Physics 123 A
Spring 2025

123A - N.TOLICH

Midterm 2
May 15th, 2025

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

Printed Name	

first *last*

UW Net ID	

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

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I. Lecture multiple choice (45 points – 9 questions)

1) (5 pts) 540-nm light passes through a single slit and produces a pattern on a distant screen. The first dark fringe (first minimum) is 35.0 degrees from the center of the interference pattern. What is the width of the slit?

   A. 1.88×10^{-6} m
   B. 4.71×10^{-7} m
   C. 5.40×10^{-7} m
   D. 8.84×10^{-7} m
   E. 9.41×10^{-7} m

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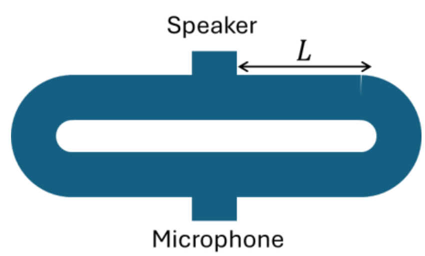
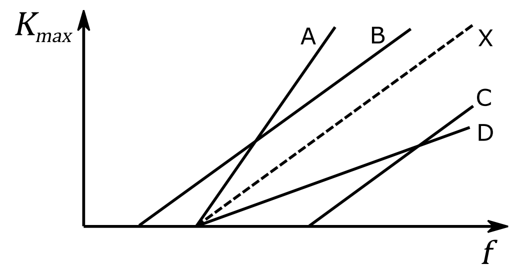
2) (5 pts) A sound wave generated at a speaker can travel down one of two paths to reach a microphone, as shown. Initially both paths are the same length, and therefore the sound detected by the microphone is maximum. By pulling on the right side of the setup you increase the length of the top and bottom parts of the path on the right. If the wavelength of the sound wave is λ = 0.32m, by how much do you need to increase L until the sound detected by the microphone is minimum for the first time?



   A. 0.040 m
   B. 0.080 m
   C. 0.16 m
   D. 0.32 m
   E. 0.64 m

3) (5 pts) You fire photons with different frequencies at a piece of metal and measure the maximum kinetic energy of the electrons emitted at each frequency. On the graph, line X (dashed line) shows the best fit to the results you obtained. If you fired photons at a piece of metal with half the work function, which line would you expect to obtain?



A. Line A
B. Line B
C. Line C
D. Line D
E. The same result, line X

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4) (5 pts) A beam of electrons traveling at a constant speed pass through a double slit and produce an interference pattern on a distant screen. Which of the following changes could <u>increase</u> the spacing between the fringes in the interference pattern?
   i. Decrease the spacing between the slits.
   ii. Decrease the distance to the screen.
   iii. Decrease the speed of the electrons.

A. i. only
B. iii. only
C. i. and ii.
D. i. and iii.
E. ii. and iii.

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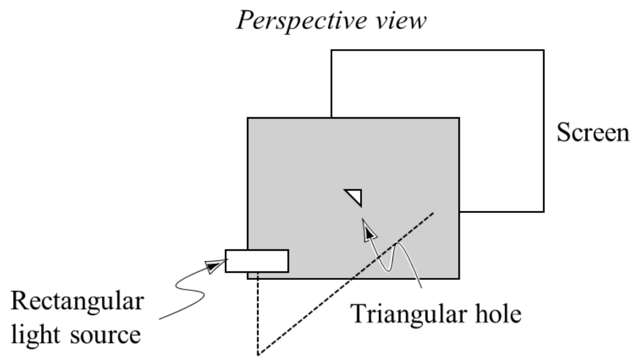
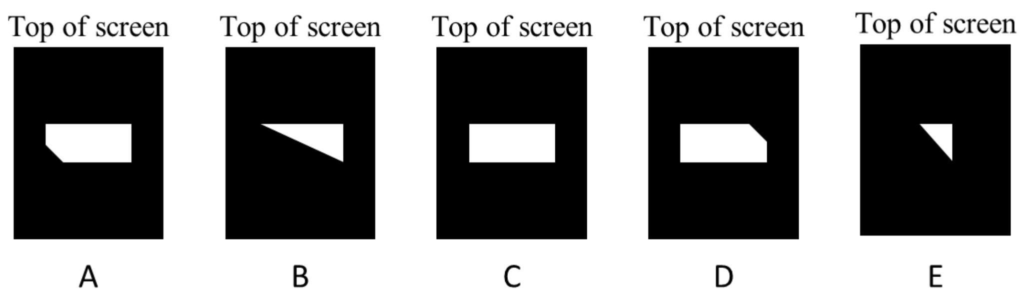
5) (5 pts) A thin glass rod is submerged in water. What is the critical angle for light traveling inside the rod? The index of refraction of water is 1.33, and the index of refraction of the glass rod is 1.50.

A. 27.5°
B. 41.8°
C. 45.0°
D. 48.8°
E. 62.5°

6) (5 pts) A mask with a triangular hole is placed between a rectangular light source and screen as shown. Which choice below is most like what you observe on the screen?





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7) (5pts) Consider a **<u>concave (converging)</u>** mirror with a focal length of 1.0 m. If an object is placed 0.5 m in front of the mirror, which of the following statements about the image formed are correct?
   i. It is real.
   ii. It is enlarged.
   iii. It is inverted.

   A. i. only
   B. ii. only.
   C. iii. only.
   D. i. and iii.
   E. All of these are correct.

8) (5 pts) The size of the smallest things that can be seen with an optical microscope is **limited by diffraction**. Which of the following could help a microscopist see smaller things? Select all that apply.

A. A microscope with a higher magnification could be used.
B. The microscope could have an eyepiece lens with a shorter focal length.
C. The diameter of the lens could be larger.
D. Light with a longer wavelength could be used.
E. None of the above.

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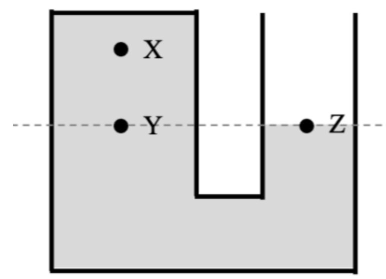
9) (5 pts) A U-tube containing water has one side open to the air, as shown in the figure. Which of the following is a correct ranking of the pressures at points X, Y and Z?



A. Z > Y > X
B. Z = Y > X
C. Z = Y < X
D. X = Y = Z
E. None of the above.

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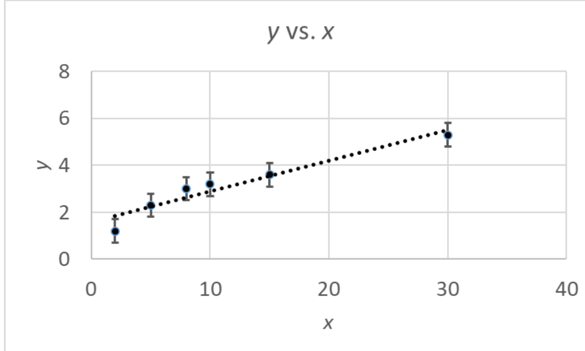
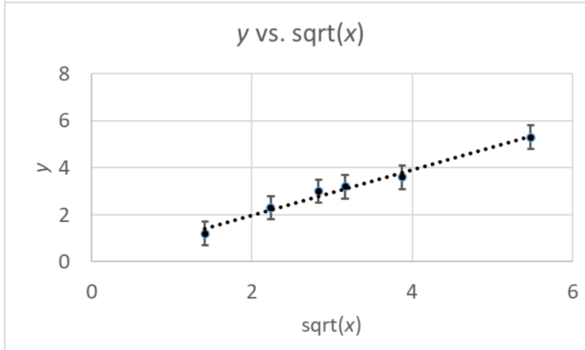
II. Lab multiple choice (15 points)

10) (5 pts) To develop a model relating variables x and y, a lab team measured y as they varied x and graphed y vs. x (top graph) and y vs. $\sqrt{x}$ (bottom graph), each with a best-fit line. Which of the following statements is/are correct based on their data? **Select all that apply**.





A. The best-fit line for the top graph is a good fit.
B. The best-fit line for the bottom graph is a good fit.
C. This experiment is **invalid** since it shows that two different models are consistent with the data simultaneously.
D. This experiment is **valid** even though it shows that two different models are consistent with the data simultaneously.
E. None of the above is correct.

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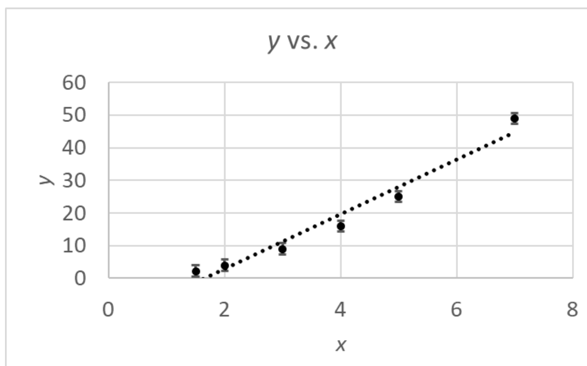
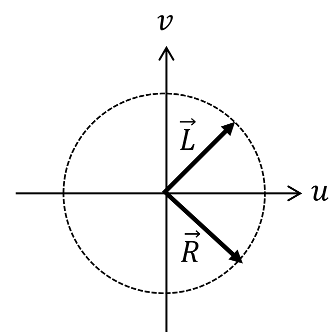
11) (5 pts) Suppose that a lab team measured variable y as they varied variable x and graphed y vs. x with a best-fit line as shown at right. Which of the following should they attempt to create a properly linearized graph with a good fit? **Select only <u>one</u> best choice from below**.



A. Try increasing the uncertainty bars for the data points so that the best-fit line becomes a better fit.
B. Try decreasing the uncertainty of the data points by measuring the variables more carefully.
C. Try graphing y vs. x^2.
D. Try graphing y vs. $\sqrt{x}$.
E. The graph is already properly linearized, so there is nothing they should attempt.

12) (5 pts) Monochromatic light is normally incident on a mask containing two very narrow identical slits. The interference pattern is viewed on a distant screen. The diagram at right illustrates two phasors that represent the light from the left slit, $\vec{L}$, and the right slit, $\vec{R}$, arriving at a point on the screen. Which <u>one</u> of the following points could these phasors represent?

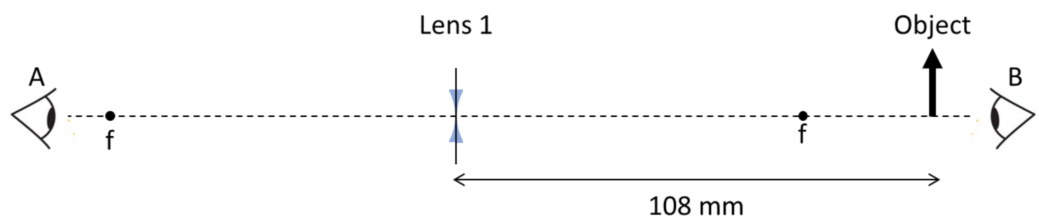


A. The center of the central bright fringe
B. The center of a bright fringe other than the central bright fringe
C. The center of a dark fringe
D. Somewhere between the centers of a bright fringe and a dark fringe
E. Not enough information to determine

III. Lecture free response (25 points)

An object is placed 108 mm to the right of lens 1, which has a focal length of -78.0 mm.

13) (7 pts) On the diagram below draw the three "special" rays to determine the location of the imaged formed by this lens. Clearly indicate where the image is formed.



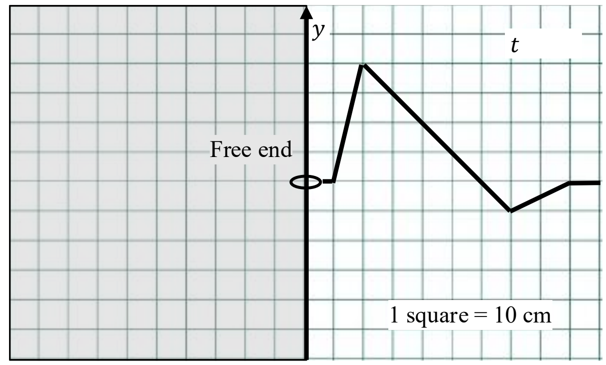
14) (5 pts) Two people, A and B, are located and looking in the directions shown. Can A, B, both or neither see the image? Explain.

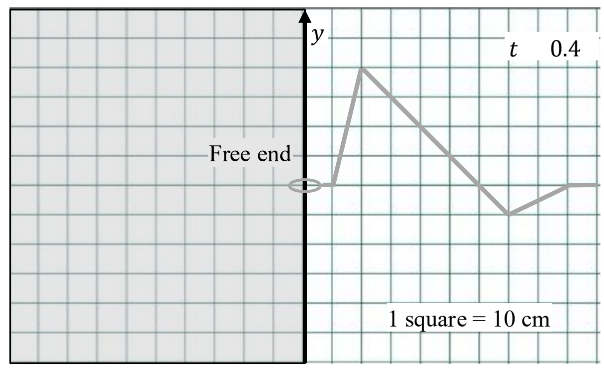
15) (5 pts) What is image distance relative to lens 1? Show your work and be sure to indicate if it is on the left or right of lens 1.

16) (8 pts) Now lens 2, which has a focal length of +98.0 mm, is placed 250 mm to the left of lens 1, as shown below. Where is the image for the lens combination located relative to lens 2? Show your work and be sure to indicate if it is on the left or right of lens 2.

IV. Tutorial free response (15 points)

17) (7 pts) A pulse with a wave speed of 1.0 m/s is approaching the free end of a spring. The shape of the pulse at t = 0 s is shown on the top right figure.
On the bottom right diagram, draw the shape of the pulse at t = 0.4 s. Be sure to include and label any pulses you use to determine your answer. The shape of the pulse at t = 0 s is shown in gray for your reference.





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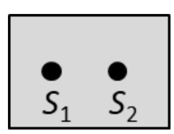
18) (4 pts) Two point-sources, S_1 and S_2, are oscillating in phase in water and each producing periodic circular waves of wavelength λ. S_1 and S_2 are separated by 1.5λ. The top-view of the sources are shown below. In the space below, draw qualitatively accurate nodal (dashed) and antinodal (solid) lines. You do not need to draw any lines inside the gray box near the sources. Label each line with path length difference, δs, in terms of λ.



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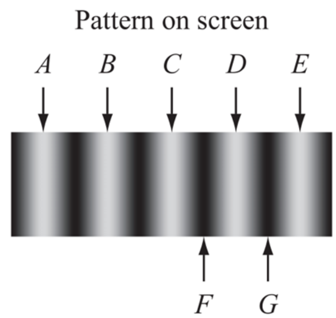
19) (4 pts) Monochromatic light from a distant point source is incident on a mask with two identical, very narrow vertical slits. The diagram at right illustrates the pattern that appears at the center of a distant screen. If the left slit is now covered, which of the points labeled A through G would appear brighter? Explain your reasoning.



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Constants

Speed of light $c = 3.00 \times 10^8$m/s

Speed of sound in 20°C air $v_{\text{sound in air}} = 343$m/s

Gravitational acceleration $g = 9.8$m/s^2

Fundamental charge $e = 1.6 \times 10^{-19}$C

Plank's constant $h = 6.63 \times 10^{-34}$J·s $= 4.14 \times 10^{-15}$eV·s

Atmospheric pressure $p_{\text{atmos}} = 1.013 \times 10^5$Pa

Mathematics

Vector components $\vec{A} = \vec{A}_x + \vec{A}_y = A_x\hat{\imath} + A_y\hat{\jmath}$

Vector magnitude $A = \sqrt{A_x^2 + A_y^2}$

θ ccw from x-axis $A_x = A\cos\theta$

$A_y = A\sin\theta$

$\theta = \tan^{-1}(A_y/A_x)$

Adding vectors $\vec{C} = \vec{A} + \vec{B}$ $C_x = A_x + B_x$

$C_y = A_y + B_y$

Dot product $\vec{A} \cdot \vec{B} = AB\cos\alpha$

$\vec{A} \cdot \vec{B} = A_xB_x + A_yB_y$

Cross product $|\vec{A} \times \vec{B}| = AB\sin\alpha$

$\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}$

Area of sphere $4\pi r^2$

Volume of sphere $\frac{4}{3}\pi r^3$

Area of cylinder $2\pi(r^2 + rh)$

Volume of cylinder $\pi r^2 h$

Sample standard deviation $s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{\text{ave}})^2}{n-1}}$

Equations from 121

Constant acceleration (in "s" direction)

$$v_{\text{fs}} = v_{\text{is}} + a_s\Delta t$$

$$s_{\text{f}} = s_{\text{i}} + v_{\text{is}}\Delta t + \tfrac{1}{2}a_s(\Delta t)^2$$

$$v_{\text{fs}}^2 = v_{\text{is}}^2 + 2a_s\Delta s$$

Newton's 2nd law $\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$

Newton's 3rd law $\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

Kinetic energy $K = \frac{1}{2}mv^2$

Chapter 15

Frequency $f = \frac{1}{T}$

Angular frequency $\omega = 2\pi f$

SHM position $x(t) = A\cos(\omega t + \phi_0)$

SHM velocity $v(t) = -A\omega\sin(\omega t + \phi_0)$

SHM acceleration $a(t) = -A\omega^2\cos(\omega t + \phi_0) = -\omega^2 x(t)$

Spring energy $\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \frac{1}{2}m(v_{\max})^2$

Angular frequencies:

- Mass on a spring $\omega = \sqrt{\frac{k}{m}}$
- Simple pendulum $\omega = \sqrt{\frac{g}{l}}$
- Physical pendulum $\omega = \sqrt{\frac{Mgl}{I}}$

Damping time constant with drag $\vec{F} = -b\vec{v}$ $\tau = m/b$

Damped oscillations $x(t) = Ae^{-t/(2\tau)}\cos(\omega t + \phi_0)$

Damped energy $E(t) = E_0 e^{-t/\tau}$

Chapter 16

Wave speed on string $v = \sqrt{\frac{T_{\text{s}}}{\mu}}$

Linear mass density $\mu = \frac{m}{L}$

Wavelength $\lambda = \frac{v}{f}$

Wave number $k = \frac{2\pi}{\lambda}$

Sinusoidal wave

- moving in the <u>$+x$-dir.</u> $D(x,t) = A\sin(kx - \omega t + \phi_0)$
- moving in the <u>$-x$-dir.</u> $D(x,t) = A\sin(kx + \omega t + \phi_0)$

Wave equation $\frac{\partial^2 D}{\partial t^2} = v^2\frac{\partial^2 D}{\partial x^2}$

Speed of light in material $v = \frac{c}{n}$

Intensity of three-dimensional wave $I = \frac{P}{a}$

Sound intensity level $\beta = (10\text{dB})\log\left(\frac{I}{1.0\times10^{-12}\text{W/m}^2}\right)$

Doppler effect:

Approaching source $f_+ = \frac{f_0}{1 - v_s/v}$

Receding source $f_- = \frac{f_0}{1 + v_s/v}$

Observer approaching a source $f_+ = (1 + v_o/v) f_0$

Observer receding from a source $f_- = (1 - v_o/v) f_0$

Chapter 17

Standing wave $D(x,t) = 2a \sin(kx) \cos(\omega t)$

Wavelengths of standing waves:

Node or antinode at both ends, $m = 1, 2, \ldots$ $\lambda_m = \frac{2L}{m}$

Node and antinode at ends, $m = 1, 3, \ldots$ $\lambda_m = \frac{4L}{m}$

Phase difference $\Delta\phi = 2\pi \frac{\Delta x}{\lambda} + \Delta\phi_0$

Thin-film total phase difference:

Both surfaces π or 0 phase shift $\Delta\phi = 2\pi \frac{2nd}{\lambda}$

One surface π & other 0 phase shift $\Delta\phi = 2\pi \frac{2nd}{\lambda} + \pi$

Beating wave $D = 2a \cos(\omega_{\text{mod}} t) \sin(\omega_{\text{avg}} t)$

Beat frequency $f_{\text{beat}} = 2 \frac{\omega_{\text{mod}}}{2\pi} = |f_1 - f_2|$

Average frequency $f_{\text{avg}} = \frac{\omega_{\text{avg}}}{2\pi} = \frac{1}{2}(f_1 + f_2)$

Chapter 33

Double-slit interference (small angles), $m = 0, 1, 2, \ldots$

Angles of bright fringes $\theta_m = m \frac{\lambda}{d}$

Positions of bright fringes $y_m = \frac{m\lambda L}{d}$

Angles of dark fringes $\theta_m = \left(m + \frac{1}{2}\right) \frac{\lambda}{d}$

Positions of dark fringes $y_m = \frac{(m + \frac{1}{2})\lambda L}{d}$

Diffraction grating, $m = 0, 1, 2, \ldots$

Angle of bright fringes $d \sin\theta_m = m\lambda$

Position of bright fringes $y_m = L \tan\theta_m$

Single slit diffraction, $p = 0, 1, 2, \ldots$

Angle of dark fringes $a \sin\theta_p = p\lambda$

Positions of dark fringes (small angle) $y_p = \frac{p\lambda L}{a}$

Width of central maximum (small angle) $w = \frac{2\lambda L}{a}$

Circular aperture

Angle first dark ring $\sin\theta_1 = 1.22 \frac{\lambda}{D}$

Width of central maximum (small angle) $w \approx \frac{2.44\lambda L}{D}$

Michelson interferometer, $m = 0, 1, 2, \ldots$

Constructive interference $L_2 - L_1 = m \frac{\lambda}{2}$

Destructive interference $L_2 - L_1 = \left(m + \frac{1}{2}\right) \frac{\lambda}{2}$

Chapter 38

Photoelectric effect

Stopping potential $V_{\text{stop}} = \frac{K_{\max}}{e}$

Electron maximum kinetic energy $K_{\max} = hf - E_0$

Photon energy $E = hf$

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Chapter 34

Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Critical angle ($n_1 > n_2$) $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

Lateral magnification $m = -\frac{s'}{s}$ and $|m| = \frac{h'}{h}$

Thin-lens and mirror equation $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

Lens maker's equation $\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Circular mirror focal length $f = \frac{R}{2}$

Chapter 35

Effective focal length $\frac{1}{f_{\text{eff}}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{L}{f_1 f_2}$

Power of lens $P = \frac{1}{f}$

f-number $\text{f-number} = \frac{f}{D}$

Angular magnification $M = \frac{\theta}{\theta_{\text{NP}}} = \frac{25\text{cm}}{f}$

Microscope angular magnification $M = m_{\text{obj}} M_{\text{eye}}$

Telescope angular magnification $M = \frac{\theta_{\text{eye}}}{\theta_{\text{obj}}} = -\frac{f_{\text{obj}}}{f_{\text{eye}}}$

Angular resolution $\theta_{\min} \approx 1.22 \frac{\lambda}{D}$

Chapter 14

Mass density	$\rho = \frac{m}{V}$
Pressure	$p = \frac{F}{A}$
Pressure in liquid	$p = p_0 + \rho g d$