Physics 161 - Final Exam  
Prof. Kloet  
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3. During the exam, you may use pencils, a calculator, and three handwritten 8.5 x 11 inch sheets with formulas and notes, without attachments.

4. There are 30 multiple-choice questions on the exam. For each question mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.

5. At the end of the exam, hand in only the signed cover sheet with your answers. Retain the question sheets for future reference and study.

6. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.

BATHROOM RULE: ONE PERSON AT A TIME

Good Luck!
Natural Constants, etc.

- $N_A = 6.02 \times 10^{23} \, mol^{-1}$
- $k_B = 1.38 \times 10^{-23} \, J/K$
- $R = 8.31 \, J/mol/K$
- $G = 6.67 \times 10^{-11} \, N \cdot m^2/kg^2$, and $g = 9.8 \, m/s^2$
- $e = 1.602 \times 10^{-19} \, C$
- $m_e = 9.11 \times 10^{-31} \, kg$
- $m_p = 1.67 \times 10^{-27} \, kg$
- $k_e = 8.99 \times 10^9 \, N.m^2/C^2$
- $\epsilon_0 = 8.85 \times 10^{-12} \, C^2/N.m^2$ (permittivity of free space)
- $c = 3.0 \times 10^8 \, m/s$
- $1 \, \text{atm} = 1.013 \times 10^5 \, Pa$, and $1 \, \text{m}^3 = 1000 \, \text{liter}$
- $m_{\text{earth}} = 5.98 \times 10^{24} \, kg$, and $R_{\text{earth}} = 6.38 \times 10^6 \, m$
- $T_C = T_K - 273.15$
- $c_{\text{water}} = 4186 \, J/kg/\degree C$
- $c_{\text{ice}} = 2090 \, J/kg/\degree C$, and $L_{\text{ice}} = 3.33 \times 10^5 \, J/kg$
- $\rho_{\text{water}} = 1000 \, kg/m^3$, and $\rho_{\text{ice}} = 917 \, kg/m^3$
- $\log(ab) = \log(a) + \log(b)$, and $\log(a/b) = \log(a) - \log(b)$
1. In a double slit interference experiment the distance between the slits is 0.020 \text{ mm} and the distance between the slits and screen is 1.20 \text{ m}. The m = 2 bright fringe appears at 9.00 \text{ cm} from the central m = 0 bright line. What is the wavelength of the light?
   a) 563 \text{ nm}
   b) 690 \text{ nm}
   c) 614 \text{ nm}
   d) 490 \text{ nm}
   e) 750 \text{ nm}

2. A converging lens has a focal length of 26.0 \text{ cm}. The object is at 15 \text{ cm} in front of the lens. Is the image real or virtual and what is its location?
   a) real image at 9.5 \text{ cm} in back of the lens
   b) virtual image at 9.5 \text{ cm} in front of the lens
   c) real image at 35.5 \text{ cm} in back of the lens
   d) virtual image at 35.5 \text{ cm} in back of the lens
   e) virtual image at 35.5 \text{ cm} in front of the lens

3. A diverging lens has a focal length of 26.0 \text{ cm}. The object is at 15 \text{ cm} in front of the lens. Is the image real or virtual and what is its location?
   a) real image at 9.5 \text{ cm} in back of the lens
   b) virtual image at 9.5 \text{ cm} in front of the lens
   c) real image at 35.5 \text{ cm} in back of the lens
   d) virtual image at 35.5 \text{ cm} in back of the lens
   e) virtual image at 35.5 \text{ cm} in front of the lens

4. A concave mirror has a focal length of 26.0 \text{ cm}. The object is at 15 \text{ cm} in front of the mirror. Is the image real or virtual and what is its location?
   a) real image at 9.5 \text{ cm} in back of the mirror
   b) virtual image at 9.5 \text{ cm} in front of the mirror
   c) real image at 35.5 \text{ cm} in back of the mirror
   d) virtual image at 35.5 \text{ cm} in back of the mirror
   e) virtual image at 35.5 \text{ cm} in front of the mirror

5. A convex mirror has a focal length of 26.0 \text{ cm}. The object is at 15 \text{ cm} in front of the mirror. Is the image real or imaginary and what is its location?
   a) virtual image at 9.5 \text{ cm} in back of the mirror
   b) real image at 9.5 \text{ cm} in front of the mirror
   c) real image at 35.5 \text{ cm} in back of the mirror
   d) virtual image at 35.5 \text{ cm} in back of the mirror
   e) virtual image at 35.5 \text{ cm} in front of the mirror

6. A converging lens is placed 26.0 \text{ cm} to the right of a diverging lens of focal length of 7.0 \text{ cm}. A light beam, parallel to the axis, enters the diverging lens from the left. The beam is again parallel when it emerges from the converging lens. What is the focal length of the converging lens?
   a) 7.0 \text{ cm}
   b) 26.0 \text{ cm}
   c) 19.0 \text{ cm}
   d) 33.0 \text{ cm}
   e) 40.0 \text{ cm}

7. A light ray propagating in medium A is incident under an angle of 55^\circ on medium B and refracts as shown in the figure. The same light ray propagating in medium A refracts upon entering medium C as shown in the figure. What is the relation for the wavelength of the light ray in media A, B, C?
   a) \lambda_C < \lambda_B < \lambda_A
   b) \lambda_B < \lambda_A < \lambda_C
   c) \lambda_C < \lambda_A < \lambda_B
   d) \lambda_B < \lambda_C < \lambda_A
   e) \lambda_A = \lambda_B = \lambda_C
8. A beaker half-full of water rests on a scale which is calibrated in grams. Later, a stone of volume 1 cm$^3$ and density 5 g/cm$^3$ is suspended from a massless cord and fully submerged in the water without touching the beaker. The water does not overflow. The reading on the scale
   a) does not change
   b) increases by 1 gm
   c) increases by 4 gm
   d) increases by 5 gm
   e) decreases by 1 gm

9. The gas in a container in thermal equilibrium at 300$^\circ$K consists of 3 grams of neon and 10 grams of helium.
   a) The temperature of the neon molecules is different from that of the helium molecules.
   b) The rms speeds of the two kinds of molecules are different but the average kinetic energies are the same.
   c) The rms speeds of the two kinds of molecules are the same, but the average kinetic energies are different.
   d) The rms speeds and the average kinetic energies of the two kinds of molecules are the same.
   e) The rms speeds and the average kinetic energies of the two kinds of molecules are different.

10. Block A, with a mass of 10 kg, rests on a 30$^\circ$ incline. The incline is frictionless. The attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. Block B, with a mass of 3.0 kg, is attached to the dangling end of the string. The acceleration of B is:
   a) 1.5 m/s$^2$, up
   b) 1.5 m/s$^2$, down
   c) 4.3 m/s$^2$, up
   d) 4.3 m/s$^2$, down
   e) 0

11. A parallel plate capacitor has a capacitance $C = 3 \times 10^{-8}$ Farad. How much electrical energy does this capacitor store if the potential difference over the plates is 4,920 Volts?
   a) 0.36 J
   b) 72 J
   c) 7,130 J
   d) 14,300 J
   e) 28,500 J

12. Three light bulbs, labeled 75 W, 60 W, and 40 W, are connected in series to an AC outlet source as shown. Which of the statements below is correct? (hint: The power label of a light bulb is given as $P = V^2/R$ for the case where $V$ is 110 Volts and $R$ is the resistance of the bulb.)
   a) The 75 W bulb appears brightest
   b) The 60 W bulb appears brightest
   c) The 40 W bulb appears brightest
   d) All 3 bulbs appear equally bright
   e) None of the bulbs light up

13. A positive charge $4Q$ and a negative charge $-Q$ are located at $x = 0$ and $x = d$ ($d > 0$), respectively. Where should a third charge $q$ be placed on the x-axis such that the net force on $q$ is zero?
   a) $x = -d$
   b) $x = 2d$
   c) $x = 0.5d$
   d) $x = 3d$
   e) It depends on the sign of the charge $q$
14. The index of refraction for glass is 1.50, that for water is 1.33. Total internal reflection:
   a) always occurs when light originates in water and tries to enter glass
   b) always occurs when light originates in glass and tries to enter water
   c) may occur when light originates in water and tries to enter glass
   d) may occur when light originates in glass and tries to enter water
   e) never occurs at either side of the interface between glass and water

15. The car model Lamborghini Huracán can reach a speed of 60 miles/hour in 2.5 seconds after starting from rest. Assume this speed is reached at constant acceleration. What is its 1/4 mile time (How long does it take to go 0.25 mile starting from rest)? (1 mile = 1609 m)
   a) 2.50 s
   b) 5.00 s
   c) 7.50 s
   d) 8.66 s
   e) 10.4 s

17. A charge of $+1 \times 10^{-9}$ C and another charge of $-1 \times 10^{-9}$ C are separated by 1 m. What is the magnitude of the electric potential at the point midway between the two charges?
   
   a) 0 V
   b) 18 V
   c) 27 V
   d) 36 V
   e) 72 V

18. Doubling the weight suspended vertically from a coil spring will result in a change in the displacement of the spring's lower end by what factor?
   
   a) 0.5
   b) 1.0
   c) 2.0
   d) 4.0
   e) 0.25

19. Suppose the half life of an isotope is 5 seconds. A sample contains $N_0$ nuclei of that isotope. What fraction of the original sample is left after 20 seconds?
   
   a) $N_0/4$
   b) $N_0/5$
   c) $N_0/10$
   d) $N_0/16$
   e) $N_0/20$

20. A harmonic wave is traveling along a rope. It is observed that the oscillator that generates the wave completes 40 vibrations in 30 seconds. Also a given maximum travels 425 cm along the rope in 10 seconds. What is the wavelength?
   
   a) 0.425 m
   b) 0.319 m
   c) 0.566 m
   d) 0.750 m
   e) 1.333 m
21. Two charges of equal magnitude 5.0μC, but opposite sign, are separated by a distance of 6.0 m. What is the magnitude of the electric field midway between them.

- a) 10000 N/C
- b) 5000 N/C
- c) 2500 N/C
- d) 1250 N/C
- e) 0 N/C

22. Blocks A and B are moving toward each other. A has a mass of 2.0 kg and a velocity of 50 m/s, while B has a mass of 4.0 kg and a velocity of -25 m/s. They suffer a completely inelastic collision. The kinetic energy lost during the collision is:

- a) 0
- b) 1250 J
- c) 3750 J
- d) 5000 J
- e) 5600 J

23. Which of the curves on the graph below best represents the vertical component \( v_y \) of the velocity versus the time \( t \) for a projectile fired at an angle of 45° above the horizontal?

24. A projectile is shot vertically upward with a given initial velocity. It reaches a maximum height of 100 m. If, on a second shot, the initial velocity is doubled then the projectile will reach a maximum height of:

- a) 70.7 m
- b) 141 m
- c) 200 m
- d) 241 m
- e) 400 m

25. Increasing the tension in a guitar string to 4 times the original tension will change its fundamental frequency by what factor?

- a) 1.4
- b) 1.0
- c) 2.0
- d) 4.0
- e) 16.0

26. The volume of an ideal gas changes from 0.40 m\(^3\) to 0.58 m\(^3\) although its pressure remains constant at 51000 Pa. What work is done on the system by its environment?

- a) -9180 J
- b) 9180 J
- c) -20400 J
- d) 20400 J
- e) -29580 J

27. A beam of light in air (\( n = 1 \)) is incident on the surface of a rectangular block of plastic (\( n = 1.48 \)). The speed of the beam before it enters the plastic is \( 3.00 \times 10^8 \) m/s. What is the speed of light inside the block?

- a) \( 3.00 \times 10^8 \) m/s
- b) \( 1.37 \times 10^8 \) m/s
- c) \( 2.03 \times 10^8 \) m/s
- d) its speed will depend on its angle of incidence
- e) \( 1.56 \times 10^8 \) m/s
28. A 250 kg box is placed on a ramp. As one end of the ramp is raised, the box begins to move downward just as the angle of inclination reached 20°. What is the coefficient of static friction between box and ramp?
   a) 0.47
   b) 0.36
   c) 0.73
   d) 0.30
   e) 0.85

29. A quantity of monoatomic gas is compressed isothermally from a volume $2V_0$ to volume $V_0$. The initial pressure is $P_0$. What is a correct statement about this process?
   a) There is no heat added or extracted from the gas
   b) The pressure decreases to 0.5 $P_0$
   c) The sum of heat added to the gas and work done on the gas is zero
   d) Heat added to the gas is equal to the work done on the gas
   e) The work on the gas is negative

30. An electric circuit consists of a battery of 12 V and three resistors of 6, 9, 12 Ω arranged as in the figure. What is the current in the 12 Ω resistor?
   a) 1.33 A
   b) 0.46 A
   c) 0.62 A
   d) 0.78 A
   e) 2.00 A