

SOLUTIONS

Physics 2101, Exam #4, Fall 2009

November 24, 2009

Name: _____

SOLUTIONS

ID#: _____

Section: (Circle one)

1 (Chastain, MWF 8:40 AM)

4 (Plummer, TTh 9:10)

2 (Chastain, MWF 10:40 AM)

5 (Adams, TTh 12:10)

3 (Rupnik, MWF 12:40 PM)

- Please be sure to write (print) your name and circle your section above.
- Please turn OFF your cell phone and MP3 player!
- Feel free to detach, use, and keep the formula sheet. No other reference material is allowed during the exam.
- You may use either a scientific or a graphing calculator...
- GOOD LUCK!

1. (Show your work) Planet X has a mass of 5.0×10^{24} kg, a radius of 4×10^6 m, and no atmosphere. Calculate the following quantities for a projectile launched vertically from its surface with an initial speed of 5000 m/s.

(A) (10pts) The speed of the projectile when it reaches a height of 1.0×10^5 m above the surface?

$$E_{\text{mech}} = U_1 + K_1 = U_2 + K_2 = -\frac{Mm}{R} - \frac{1}{2}mV_i^2 = -\frac{Mm}{R+h} + \frac{1}{2}mV_f^2$$

$$-\frac{M}{R} - \frac{1}{2}V_i^2 = -\frac{M}{R+h} + \frac{1}{2}V_f^2$$

$$= -\frac{(5 \times 10^{24})}{4 \times 10^6} - \frac{1}{2}(5000)^2 = -\frac{(5 \times 10^{24})}{4 \times 10^6 (1 + 0.025)} + \frac{1}{2}V_f^2$$

(B) (5pts) What is the escape velocity of the projectile from the surface of Planet X?

$$\text{Now } E_{\text{mech}} = U_1 + K_1 = U_2 + K_2 = 0$$

$$-\frac{Mm}{R} - \frac{1}{2}mV_i^2 = 0 \quad V_i^2 = 1.6 \times 10^8$$

$$V_i = 1.3 \times 10^4 \frac{\text{m}}{\text{sec}}$$

$$\text{Check } V = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2(6.67 \times 10^{-11})(5 \times 10^{24})}{4 \times 10^6}} = 1.3 \times 10^4$$

$$V_f^2 = 2 \left[1.25 \times 10^7 - 0.2 \times 10^7 \right]$$

$$V_f = 4.57 \times 10^3 \frac{\text{m}}{\text{sec}}$$

2. (5pts) Kepler's second law of planetary motion states that the area swept out by a line connecting the planet to the sun is a constant in time, $dA/dt = \text{constant}$. This statement is equivalent to which of the following conservation laws?

- (a) Conservation of Mechanical Energy
- (b) Conservation of Linear Momentum
- (c) Conservation of Kinetic Energy
- ☒ (d) Conservation of Angular Momentum
- (e) All of the above.

$$\frac{dA}{dt} = \frac{L}{2m}$$

3. (Show your work). In the figure below, a 2 kg cube of aluminum is suspended by a rope tied to a balloon which is floating on a fluid of density $1.5 \times 10^3 \text{ kg/m}^3$. Assume the balloon has negligible mass. ($\rho_{\text{Al}} = 2.7 \times 10^3 \text{ kg/m}^3$)

(A) (5pts) What is the tension in the rope?

$$T = Mg - F_B = Mg - m_f g$$

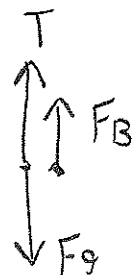
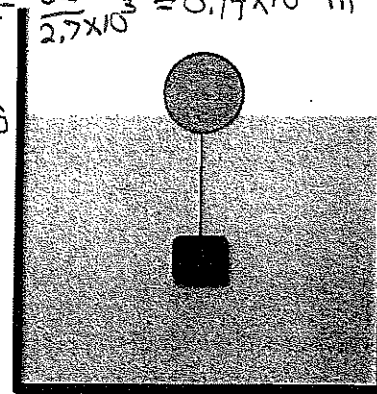
$$T = [2 - 1.112]g =$$

$$T = 8.7 \text{ N}$$

$$m_f = V \times 1.5 \times 10^3 \text{ kg/m}^3$$

$$V = \frac{2 \text{ kg}}{2.7 \times 10^3} = 0.74 \times 10^{-3} \text{ m}^3$$

$$\text{so } m_f = 1.112 \text{ kg}$$



(B) (5pts) What volume of the balloon is submerged?

$$g(V \cdot \rho) = 8.7 \text{ N}$$

$$V = \frac{8.7}{9.8 \times 1.5 \times 10^3} = 0.59 \times 10^{-3} \text{ m}^3$$

4. The function $x = (2 \text{ m}) \cos[(0.333\pi \text{ rad/s})t + \pi/4 \text{ rad}]$ gives the simple harmonic motion of a body.

(A) (5pts) What is the earliest time at which $x = 1$?

- (a) 1 sec
- (b) 0.25 sec
- (c) 0.1 sec
- (d) 0.05 sec
- (e) it is never at $x = 1$.

At $t=0$
 $x = 2 \cos \frac{\pi}{4} = 1.414$
 $x = 1$
 $1 = 2 \cos \left[\frac{\pi}{3} t + \frac{\pi}{4} \right]$
 $\cos^{-1} 0.5 = 1.047 = \frac{\pi}{3} \left[t + \frac{3}{4} \right]$
 $t = 1 - \frac{3}{4} = 0.25 \text{ sec}$

(B) (5pts) What is maximum acceleration of the body?

- (a) 9.8 m/s²
- (b) 5.2 m/s²
- (c) 3.1 m/s²
- (d) 2.2 m/s²
- (e) 1.1 m/s²

$a_m = (2) \omega^2 = (2) \left(\frac{\pi}{3} \right)^2$
 $a_m = 2.19 \frac{\text{m}}{\text{sec}^2}$

5. The equation of a certain transverse wave on a long string is given by $y(x,t) = (0.1 \text{ m}) \sin(2\pi x - 6\pi t)$, where x is in units of meters and t is in seconds. The tension in the string is 20 N.

A) (5pts) What is the speed of the wave?

- (a) zero, it is a standing wave
- (b) 4 m/s
- (c) 3 m/s
- (d) 0.25 m/s
- (e) 0.1 m/s

$y = y_m \sin [kx - \omega t]$
 $v = \frac{\omega}{k} = \frac{6\pi}{2\pi} = 3$

B) (5pts) What is the linear density of the string?

- (a) 5 kg/m
- (b) 2.2 kg/m
- (c) 1.4 kg/m
- (d) 0.5 kg/m
- (e) the string must be massless

$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{20}{\mu}} = 3$
 $\mu = 2.22 \frac{\text{kg}}{\text{m}}$

C) (5pts) What is the maximum transverse speed of a point on the string?

- (a) zero
- (b) 0.1π m/s
- (c) 0.6π m/s
- (d) 6π m/s
- (e) none of the above

$v_m = \omega y_m = (0.1) 6\pi = 0.6\pi$

6. A rope of length 2 m has a transverse $n = 5$ standing wave of frequency 30 Hz propagating on it.

(A) (5pts) What is the speed of the interfering waves on the rope?

- (a) 0.6 m/s
- (b) 18 m/s
- (c) 20 m/s
- (d) 24 m/s
- (e) 50 m/s

$$f_n = \frac{V}{\lambda_n} = n \frac{V}{2L} \quad V = \sqrt{\frac{T}{\rho}}$$

$$30 = \frac{5V}{2 \cdot 2} \quad V = 24 \frac{\text{m}}{\text{sec}}$$

(B) (5pts) By what factor would the tension in the rope have to be increased in order that the $n = 5$ mode have a frequency of 60 Hz?

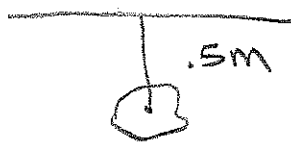
- (a) 1
- (b) 2
- (c) 4
- (d) 10
- (e) 100

$$f_n = \frac{nV}{2L} = \frac{n}{2L} \sqrt{\frac{T}{\rho}}$$

f_n doubles $T_f = 4T_i$

7. (5pts) A physical pendulum consists of a 0.5 m rod of negligible mass that is connected to the center of mass of a 5 kg irregularly shaped object on one end and connected to a pivot on the other end. When the pendulum is set into motion it is observed to oscillate at a frequency 0.6 Hz. What is the moment of inertia of the pendulum?

- (a) 5.1 kg-m²
- (b) 2.6 kg-m²
- (c) 1.7 kg-m²
- (d) 0.9 kg-m²
- (e) zero



$f = 0.6 \text{ Hz} = \frac{\omega}{2\pi}$

$\omega = (0.6) 2\pi = 1.2\pi$

$\omega = \sqrt{\frac{mgh}{I}}$

$h = 0.5$

$(1.2\pi)^2 = \frac{(5)(9.8)(0.5)}{I}$

$I = 1.73$

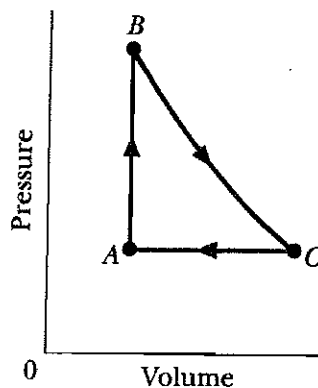
8. (5pts) If two objects are in thermal equilibrium, then which of the following statements must be true?

- (a) They must have the same internal energy.
- (b) They must have the same temperature.
- (c) They must have the same heat capacity.
- (d) They must have the same mass.
- (e) None of the above.

9. (Show your work) Gas within a chamber passes through the cycle shown in the figure. The BC leg is an expansion where no heat is transferred. CA is a compression at constant pressure and AB is pressurization at a constant volume. For this specific case the heat added in AB is $Q_{AB} = 20.0 \text{ J}$, and the total work done in the cycle is $\pm 15 \text{ J}$.

(A) (5pts) Is the total work done in the cycle positive or negative, explain?

CLOCK WISE SO IT IS +



(B) (5pts) How much work is done in going from A to B?

$$W = 0 \quad \Delta V = 0$$

(C) (10pts) Determine the energy transferred in going from C to A.

$$\begin{aligned} \Delta E_{\text{cycle}} &= \Delta E_{AB} + \Delta E_{BC} + \Delta E_{CA} = 0 \\ \text{so } Q_{AB} + Q_{BC} + Q_{CA} &= W_{AB} + W_{BC} + W_{CA} \\ 20 + 0 + Q_{CA} &= 15 \text{ J} \\ \boxed{Q_{CA} = -5 \text{ J}} \end{aligned}$$

10. (5pts) How much heat energy is required to turn 0.3 kg of water at 20°C into steam at 100°C ?

- (a) $3.0 \times 10^6 \text{ J}$
- (b) $2.2 \times 10^6 \text{ J}$
- (c) $1.3 \times 10^6 \text{ J}$
- (d) $7.8 \times 10^5 \text{ J}$
- (e) $1.0 \times 10^5 \text{ J}$

WATER $20^\circ\text{C} \rightarrow$ WATER 100°C

$$Q = cm\Delta T = (4180)(0.3)80 = 100320 \text{ J}$$

WATER AT 100°C to STEAM

$$Q = L_f m = \left(2.256 \times 10^6 \frac{\text{J}}{\text{kg}}\right)(0.3 \text{ kg}) = 6.77 \times 10^5 \text{ J}$$

$$Q_T = 7.77 \times 10^5 \text{ J}$$