This exam consists of 18 problems. Please check that you have all of them. Please sign the op-scan sheet and print your name on it. Use a #2 pencil to fill in your full name, your student identification number (old one), and finally the answers for problems 1–18. Please be prepared to show your Purdue ID when you hand in your opscan sheet.

A 8 1/2" x 11" crib sheet of your own creation is allowed. You can also consult the crib sheets that you have prepared for Exam 1 and 2 or the formula sheet provided on the Phys 220 web page.

Useful constants and conversions factors:

Average Atmospheric pressure: 101.3 kPa

Density of Water (3.98 °C) = 1000 kg/m³

Specific heat of water (1 ATM, ≈ 20 °C) = 1.00 \( \frac{\text{kcal}}{\text{kg} \cdot \text{K}} = 4.186 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \)

Atomic mass unit = \( u = 1.66 \times 10^{-27} \text{ kg} \)

1 cal = 4.186 J

1 Cal = 1000 cal

1 liter = 10⁻³ m³

1 atm = 0.1013 MPa

\[ R = N_A k_B = 8.31 \frac{J}{K \text{ mol}} \]

\[ k_B = 1.38 \times 10^{-23} \frac{J}{K} \quad N_A = 6.022 \times 10^{23} \text{ mol}^{-1} \]

\[ \sigma = 5.670 \times 10^{-8} \text{ W} / (\text{m}^2 \text{ K}^4) \]

\[ g = 9.8 \text{ m/s}^2 \]
1. An ambulance is generating a siren sound at a frequency of 2,400 Hz. The velocity of sound is 345 m/s. If the ambulance is traveling at a velocity of 24.0 m/s away from the stationary observer, then what is the frequency of the siren perceived by the observer?

A) 2,375 Hz  
B) 2,306 Hz  
C) 2,266 Hz  
D) 2,244 Hz  
E) 2,210 Hz  

2. A submarine is at a depth of 500 m under the water. The force on a circular hatch of 1.0 m in diameter due to the seawater (density = 1.025 kg/m$^3$) pressure from outside the submarine is,

A) 2.45 $\times 10^6$ N  
B) 3.95 $\times 10^6$ N  
C) 4.94 $\times 10^6$ N  
D) 5.50 $\times 10^6$ N  
E) 6.34 $\times 10^6$ N
3. A roller coaster has a vertical loop with radius 20 m. With what minimum speed should the roller coaster car be moving at the top of the loop so that passengers do not lose contact with the seats?

A) 14 m/s  
B) 28 m/s  
C) 0 m/s  
D) 7 m/s  
E) 9.8 m/s

4. A 2000 kg car is traveling at 20 m/s and then puts on the brakes and comes to a complete stop. All of the work required to stop the car is converted into heat and absorbed by the brakes.

The mass of the brake system is 20 kg and has a specific heat of 0.84 kJ/(kg °C). What is the increase in the temperature of the brakes?

A) 75.3 °C  
B) 53.1 °C  
C) 23.8 °C  
D) 18.9 °C  
E) 12.4 °C
5. A sample of CO₂ has a mass of 50.0 grams. What is the number of molecules of carbon dioxide in the 50.0 gram sample? (C=12u, O=16u)

A) $4.02 \times 10^{23}$
B) $4.95 \times 10^{23}$
C) $5.66 \times 10^{23}$
D) $6.02 \times 10^{23}$
E) $6.84 \times 10^{23}$

6. Chris and Jamie are carrying Wayne on a horizontal stretcher. The uniform stretcher is 2.0 m long and weighs 100 N. Wayne weighs 800 N. Wayne’s center of gravity is 75 cm from Chris. Chris and Jamie are at the ends of the stretcher. The force that Jamie is exerting to support the stretcher with Wayne on it, is

A) 250 N
B) 300 N
C) 350 N
D) 400 N
E) 550 N

7. When 2 kg of water evaporates, $22.6 \times 10^5$ J/kg of heat are needed. What is the entropy change in the boiling process?

A) 12,120 J/K
B) 8,566 J/K
C) 6,750 J/K
D) 5,844 J/K
E) 0 J/K
8. A string on a guitar is stretched between two points 35 cm apart with a tension of 65 N. The mass/length of the string is 0.004 kg/m. The frequency of the mode of vibration with the lowest frequency is,

A) 315 Hz  
B) 276 Hz  
C) 250 Hz  
D) 205 Hz  
E) 182 Hz

9. A ski lift carries passengers up a 150 m high slope at the rate of one chair every 30 seconds. If the chair will hold two passengers with a total mass of 190 kg, then the power of the engine that powers the ski lift is,

A) 6.96 kWatts  
B) 7.83 kWatts  
C) 8.75 kWatts  
D) 9.32 kWatts  
E) 9.90 kWatts

10. 0.5 moles of an ideal gas has a volume of 0.01 m³ and a temperature of 300 K. What is the pressure of the sample of gas?

A) 125 kPa  
B) 143 kPa  
C) 157 kPa  
D) 198 kPa  
E) 217 kPa
11. Water is flowing through a pipe with a constriction. The diameter of the narrow section is one-third the diameter of the wide section. If the velocity of the incompressible fluid is 3.6 m/s in the narrow section, then what is the velocity of the fluid in the wide section?

A) 2.0 m/s  
B) 1.8 m/s  
C) 1.4 m/s  
D) 1.0 m/s  
E) 0.4 m/s

12. A transverse periodic wave is represented by the equation

\[ y(x,t) = (2.5 \text{ cm}) \cos \left( 2,500 \text{ rad/s} \cdot t - (15.0 \text{ m}^{-1}) \cdot x \right) \].

What is the velocity of the wave?

A) 33.3 m/s  
B) 0.167 m/s  
C) 333 m/s  
D) 6 m/s  
E) 167 m/s

13. A runner starts from rest and with an acceleration of 1.0 m/s² travels a distance of 10 meters. The time it takes the runner to cover the distance is,

A) 6.3 s  
B) 5.7 s  
C) 5.0 s  
D) 4.5 s  
E) 3.8 s
14. The PV diagram for an ideal gas is shown in the figure below where:
\( P_1 = 4.04 \times 10^4 \) Pa, \( V_1 = 1 \times 10^{-3} \) m\(^3\), \( T_1 = 200 \) K,
\( P_2 = 1.01 \times 10^5 \) Pa, \( V_2 = 4 \times 10^{-3} \) m\(^3\), and \( T_2 = 800 \) K.

What is the change in the internal energy of the gas in the isobaric (same pressure) process from point a to point b?

A) -1,820 J
B) +1,820 J
C) -3,770 J
D) +3,770 J
E) -5,590 J

15. A ball with a diameter of 10 cm is submerged in water. The buoyant force of the water on the ball is,

A) 4.25 N
B) 4.75 N
C) 5.13 N
D) 5.75 N
E) 6.00 N
16. A pendulum is made with a 4.0 kg mass suspended at the end of a thin massless rod. The period of the small angle simple harmonic motion is 1.0 sec. What is the length of the thin rod?

A) 24.8 cm
B) 29.7 cm
C) 31.4 cm
D) 34.1 cm
E) 36.2 cm

17. If 30 kcal of heat are supplied to $5.00 \times 10^2$ g of water at 22 °C what is the final temperature of the water?

A) 60 °C
B) 82 °C
C) 22 °C
D) 100 °C
E) 0 °C

18. A 1200 kg car travels at 25 m/s and collides head-on in a perfectly inelastic collision with a stationary 2400 kg truck. The kinetic energy lost in the collision is,

A) 330,000 J
B) 250,000 J
C) 125,000 J
D) 95,000 J
E) 75,000 J
Translation

\[ m \]
\[ x \]
\[ v_{av} = \frac{\Delta x}{\Delta t} \]
\[ a_{av} = \frac{\Delta v}{\Delta t} \]
\[ v = v_0 + at \]
\[ x - x_0 = \frac{1}{2}(v + v_0)t \]
\[ x - x_0 = v_0 t + \frac{1}{2}at^2 \]
\[ v^2 = v_0^2 + 2a(x - x_0) \]
\[ \Sigma F = m \ddot{a} \]
\[ \ddot{p} = m \ddot{v} \]
\[ \Sigma F_{av} = \frac{\Delta \ddot{p}}{\Delta t} \]
\[ W = F \Delta r \cos \theta \]
\[ K = \frac{1}{2}mv^2 \]
\[ U = mgy + \frac{1}{2}kx^2 \]
\[ P = Fv \cos \theta \]
\[ f = \mu N \]
\[ F = kx \]

Translation ↔ Rotation Conversion

\[ v = r \omega \quad a_r = \frac{v^2}{r} = \omega^2 r \]
\[ a_t = r \alpha \quad \tau = r \perp F = rF \perp = rF \sin \theta \]

Constants

\[ g = 9.8 m/s^2 \]
\[ G = 6.67 \times 10^{-11} N \cdot m^2 / kg^2 \]
\[ M_E = 5.98 \times 10^{24} kg \]
\[ R_E = 6.37 \times 10^8 m \]
\[ \rho_{water} = 1000 kg / m^3 \]

Rotation

\[ l = \sum m_i r_i^2 \]
\[ \theta \]
\[ \omega_{av} = \frac{\Delta \theta}{\Delta t} \]
\[ \alpha_{av} = \frac{\Delta \omega}{\Delta t} \]
\[ \omega = \omega_0 + at \]
\[ \theta - \theta_0 = \frac{1}{2}(\omega + \omega_0)t \]
\[ \theta - \theta_0 = \omega_0 t + \frac{1}{2} \alpha t^2 \]
\[ \omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0) \]
\[ \Sigma \tau = l \alpha \]
\[ L = I \omega \]
\[ \Sigma \tau_{av} = \frac{\Delta L}{\Delta t} \]
\[ W = \tau \theta \]
\[ K = \frac{1}{2} I \omega^2 \]

Gravitational Force

\[ F = \frac{G m_1 m_2}{r^2} \]

Fluids

\[ \rho = \frac{m}{V} \]
\[ P = \frac{F}{A} \]
\[ P_2 = P_1 + \rho gd \]
\[ Av = \text{constant} \]

Sound

\[ \beta = (10dB) \log_{10} \left( \frac{l}{l_0} \right) \]
\[ \text{where } l_0 = 10^{-12} W/m^2 \]
\[ f_0 = \left( \frac{1 - \frac{v_0}{V}}{1 - \frac{v_s}{V}} \right) f_s \]

Elasticity

\[ F = \frac{\Delta L}{A} \]
\[ F = \frac{S \Delta x}{L} \]
\[ \Delta P = -B \frac{\Delta V}{V} \]

Simple Harmonic Motion

\[ a_x = -\omega^2 x \]
\[ x = A \cos(\omega t) \]
\[ E = \frac{1}{2} kA^2 \]
\[ \omega = 2 \pi f = \frac{2 \pi}{T} \]
\[ \omega = \sqrt{\frac{k}{m}} \]
\[ \omega = \sqrt{g} \]

Traveling Wave

\[ v = \lambda f \]
\[ k = \frac{2 \pi}{\lambda} \]
\[ y = A \cos(\omega t - kx) \]
Temperature

\[ T_c = T - 273.15 \]

\[ \Delta L/L = \Delta A/2A = \Delta V/3V = \alpha \Delta T \]

Ideal gas

\[ N_A = 6.022 \times 10^{23} \text{ mol}^{-1} \]
\[ k = 1.38 \times 10^{-23} \text{ J/K} \]
\[ R = N_A k = 8.31 J/mol \cdot K \]

\[ \text{molecules/mol} = N/n = N_A \]

\[ 1u = 1.66 \times 10^{-27} \text{ kg} \]

\[ PV = NkT = nRT = \frac{2}{3} N \langle K_r \rangle \]

Heat

\[ 1 \text{ cal} = 4.186 \text{ J} \]
\[ 1 \text{ Calorie} = 1,000 \text{ cal} \]

heat capacity = \( Q/\Delta T \)

specific heat capacity = \( Q/(m\Delta T) \)

molar specific heat \( C = Q/(n\Delta T) \)

for monatomic ideal gas at constant volume:

\[ Q = \frac{3}{2} nR\Delta T = nC_v\Delta T \]

latent heat \( L = \frac{|Q|}{m} \)

Heat Conduction

\[ I_{cd} = Q/t = \kappa A \Delta T/d \]

\[ R = \frac{d}{\kappa A} \]

\[ R - \text{factor} = \frac{d}{\kappa} = RA \]

with units:

\[ (\circ F \cdot ft^2/(\text{Btu/h})) \]
Physics 220 Final Exam

1. D
2. B
3. A
4. C
5. E
6. C
7. A
8. E
9. D
10. A
11. E
12. E
13. D
14. B
15. C
16. A
17. B
18. B