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 virtual 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

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.
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 \( m = 0.65 \).

![Diagram of a diverging mirror with a candle and an image]

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
   
   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
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 \( f = 2.4 \text{ cm} \).

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

   a. \( d_i = 2.07 \text{ cm} \)
   b. \( d_i = 2.86 \text{ cm} \)
   c. no image is formed

7) The resulting image is also

   a. inverted
   b. neither
   c. upright

8) Now the candle is placed at \( d_o = 1.2 \text{ cm} \). Now the image is located at

   a. \( d_i = -2.4 \text{ cm} \)
   b. \( d_i = -0.8 \text{ cm} \)
   c. no image is formed

9) This new image is also

   a. real
   b. neither
   c. virtual
The next three questions pertain to the situation described below.

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

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

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

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.

12) The final image from the lens mirror system is

a. real.
b. virtual.
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 \( d_{\text{far}} = 35 \text{ cm} \). 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
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.

a. \( f_{\text{air}} > f_{\text{water}} \)

b. \( f_{\text{air}} = f_{\text{water}} \)

c. \( f_{\text{air}} < f_{\text{water}} \)

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?

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?

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.

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.

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)
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.

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

   a. \( \lambda = 480 \) nm
   b. \( \lambda = 720 \) nm
   c. \( \lambda = 624 \) nm

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 \( \lambda = 480 \) nm is incident on the oil, what type of interference will be observed?

   a. Destructive
   b. Constructive
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 $\Delta y = 6.5$ cm and located a distance $L = 125$ m away, as shown in the figure below. (Figure is not to scale.)

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

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

23) If the aperture 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 \( w = 865 \, \mu m \) is illuminated by light of wavelength \( \lambda = 620 \, \text{nm} \). A diffraction pattern is shown on a screen a distance \( L = 3.9 \, \text{m} \) away as shown in the figure.

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

a. \( y_3 = 8.39 \, \text{mm} \)
b. \( y_3 = 41.9 \, \text{mm} \)
c. \( y_3 = 2.1 \, \text{mm} \)
d. \( y_3 = 3.35 \, \text{mm} \)
e. \( y_3 = 21 \, \text{mm} \)

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

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.
26) A diffraction grating has $3.7 \times 10^5$ 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

Answers
1. b  
2. c  
3. c  
4. a  
5. a  
6. c  
7. a  
8. a  
9. c  
10. a  
11. d  
12. a  
13. b  
14. a  
15. c  
16. c  
17. b  
18. d  
19. a  
20. b  
21. a  
22. c  
23. a  
24. a  
25. c  
26. a
Mechanics:
\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]  
\[ v = v_0 + a t \]  
\[ F = ma \]  
\[ a_c = \frac{v^2}{r} \]  
\[ E_{tot} = K.E. + P.E. \]  
\[ K.E. = \frac{1}{2} m v^2 = \frac{p^2}{2m} \]  
\[ p = mv \]  
\[ W_F = F d \cos \theta \]

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:  
\[ E = \frac{kq}{r^2}, \quad V = \frac{q}{r} \]
\[ U_{12} = \frac{k q_1 q_2}{r} \]  
\[ W_E = -\Delta U = -W_{you} \]

Capacitance:
\[ C \equiv \frac{Q}{V} \]  
Parallel plate capacitor:  
\[ C = \frac{k \varepsilon_0 A}{d}, \quad V = Ed \]  
\[ U_C = \frac{1}{2} Q V = \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C} \]  
\[ C_p = C_1 + C_2 + \cdots \]  
\[ \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \]

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:
\[ F = q v B \sin \theta \]  
\[ r = \frac{m v}{q B} \]  
\[ F = IL B \sin \theta \]  
\[ \tau = NIAB \sin \phi \]
\[ B_{wire} = \frac{\mu_0 I}{2 \pi r} \]  
\[ B_{sol} = \mu_0 n I \]

Induction and inductance:
\[ \varepsilon = -N \frac{\Delta \Phi}{\Delta t} \]  
\[ \Phi = BA \cos \phi \]  
\[ \varepsilon_{bar} = BL V \]  
\[ \varepsilon_{gen} = \varepsilon_{max} \sin \omega t = \omega N A B \sin \omega t \]  
\[ \omega = 2 \pi f \]
\[ L \equiv \frac{N \Phi}{I} \]  
\[ \varepsilon = -L \frac{\Delta I}{\Delta t} \]  
Solenoid inductor:  
\[ L = \mu_0 n^2 A \ell \]  
\[ U_L = \frac{1}{2} L I^2 \]

AC circuits and transformers:
\[ V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \quad I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} \quad \frac{V_p}{V_s} = \frac{I_p}{I_s} = \frac{N_p}{N_s} \]

\[ V_R(t) = V_{R,\text{max}} \sin(\omega t) = I_{\text{max}} R \sin(\omega t) \quad \omega = 2\pi f \]

\[ V_C(t) = V_{C,\text{max}} \sin(\omega t - \pi/2) = I_{\text{max}} X_C \sin(\omega t - \pi/2) \quad X_C = \frac{1}{\omega C} \]

\[ V_L(t) = V_{L,\text{max}} \sin(\omega t + \pi/2) = I_{\text{max}} X_L \sin(\omega t + \pi/2) \quad X_L = \omega L \]

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

\[ \bar{P} = I_{\text{rms}} V_{R,\text{rms}} = I_{\text{rms}} V_{\text{gen, rms}} \cos \varphi \quad f_0 = \frac{1}{2\pi \sqrt{LC}} \]

**Electromagnetic waves:**

\[ \lambda = \frac{c}{f} \quad E = cB \]

\[ u_E = \frac{1}{2} \varepsilon_0 E^2 \quad u_B = \frac{1}{2\mu_0} B^2 \quad \vec{u} = \frac{1}{2} \varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0} B_{\text{rms}}^2 = \varepsilon_0 E_{\text{rms}}^2 = \frac{B_{\text{rms}}^2}{\mu_0} \quad S = I = \vec{u} c \]

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

**Reflection and refraction:**

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

\[ n_1 \sin \theta_i = n_2 \sin \theta_2 \quad v = \frac{c}{n} \quad \sin \theta_c = \frac{n_2}{n_1} \quad M = \frac{\theta'}{\theta} \approx \frac{d_{\text{near}}}{f} \]

**Interference and diffraction:**

- Double slit interference: \( d \sin \theta = m\lambda \quad d \sin \theta = (m + \frac{1}{2})\lambda \quad m = 0, 1, 2, \ldots \)
- Single-slit diffraction: \( w \sin \theta = m\lambda \quad m = 1, 2, \ldots \)
- Circular aperture: \( D \sin \theta \approx 1.22\lambda \)
- Thin film: \( \delta_1 = (0 \text{ or } \frac{1}{2}) \quad \delta_2 = (0 \text{ or } \frac{1}{2}) + 2f \frac{n_{\text{film}}}{\lambda_0} \quad |\delta_2 - \delta_1| = (m \text{ or } m + \frac{1}{2}) \quad m = 0, 1, 2, \ldots \)

**Quantum mechanics:**

\[ E = hf = \frac{hc}{\lambda} \quad \lambda = \frac{h}{p} \]

\[ \Delta p_x \Delta x \geq \frac{h}{2} \quad h = \frac{h}{2\pi} \]

\[ 2\pi r_n = n\lambda \quad n = 1, 2, 3, \ldots \quad L_n = mv_n r_n = nh \]
\[ r_n = \left( \frac{\hbar^2}{mke^2} \right) \frac{n^2}{Z} \approx (5.29 \times 10^{-11} m) \frac{n^2}{Z} \]

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

\[ \frac{1}{\lambda} \approx (1.097 \times 10^7 m^{-1}) Z^2 \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \]

Quantum atom: \[ L = \sqrt{\ell(\ell+1)} \hbar \]

\[ L_z = m_i \hbar \]

**Nuclear physics and radioactive decay:**

\[ A = Z + N \quad r \approx (1.2 \times 10^{-15} m) A^{1/3} \quad E_0 = mc^2 \]

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

**Special relativity:**

\[ \Delta t = \gamma \Delta t_0 \quad L = \frac{L_0}{\gamma} \]

\[ \gamma \equiv \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \]

**Constants and unit conversions:**

\[ g = 9.8 \text{ m} / \text{s}^2 \quad e = 1.60 \times 10^{-19} \text{ C} \]

\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{Nm}^2 \quad k \equiv \frac{1}{4\pi \varepsilon_0} = 8.99 \times 10^9 \text{ Nm}^2 / \text{C}^2 \quad \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A} \]

\[ c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3 \times 10^8 \text{ m} / \text{s} \quad h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \quad hc = 1240 \text{nm} \cdot \text{eV} \]

\[ 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \quad m_{\text{proton}} = 1.67 \times 10^{-27} \text{ kg} = 938 \text{ MeV} \quad m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg} = 511 \text{ keV} \]

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<th>SI Prefixes</th>
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Physics 102 Exam 3 –
Spring 2014

1. b
2. c
3. c
4. a
5. a
6. b
7. a
8. a
9. c
10. a
11. d
12. a
13. b
14. a
15. c
16. c
17. b
18. d
19. a
20. b
21. a
22. c
23. a
24. a
25. c
26. a