shorter** than the distance between the eye lens and the retina,  $d$ .

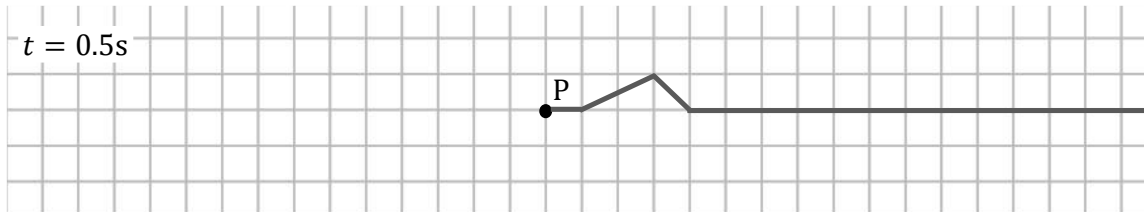
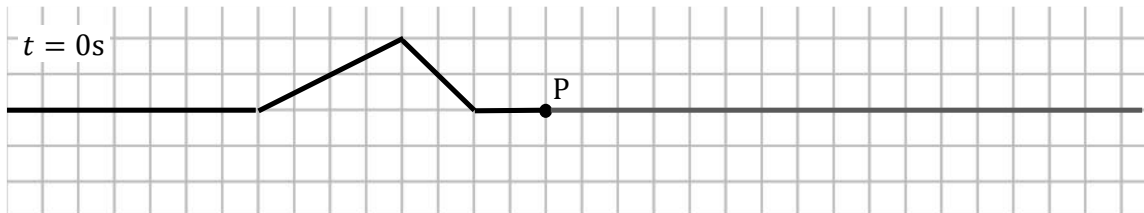
15) (3 pts) To correct your distance vision so that far-away objects appear in focus on the retina, should the corrective lens you use be converging or diverging? Explain your reasoning.

16) (5 pts) What is the expression for your far point in terms of  $f_{\text{eye}}$  and  $d$ ?

**Continue on the next page.**

**III. Tutorial free response (20 points)**

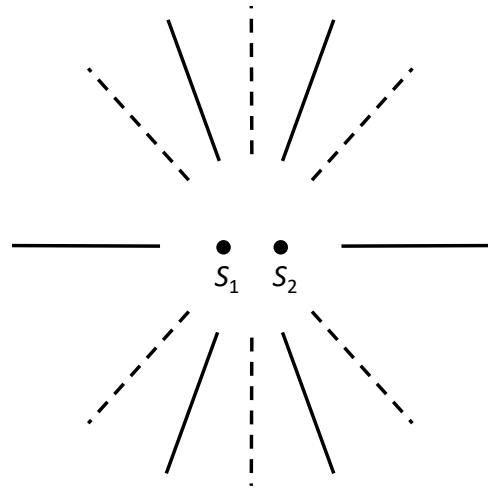
- 17) (7 pts) Two horizontal springs with different linear mass densities are connected at point P. A pulse is sent from the left end of the left spring toward point P. The top figure below shows the incident pulse before it reaches point P at  $t = 0\text{s}$ . The bottom figure below shows the transmitted pulse at  $t = 0.5\text{s}$ . Draw the corresponding reflected pulse at  $t = 0.5\text{s}$  in the bottom figure. You do not need to worry about the heights of the pulses.



**Continue on the next page.**

Use the following scenario for the next two questions.

Two point-sources ( $S_1$  and  $S_2$ ) generate periodic waves of wavelength  $\lambda_0$  in a body of water. The diagram at right shows the interference pattern created far away from the sources: antinodal lines are represented by solid lines, and nodal lines are represented by dashed lines.

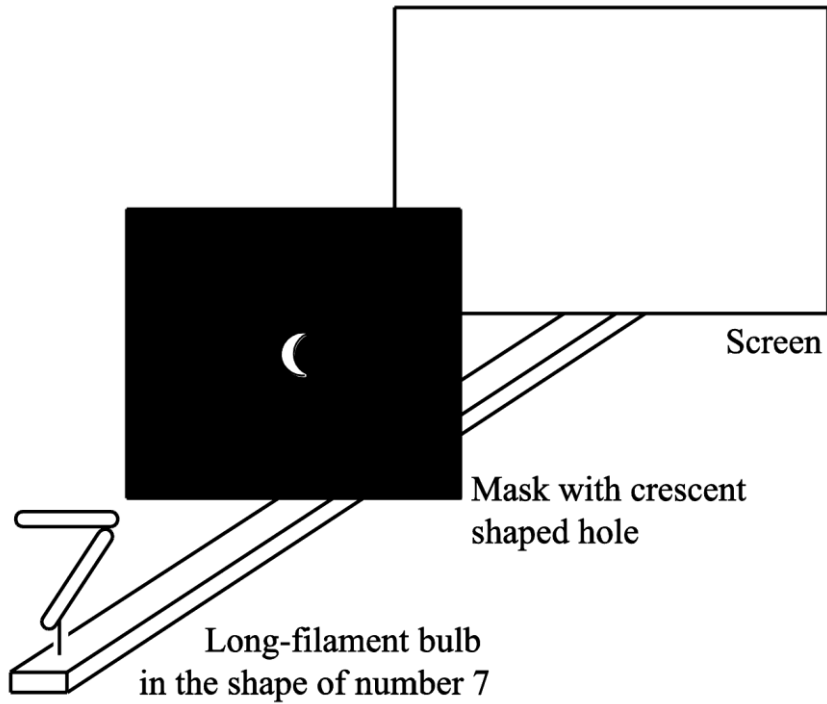


18) (3 pts) Label each nodal and antinodal line in the figure with path length difference,  $\Delta r$ , from the sources, expressed in terms of  $\lambda$ .

19) (3 pts) Are the sources  $S_1$  and  $S_2$  in phase or out of phase? Explain.

Continue on the next page.

20) (7 pts) A mask with a small crescent-shaped hole is placed between a bulb in the shape of the number 7 and a screen, as shown below. (Assume that the room is dark before the bulb is turned on and ignore any interference or diffraction effects.) Sketch what you will see on the screen in the figure below or describe the image when the bulb is lit.



**This page intentionally left blank.**

## Constants

Gas constant	$R = 8.31 \text{ J}/(\text{mol} \cdot \text{K})$
Speed of light in vacuum	$c = 3.00 \times 10^8 \text{ m/s}$
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$
Planck's constant	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$ $h = 4.14 \times 10^{-15} \text{ eV} \cdot \text{s}$
Electron charge	$e = 1.602 \times 10^{-19} \text{ C}$

## Frequency for:

Mass on a spring	$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$
Simple pendulum	$f = \frac{1}{2\pi} \sqrt{\frac{g}{L}}$
Physical pendulum	$f = \frac{1}{2\pi} \sqrt{\frac{mgd}{I}}$
Damped oscillation	$x_{\text{max}}(t) = Ae^{-t/\tau}$

## Equations from 114 and 115

Acceleration of gravity	$g = 9.8 \text{ m/s}^2$
Kinematic equations	$(v_x)_f = (v_x)_i + a_x \Delta t$ $x_f = x_i + (v_x)_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$ $(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x$
Newton's 2nd law	$\vec{F}_{\text{net}} = m\vec{a}$
Hooke's law	$\vec{F}_{\text{spring}} = -k\Delta\vec{x}$
Linear momentum	$\vec{p} = m\vec{v}$
Translational kinetic energy	$K = \frac{1}{2}mv^2$
Elastic potential energy	$\Delta U_s = \frac{1}{2}k(x_f^2 - x_i^2)$
Gravitational potential energy	$\Delta U_g = mg\Delta y$
Power	$P = \frac{\Delta E}{\Delta t}$
Pressure	$p = \frac{F}{A}$
Temperature conversion	$T(\text{K}) = T(^{\circ}\text{C}) + 273$
Thermal radiation	$\frac{Q_{\text{net}}}{\Delta t} = e\sigma A(T^4 - T_0^4)$

## Oscillations

Position in SHM	$x(t) = A \cos(2\pi ft)$
Velocity in SHM	$v_x(t) = -2\pi f A \sin(2\pi ft)$
Acceleration in SHM	$a_x(t) = -(2\pi f)^2 A \cos(2\pi ft)$
Angular velocity	$\omega = 2\pi f = \frac{2\pi}{T}$
Mechanical energy in SHM	$E = K + U = \frac{1}{2}kA^2$

## Waves and sound

Sinusoidal wave function	$y(x, t) = A \cos(2\pi(\frac{x}{\lambda} \pm \frac{t}{T}))$
Speed of sinusoidal waves	$v = \lambda f$
Speed of a wave on a string	$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$
Speed of sound in gas	$v_{\text{sound}} = \sqrt{\frac{\gamma RT}{M}}$
Intensity	$I = \frac{P}{a}$
Intensity of spherical wave	$I = \frac{P_{\text{source}}}{4\pi r^2}$
Sound intensity level	$\beta = (10 \text{ dB}) \log_{10} \left( \frac{I}{I_0} \right)$ $I_0 = 1.0 \times 10^{-12} \text{ W} \cdot \text{m}^{-2}$
Log function	$b = a^x \leftrightarrow \log_a(b) = x$ $\log(ab) = \log(a) + \log(b)$ $\log(\frac{a}{b}) = \log(a) - \log(b)$ $\log(a^b) = b \log(a)$

## Sound Doppler effect for:

Moving source	$f_{\pm} = \frac{f_s}{1 \mp v_s/v}$
Moving observer	$f_{\pm} = \left(1 \pm \frac{v_o}{v}\right) f_s$
Moving object reflection	$\Delta f = \pm 2f_s \frac{v_o}{v}$ for $v_o \ll v$

## Standing waves:

On a string	$f_m = m \left( \frac{v}{2L} \right) = m f_1,$ $\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m}, m = 1, 2, 3, \dots$
-------------	--

Open-open or closed-closed pipe	$f_m = m \left( \frac{v}{2L} \right) = mf_1,$ $\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m}, m = 1, 2, 3, \dots$	<b>Circular aperture:</b> Central maximum diameter	$w = \frac{2.44\lambda L}{D}$
Open-closed pipe	$f_m = m \left( \frac{v}{4L} \right) = mf_1,$ $\lambda_m = \frac{\lambda_1}{m} = \frac{4L}{m}, m = 1, 3, 5, \dots$	First dark fringe	$\theta_1 = \frac{1.22\lambda}{D}$ $y_1 = \frac{1.22\lambda L}{D}$

## Ray optics

Law of reflection	$\theta_r = \theta_i$
Image by plane mirror	$s' = s$
Snell's law	$n_1 \sin \theta_1 = n_2 \sin \theta_2$
Critical angle	$\theta_c = \sin^{-1} \left( \frac{n_2}{n_1} \right), n_1 > n_2$
Image by refraction	$s' = \frac{n_2}{n_1} s$
Magnification of lens or mirror	$m = -\frac{s'}{s}$

### Thin lens & curved mirrors:

Thin-lens equation	$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$
<b>Sign conventions:</b>	
Object	$s > 0$ , always
Image	$s' > 0$ , for real image
Focal length	$f > 0$ , for converging lens or converging mirror
Magnification	$m > 0$ for upright image

## Optical instruments

Refractive power	$P = \frac{1}{f}$
Normal near point	$NP_{\text{normal}} = 25 \text{ cm}$

### Angular magnifications:

Magnifying glass	$M = \frac{NP}{f}$
Microscope	$M = -\frac{L \times NP}{f_o f_e}$
Telescope	$M = -\frac{f_o}{f_e}$

## Wave optics

Index of refraction	$v = \frac{c}{n}$
Wavelength in material	$\lambda_{\text{mat}} = \frac{\lambda_{\text{vac}}}{n}$
<b>Double-slit interference:</b>	
Small angle approx.	$\sin(\theta) \approx \theta$
Bright (sources in phase)	$\sin(\theta_m) = m \frac{\lambda}{d}$ $y_m = \frac{m\lambda L}{d}$ $m = 0, 1, 2, \dots$
Dark (sources in phase)	$y'_m = \left( m + \frac{1}{2} \right) \frac{\lambda L}{d}$ $m = 0, 1, 2, \dots$
Diffraction grating (bright)	$d \sin \theta_m = m\lambda$ $y_m = L \tan \theta_m$ $m = 0, 1, 2, \dots$

### Thin film:

Bright (0 or 2 phase changes)	$2t = m \frac{\lambda}{n}$
or dark (1 phase change)	$m = 0, 1, 2, \dots$
Dark (0 or 2 phase changes)	$2t = \left( m + \frac{1}{2} \right) \frac{\lambda}{n}$
or bright (1 phase change)	$m = 0, 1, 2, \dots$

### Single slit diffraction:

Dark fringes	$a \sin \theta_p = p\lambda$ $p = 1, 2, 3, \dots$
Central maximum width	$w = \frac{2\lambda L}{a}$ for $\frac{\lambda}{a} \ll 1$

**Resolution:**

Telescope

$$\theta_1 = \frac{1.22\lambda}{D}$$

Microscope

$$d_{\min} = \frac{0.61\lambda}{\text{NA}} = \frac{0.61\lambda}{n \sin \phi_0}$$

**Electromagnetic waves**

Speed

$$c = \lambda f = \frac{E_0}{B_0}$$

Intensity

$$I = \frac{P}{A} = \frac{1}{2} c \epsilon_0 E_0^2 = \frac{1}{2} \frac{c}{\mu_0} B_0^2$$

Malus's law

$$I_{\text{transmitted}} = I_{\text{incident}} (\cos \theta)^2$$

**Quantum physics**

Thermal radiation

$$\lambda_{\text{peak}} = \frac{2.9 \times 10^6 \text{ nm} \cdot \text{K}}{T}$$

Bragg condition

$$\Delta r = 2d \cos \theta_m = m\lambda$$

$$m = 1, 2, 3, \dots$$

Photon energy

$$E = hf$$

**Photo-electric effect:**

Cutoff frequency

$$f_0 = \frac{E_0}{h}$$

Stopping potential

$$V_{\text{stop}} = \frac{K_{\max}}{e} = \frac{hf - E_0}{e}$$

de Broglie wavelength

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

Uncertainty principle

$$\Delta x \Delta p_x \geq \frac{h}{4\pi}$$

**Atoms and molecules**

Balmer formula

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

$m$  &  $n$  integers,  $n > m$

**Bohr hydrogen atom:**

Radius

$$r_n = n^2 a_B$$

$$= (5.29 \times 10^{-11} \text{ m}) n^2$$

Energy

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

$$n = 1, 2, 3, \dots$$

**Nuclear physics**

Mass number

$$A = Z + N$$

Designation

$${}^A_Z X$$

Binding energy

$$B = (Zm_H + Nm_n - m_{\text{atom}})$$

$$\times (931.49 \frac{\text{MeV}}{\text{u}})$$

Alpha decay

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

Beta-minus decay

$${}^A_Z X \rightarrow {}^A_{Z+1} Y + e^- + \text{energy}$$

Beta-plus decay

$${}^A_Z X \rightarrow {}^A_{Z-1} Y + e^+ + \text{energy}$$

Time constant

$$\tau = \frac{t_{1/2}}{\ln 2} = (1.44) t_{1/2}$$

Half-life

$$t_{1/2} = \tau \ln 2 = 0.693\tau$$

Number of nuclei

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

Activity

$$R = \frac{N}{\tau} = R_0 \left(\frac{1}{2}\right)^{t/t_{1/2}} = R_0 e^{-t/\tau}$$

Radiation dose

$$1 \text{ Gy} = 1.00 \text{ J/kg}$$

(absorbed energy)

Dose equivalent

$$\text{dose equivalent in Sv}$$

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