Last Name:________________First Name_________________Network-ID__________

Discussion Section:________Discussion TA Name:______________________________

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 11 ***numbered pages*** *plus three (3) Formula Sheets following these instructions.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **96** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

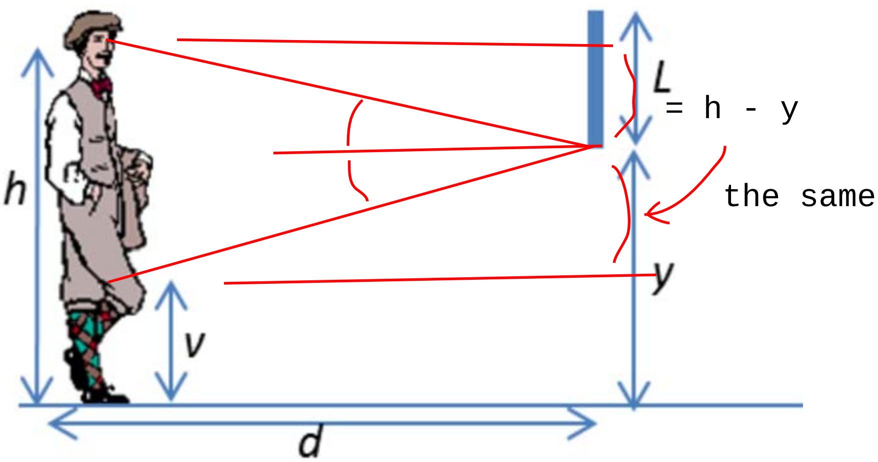
Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

Check to make sure that you bubble in ALL of your answers on the scantron (answer sheet).
Only what is marked on your scantron/answer sheet will count!

The next two questions pertain to the situation described below.

A man stands a distance d = 240 cm in front of a vertical flat mirror of length L = 45 cm that is hung a distance y = 129 cm above the ground as shown in the figure. The mans eyes are a distance h = 174 cm above the ground.



1) What is lowest point above the ground, that he can see his image reflection in the mirror?

a. v = 130 cm
b. v = 84 cm
c. v = 66 cm
d. v = 150 cm
e. v = 45 cm

v = h - 2(h-y) = 2y - h = 258 - 174 = 84

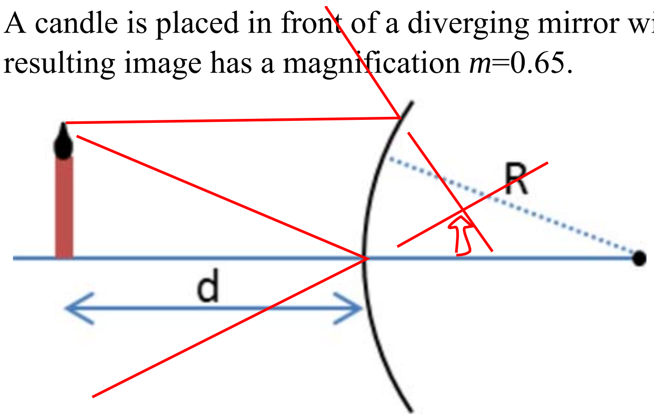
2) If the man takes a step closer to the mirror, the lowest point above the ground he can see his image reflected in the mirror

a. increase.
b. decrease.
c. remain the same.

since h and h-y do not change.

The next three questions pertain to the situation described below.

A candle is placed in front of a diverging mirror with focal length f = -19 cm as shown in the figure. The resulting image has a magnification m=0.65.



R = -2f

3) What is R, the radius of curvature of the mirror?

a. R = 19 cm
b. R = 29 cm
c. R = 38 cm

4) The resulting image is

1/f = 1/do + 1/di
1/di = 1/f - 1/do < 0 virtual

a. virtual.
b. real.

5) What is d, the distance of the candle from the mirror?

a. d = 10.2 cm
b. d = 29.2 cm
c. d = 31.4 cm
d. d = 12.3 cm
e. d = 48.2 cm

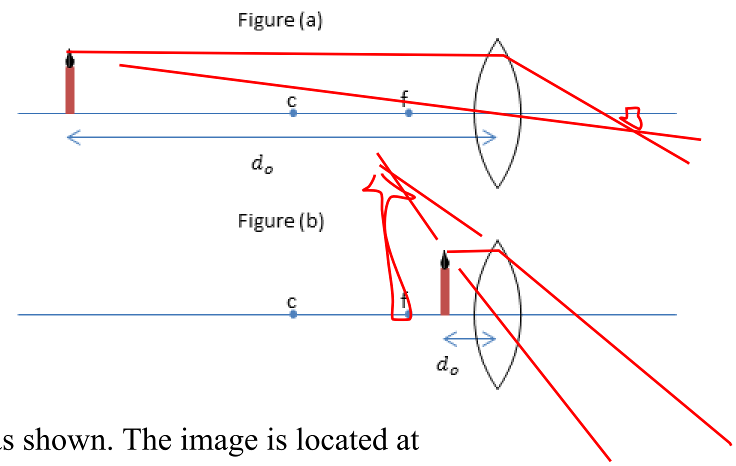
m = -di/do

di = -0.65do
so
1/f = 1/do -1/(0.65 do)
Therefore
-1/19 = -1/(1.857 do) -> do = 10.23 cm

The next four questions pertain to the situation described below.

A candle is placed before a converging lens as shown. The lens has a focal length of $f = 2.4\ cm$.

1/f = 1/do + 1/di



6) The candle is first placed at a distance $d_o = 14.8\ cm$ as shown. The image is located at

```
1/di = 1/f - 1/do
     = 1/2.4 - 1/14.8 = 1/2.86452
```

a. $d_i = 2.07\ cm$
b. $d_i = 2.86\ cm$
c. *no image is formed*

7) The resulting image is also

```
inverted from the figure or
m = -2.86/14.8<0
```

a. *inverted*
b. *neither*
c. *upright*

8) Now the candle is placed at $d_o = 1.2\ cm$. Now the image is located at

bad English.

```
1/di = 1/f - 1/do
     = 1/2.4 - 1/1.2 = -1/2.4
```

a. $d_i = -2.4\ cm$
b. $d_i = -0.8\ cm$
c. *no image is formed*

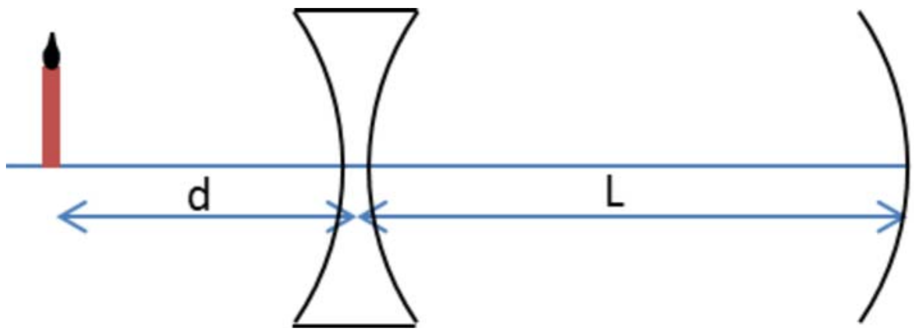
9) This new image is also

```
di < 0 or from the figure
```

a. *real*
b. *neither*
c. *virtual*

The next three questions pertain to the situation described below.

A candle is placed a distance d = 34 cm in front of a diverging lens with focal length f_{Lens} = -19 cm which is located a distance L =25 cm in front of a converging mirror with focal length f_{mirror} = 25 cm as shown in the figure.



10) What is the location of the image of the candle due to the lens alone?

1/f = 1/do + 1/di

a. 12.2 cm to the left of the lens
b. 12.2 cm to the right of the lens

```
1/di = 1/f - 1/do = -1/19 - 1/34
     = -1/12.189  virtual
```

11) What is the location of the resulting image from the lens + mirror combination?

a. 14.9 cm to the right of the mirror.
b. 76.3 cm to the right of the mirror.
c. 8.19 cm to the right of the mirror.
d. 76.3 cm to the left of the mirror.
e. 8.19 cm to the left of the mirror.

The virtual image behaves as the source of rays for the mirror, so it behaves as a real object.

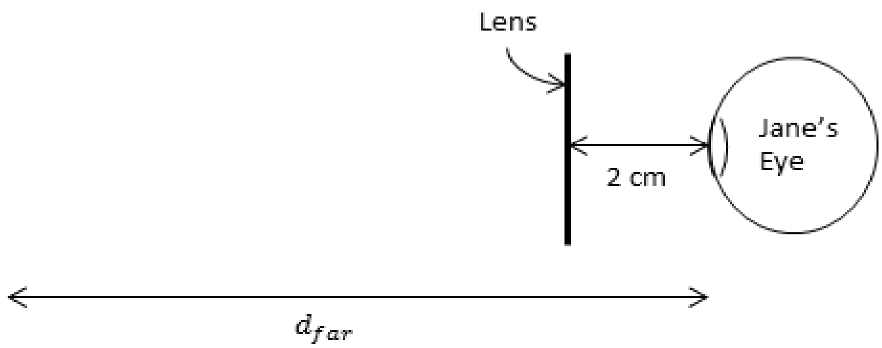
```
do = 12.189 + 25 = 37.189 cm
1/di = 1/f - 1/do = 1/25 - 1/37.189
     = 1/76.28 > 0 real
That is, actually the rays converge; this cannot
happen behind the mirror!
```

12) The final image from the lens mirror system is

a. real.
b. virtual.

```
since actually the rays are converging.
```

The next two questions pertain to the situation described below.



Jane is having trouble seeing through her glasses. Distant objects are blurry. Her corrective lenses sit 2 cm from her eyes as shown in the figure.

13) To correct her vision, Jane requires a

a. *converging lens.*
b. *diverging lens*
c. *neither.*

14) Jane's far-point is d_{far} = *35 cm*. Remembering that a diopter is $P = 1/f$ where f is measured in meters, what should her corrective lens prescription be?

a. *-3 diopters*
b. *2.9 diopters*
c. *-2.9 diopters*
d. *-2.7 diopters*
e. *3 diopters*

```
do = infity should be at 35 - 2= 33 cm virtual image
1/f = 1/¥infty - 1/33

 P = -100/33 = -3
```

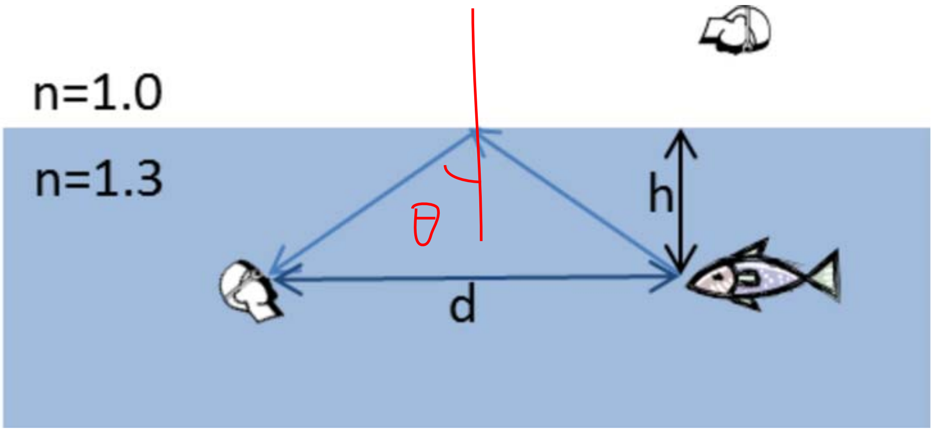
15) Compare the focal length of a converging lens when it is in air, to the focal length of the same lens when it is in water.

In water the effective refractive index is reduced, so its power is reduced -> f is larger in water

a. $f_{air} > f_{water}$
b. $f_{air} = f_{water}$
c. $f_{air} < f_{water}$

The next two questions pertain to the situation described below.

A fish is swimming in water with index of refraction $n = 1.3$ a distance $h = 1.8$ m below the surface of the water as shown in the figure.



16) What is the apparent depth of the fish as observed by a person directly above the fish?

1.8/1.3 = 1.3846 m

a. 2.34 m below the surface of the water.
b. 1.8 m below the surface of the water.
c. 1.38 m below the surface of the water.

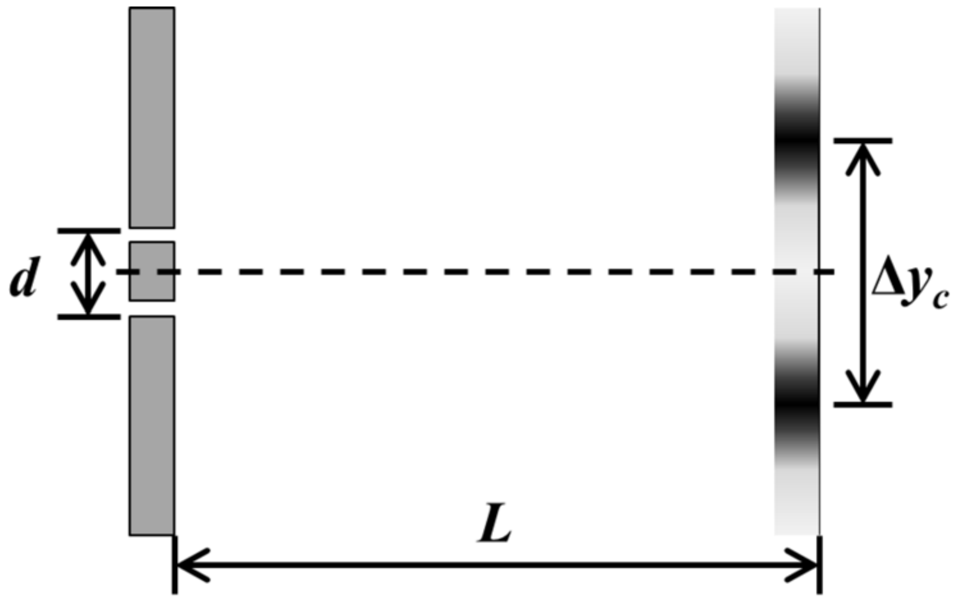
17) What is the closest distance d for which the person underwater can see a reflection of the fish from the air/water interface?

For the total reflection to occur,
1.3 sin theta = 1 or theta = 55.87 deg
h x tan theta = d/2, so
d = 2h tan(55.87)= 4.33 m

a. $d = 2.17$ m
b. $d = 4.33$ m
c. $d = 3.6$ m
d. $d = 5.63$ m
e. $d = 1.8$ m

The next two questions pertain to the situation described below.

Green light of wavelength $\lambda = 532$ nm illuminates a pair of slits separated by a distance $d = 0.42$ mm, as shown in the figure. An interference pattern is observed on a screen placed a distance L away.



interference
(bright)
d sin theta = m lambda
(dark)
d sin theta = (m+1/2)lambda

D yc/2L = lambda/2d

18) What is the distance L if the width of the central bright spot of the interference pattern is $\Delta y_c = 1.9$ cm.

L = (Dyc/lambda)d
= 1.9x10^{-2}x 0.42 x10^{-3}/532x10^{-9}
= 0.0015 x 10^{9-5} = 15 m

a. L =1.27 m
b. L =8.82 m
c. L =7.5 m
d. L = 15 m
e. L =4.52 m

19) Which light wavelength of light would produce a larger central bright spot than the green light used in the above problem?

a. Red-orange (635 nm)
b. Violet (405 nm)

Short-wavelength lights go straight!

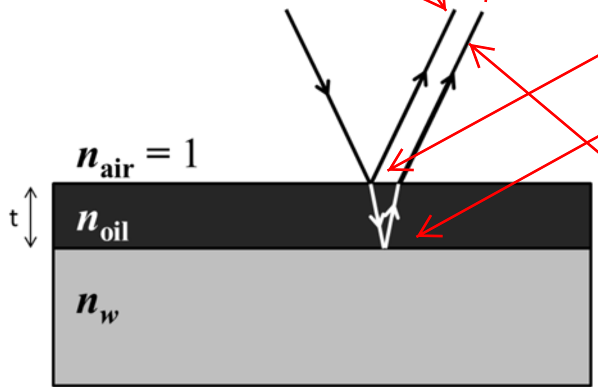
pi shift

2pi shift required

the reflection from an optically denser system -> pi shift of the pahse

The next two questions pertain to the situation described below.

A thin film of oil (n_{oil} = 1.5) of thickness t = 240 nm is floating on top of a puddle of water (n_w = 1.3) as shown in the figure.



Here, the reflection is from optically less dense material. no phase shift

These two rays must be out of phase: phases are pi different

20) For which of the following wavelengths λ (in vacuum) of light incident on the film will **destructive** interference be observed?

a. λ = 480 nm
b. λ = 720 nm
c. λ = 624 nm

The optical path length difference must correspond to one whole wave -> t = lamda/2 in the medium.

In the oil lambda/1.5 = 2t -> lambda = 3t = 720 nm

This is a tricky question.

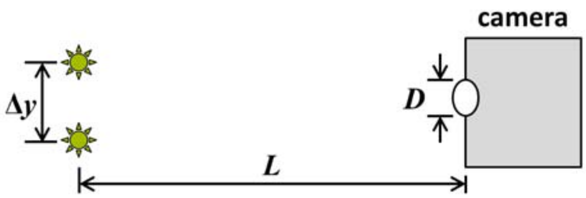
21) A film of oil of the same thickness t = 240 nm is resting on top of a block of plastic ($n_{plastic}$ = 1.8). If light of wavelength λ = 480 nm is incident on the oil, what type of interference will be observed?

a. Destructive
b. Constructive

because now we have the extra pi shift for the ray reflected between the oil and the plastic.

The next two questions pertain to the situation described below.

A pinhole camera with a circular aperture is used to make an image of two light sources separated by a distance Δy = 6.5 cm and located a distance L = 125 m away, as shown in the figure below. (Figure is not to scale.)



Rayleigh's criterion aperture
D sin theta = 1.22 lambda

22) If the light sources emit light of wavelength λ = 577 nm, what is the minimum aperture diameter D_{min} such that the two sources are just resolved by the pinhole camera?

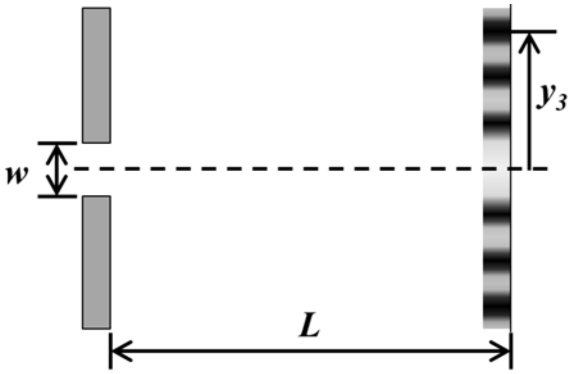
a. D_{min} = 6.77 mm
b. D_{min} = 1.69 mm
c. D_{min} = 1.35 mm
d. D_{min} = 1.08 mm
e. D_{min} = 3.38 mm

```
theta = Dy/L = 0.065/125,
D = 1.22 Lambda x L/Dy
  = 1.22 x 577 x 10^{-9} x 125/0.065
  = 0.0013537 m
```

23) If the apperture of the camera is too small to resolve the two lights, which of the following changes would help improve the resolution?

a. Replace the lights with ones that have a shorter wavelength.
b. Replace the lights with ones that have a longer wavelength.

A rectangular aperture of width w = 865 μm is illuminated by light of wavelength λ = 620 nm. A diffraction pattern is shown on a screen a distance L = 3.9 m away as shown in the figure.



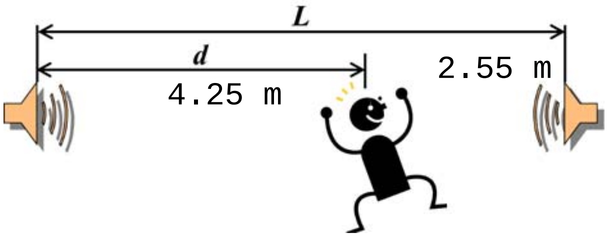
diffraction
a sin theta = m lambda

24) At what position y_3 will the third-order (m = 3) diffraction minimum be observed?

a. y_3 = 8.39 mm
b. y_3 = 41.9 mm
c. y_3 = 2.1 mm
d. y_3 = 3.35 mm
e. y_3 = 21 mm

```
865 x 10^{-6} sin theta = 3 x 620 x 10^{-9},
so theta = 3 x 620 x 10^{-9}/865 x 10^{-6}
   = 2.15 x 10^{-3} (rad)
y3 = theta x L = 8.386 x 10^{-3}
```

Two speakers are separated by a distance L = 6.8 m. You are standing between the speakers a distance d = 4.25 m away from the left speaker, as shown in the figure below.



The difference between the sound path lengths is 4.25 - 2.55 = 1.70 m

25) At first, each speaker emits a tone of frequency of 500 Hz. Then, each speaker emits a tone of frequency of 1000 Hz. Which of the tones, if any, will be the loudest? (Note: the speed of sound in air is 340 m/s.)

a. They will be equally loud.
b. The 500 Hz tone.
c. The 1000 Hz tone.

is the phase difference integer multiple of 2pi?

```
for 500 Hz lambda = 340/500 =  0.68 m
phase difference/2pi = (4.25 - 2.55)/0.68 = 2.5
This means there is a destructive interference

If 1000 Hz, then the wavelength is halved (0.34), so the phase
difference is 2.5 x 2 times 2pi -> constructive.
```

26) A diffraction grating has 3.7×10^5 slits per meter. Which of the following values is closest to the maximum wavelength of incident light such that the fifth-order (m = 5) bright fringe can still be seen?

a. 541 nm
b. 764 nm
c. 649 nm

Diffraction grating
max at d sin theta = m lambda

5 x lambda < (1/3.7 x 10^5) required (d =1/3.7 x 10^5)

lambda < 0.05405 x 10^{-5} = 540.5 nm

Mechanics:

$x = x_0 + v_0 t + \frac{1}{2} a t^2$ $v = v_0 + at$ $F = ma$ $a_c = \frac{v^2}{r}$

$E_{tot} = K.E. + P.E.$ $K.E. = \frac{1}{2} m v^2 = \frac{p^2}{2m}$ $p = mv$ $W_F = Fd\cos\theta$

Electrostatics:

$F_{12} = \frac{k q_1 q_2}{r^2}$ $E \equiv \frac{F}{q_0}$ $V \equiv \frac{U}{q_0}$ Point charge: $E = \frac{kq}{r^2}$, $V = \frac{kq}{r}$

$U_{12} = \frac{k q_1 q_2}{r}$ $W_E = -\Delta U = -W_{you}$

Capacitance:

$C \equiv \frac{Q}{V}$ Parallel plate capacitor: $C = \frac{\kappa \varepsilon_0 A}{d}$, $V = Ed$

$U_C = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $C_P = C_1 + C_2 + \cdots$ $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Resistance:

$R \equiv \frac{V}{I}$ $I = \frac{\Delta q}{\Delta t}$ Physical resistance: $R = \rho \frac{L}{A}$

$P = IV = I^2 R = \frac{V^2}{R}$ $R_S = R_1 + R_2 + \cdots$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Circuits:

$\sum \Delta V = 0$ $\sum I_{in} = \sum I_{out}$

$q(t) = q_\infty (1 - e^{-t/\tau})$ $q(t) = q_0 e^{-t/\tau}$ $I(t) = I_0 e^{-t/\tau}$ $\tau = RC$

Magnetism:

$F = qvB\sin\theta$ $r = \frac{mv}{qB}$ $F = ILB\sin\theta$ $\tau = NIAB\sin\varphi$

$B_{wire} = \frac{\mu_0 I}{2\pi r}$ $B_{sol} = \mu_0 n I$

Induction and inductance:

$\varepsilon = -N \frac{\Delta \Phi}{\Delta t}$ $\Phi = BA\cos\varphi$

$\varepsilon_{bar} = BLv$ $\varepsilon_{gen} = \varepsilon_{max} \sin\omega t = \omega NAB \sin\omega t$ $\omega = 2\pi f$

$L \equiv \frac{N\Phi}{I}$ $\varepsilon = -L \frac{\Delta I}{\Delta t}$ Solenoid inductor: $L = \mu_0 n^2 A \ell$ $U_L = \frac{1}{2} L I^2$

AC circuits and transformers:

$V_{rms} = \frac{V_{max}}{\sqrt{2}}$ $I_{rms} = \frac{I_{max}}{\sqrt{2}}$ $\frac{V_p}{V_s} = \frac{I_s}{I_p} = \frac{N_p}{N_s}$

$V_R(t) = V_{R,max}\sin(\omega t) = I_{max}R\sin(\omega t)$ $\omega = 2\pi f$

$V_C(t) = V_{C,max}\sin(\omega t - \pi/2) = I_{max}X_C\sin(\omega t - \pi/2)$ $X_C \equiv \frac{1}{\omega C}$

$V_L(t) = V_{L,max}\sin(\omega t + \pi/2) = I_{max}X_L\sin(\omega t + \pi/2)$ $X_L \equiv \omega L$

$V_{gen}(t) = V_{gen,max}\sin(\omega t + \varphi) = I_{max}Z\sin(\omega t + \varphi)$ $Z \equiv \sqrt{R^2 + (X_L - X_C)^2}$ $\tan\varphi = \frac{X_L - X_C}{R}$

$\overline{P} = I_{rms}V_{R,rms} = I_{rms}V_{gen,rms}\cos\varphi$ $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Electromagnetic waves:

$\lambda = \frac{c}{f}$ $E = cB$

$u_E = \frac{1}{2}\varepsilon_0 E^2$ $u_B = \frac{1}{2\mu_0}B^2$ $\overline{u} = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0}B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \frac{B_{rms}^2}{\mu_0}$ $S = I = \overline{u}c$

$f' = f\left(1 \pm \frac{u}{c}\right)$ $I = I_0\cos^2\theta$

Reflection and refraction:

$\theta_r = \theta_i$ $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ $f = \pm\frac{R}{2}$ $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$n_1\sin\theta_1 = n_2\sin\theta_2$ $v = \frac{c}{n}$ $\sin\theta_c = \frac{n_2}{n_1}$ $M = \frac{\theta'}{\theta} \approx \frac{d_{near}}{f}$

Interference and diffraction:

Double slit interference: $d\sin\theta = m\lambda$ $d\sin\theta = (m + \frac{1}{2})\lambda$ $m = 0, \pm 1, \pm 2\ldots$

Single-slit diffraction: $w\sin\theta = m\lambda$ $m = \pm 1, \pm 2\ldots$

Circular aperture: $D\sin\theta \approx 1.22\lambda$

Thin film: $\delta_1 = (0 \text{ or } \frac{1}{2})$ $\delta_2 = (0 \text{ or } \frac{1}{2}) + 2t\frac{n_{film}}{\lambda_0}$ $|\delta_2 - \delta_1| = (m \text{ or } m + \frac{1}{2})$ $m = 0, 1, 2\ldots$

Quantum mechanics:

$E = hf = \frac{hc}{\lambda}$ $\lambda = \frac{h}{p}$

Blackbody radiation: $\lambda_{max}T = 2.898\times 10^{-3}\, m\cdot K$ Photoelectric effect: $K.E. = hf - W_0$

$\Delta p_x \Delta x \geq \frac{\hbar}{2}$ $\hbar \equiv \frac{h}{2\pi}$

Bohr atom: $2\pi r_n = n\lambda$ $n = 1, 2, 3\ldots$ $L_n = mv_n r_n = n\hbar$

$$r_n = \left(\frac{\hbar^2}{mke^2}\right)\frac{n^2}{Z} \approx (5.29\times10^{-11} m)\frac{n^2}{Z}$$

$$E_n = -\left(\frac{mk^2e^4}{2\hbar^2}\right)\frac{Z^2}{n^2} \approx -(13.6\, eV)\frac{Z^2}{n^2}$$

$$\frac{1}{\lambda} \approx (1.097\times10^7 m^{-1}) Z^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Quantum atom: $L = \sqrt{\ell(\ell+1)}\hbar$ $\quad L_z = m_\ell \hbar$

Nuclear physics and radioactive decay:

$A = Z + N$ $\quad r \approx (1.2\times10^{-15} m) A^{1/3}$ $\quad E_0 = mc^2$

$\frac{\Delta N}{\Delta t} = -\lambda N$ $\quad N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $\quad T_{1/2} \equiv \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$

Special relativity:

$\Delta t = \gamma \Delta t_0$ $\quad L = \frac{L_0}{\gamma}$ $\quad \gamma \equiv \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

Constants and unit conversions:

$g = 9.8\, m/s^2$ $\quad e = 1.60\times10^{-19}\, C$

$\varepsilon_0 = 8.85\times10^{-12}\, C^2/Nm^2$ $\quad k \equiv \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\, Nm^2/C^2$ $\quad \mu_0 = 4\pi\times10^{-7}\, T\cdot m/A$

$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3\times10^8\, m/s$ $\quad h = 6.626\times10^{-34}\, J\cdot s$ $\quad hc = 1240\, nm\cdot eV$

$1 eV = 1.60\times10^{-19}\, J$ $\quad m_{proton} = 1.67\times10^{-27}\, kg = 938\, MeV$ $\quad m_{electron} = 9.11\times10^{-31}\, kg = 511\, keV$

SI Prefixes

Power	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^0	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p