PHYSICS 107
FINAL EXAM
DEC. 19, 2007

NAME [redacted] ______________________

Circle problem session:

Petzinger	Wed. 9
Kossler	Wed. 2
Petzinger	Wed. 3
Petzinger	Thu. 3

Calculators may be used for arithmetic operations—no preprogrammed formulas or problems may be used.

A1. ________________ **/60**

B1. ________________ **/20**

B2. ________________ **/25**

B3. ________________ **/25**

B4. ________________ **/20**

B5. ________________ **/25**

B6. ________________ **/25**

TOTAL ____________________ /200

Some possibly useful numbers: $g = 9.8$ m/sec^2 , $\rho_{water} = 1000$ kg/m^3,

$M_{Earth} = 6 \times 10^{24}$ kg, $R_{earth} = 6400$ km.,

$G = 6.67 \times 10^{-11}$ N-m^2/kg^2 , 1 mm-Hg = 133 Pa, $I_{point} = MR^2$, $I_{ball} = (2/5)MR^2$

PART A - 12 questions, 5 points each

A1. A ball is thrown vertically upward. (a) What are the velocity and acceleration when it reaches its maximum altitude? (b) What is its acceleration just before it hits the ground?

a) $v = 0 \quad a = -g$

b) $a = -g$

A2. Give one example of a case in which the acceleration is parallel to the velocity and another in which it is perpendicular to the velocity.

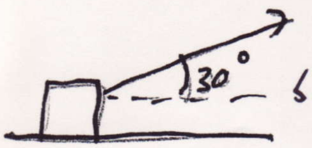
parallel: car accelerating on a straight road

perp: something going in a circle

A3. A 10 kg box is pulled by a rope at a 30 degree angle, as shown. The tension in the rope is 40 N. There is no friction. (a) What is the acceleration of the box? (b) If the box were on a scale, what would it read?

a) $ma = T\cos 30^\circ = 40\cos 30^\circ$

$a = \frac{40\cos 30}{10} = \boxed{3.5\ m/s^2}$



b) $N + T\sin 30 = mg$

$N = mg - T\sin 30 = \boxed{78\ N}$

A4. A ball of clay of mass m is thrown with a speed v against a brick wall. The clay sticks to the wall and stops. $\underbrace{\text{Does this violate the conservation}}_{\text{no}}$ of momentum? Why or why not?

wall (or earth) moves very slightly

A5. You wish to bring an ultracentrifuge which is spinning at 60,000 revolutions per minute to rest in 20 minutes. (a) What angular acceleration is needed? (b) How far does a point on the outer edge (which is 20 centimeters from the axis) travel during the 20 minutes?

$\omega_i = 60000 \text{ rpm} = 1000 \frac{\text{rev}}{\text{sec}} = 6280 \text{ rad/sec}$

a) $\alpha = \frac{\Delta\omega}{t} = \frac{6280}{20 \cdot 60} = 5.2 \text{ rad/sec}^2$

b) $\theta = \omega_i t - \frac{1}{2}\alpha t^2 = 3.8 \times 10^6 \text{ rad}$ $\quad s = R\theta = \boxed{760 \text{ km}}$

A6. Vulcan has the same mass as the Earth and 90% of the radius. What is the acceleration due to gravity on the surface?

$F = \frac{GMm}{R^2} \quad a = \frac{GM}{R^2} \quad \frac{a_{vulcan}}{a_{earth}} = \frac{1/(.9R)^2}{1/R^2} = \frac{1}{.81} = 1.21$

$a_{vulcan} = (1.21)(9.8) \approx 12.0 \text{ m/sec}^2$

~~**A7.** A warning alarm is designed to be heard at a distance of 400 meters with an intensity of 60 db. Its frequency is 1000 Hz. You wish to add identical alarms so that the sound can be heard with the same intensity at a distance of 800 meters. How many alarms must you add? (Assume the sirens radiate sound equally in all directions.)~~

in 108

~~**A8.** You hang a pendulum with a 5 kg mass at the end from the top of the Washington Monument (height is 160 meters). What is the period? How would your answer change if you used a 10 kg mass?~~

in 108

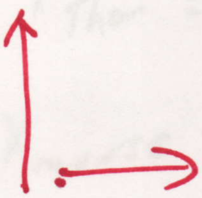
A9. Explain, using Bernoulli's principle, why roofs of buildings get blown off in hurricanes.

$$P_{inside} + \frac{1}{2}\rho v_{inside}^2 = P_{outside} + \frac{1}{2}\rho v_{outside}^2$$

$P_{inside} \downarrow$ atm. $\qquad v_{inside} = 0$

if $V_{outside}$ is big, $P_{outside}$ is small, so force outward

A10. A car (m=2000 kg) is moving 60 m/sec north. A truck (m-4000 kg) is moving 40 m/sec east. They collide and stick together. What is their final velocity?



$$P_{north} = 2000 \cdot 60$$

$$P_{east} = 4000 \cdot 40$$

$$|P_{final}| = \sqrt{(2000 \cdot 60)^2 + (4000 \cdot 40)^2}$$

$$|V_{final}| = \text{"} / 6000 = 47 \text{ m/sec.}$$

A11. Sketch the ~~displacement~~ variation for the two lowest modes of (a) a pipe closed at both ends and ~~(b) a pipe~~ open at one end.

10 f

A12. The Sun has a rotational period of 28 days. If it were to suddenly shrink to 1/100 of its original radius, what would its period be? conservation of ang. momentum.

$$I_i \omega_i = I_f \omega_f$$

$$\frac{2}{5} M R_i^2 \omega_i = \frac{2}{5} M R_f^2 \omega_f$$

$R_f = \frac{1}{100} R_i$ so $\omega_f = (100)^2 \omega_i$ $\qquad T_f = \frac{T_i}{(100)^2}$

$\simeq$ 6 minutes

B1. Thor and Mini are at rest 3 meters apart (Mini at x=0, Thor at x=3). They suddenly both see a mouse 5 meters from Thor (at x=8). Thor accelerates at 2 m/sec^2, Mini accelerates at 3 m/sec^2. At the instant that they start running, the mouse accelerates away from them at 0.5 m/sec^2.

(a)(12)Who reaches the mouse first?
(b)(8) How fast is the winner going when he/she reaches the mouse?

a) $X_{mini} = X_i + V_i t + \frac{1}{2} a t^2 = \frac{1}{2} 3 (t^2) = \frac{3}{2} t^2$

$V_i = 0$

$X_{Thor} = 3 + \frac{1}{2}(2) t^2 = 3 + t^2$

$X_{mouse} = 8 + \frac{1}{2}\left(\frac{1}{2}\right) t^2 = 8 + \frac{1}{4} t^2$

mini gets mouse when $X_{mini} = X_{mouse}$

$\frac{3}{2} t^2 = 8 + \frac{1}{4} t^2$

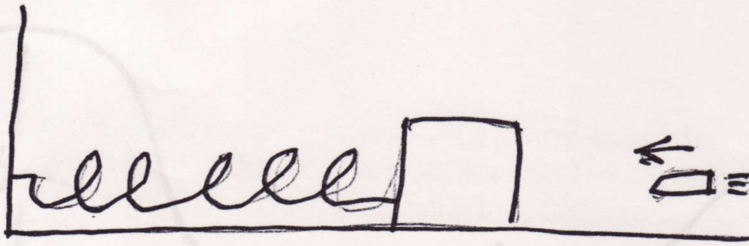
$\underline{t = 2.55 \text{ sec}}$

Thor gets mouse when $3 + t^2 = 8 + \frac{1}{4} t^2$

$\underline{t = 2.59 \text{ sec}}$

mini wins

b) $V_{mini} = at = (3)(2.59) = \underline{7.78 \text{ m/sec}}$



B2. A bullet with a speed of 700 m/sec and a mass of 3 grams hits a block with a mass of 300 grams which is attached to a spring with a force constant of 500 N/m as shown. The bullet stays in the block.

(a)(7) Just after the collision, what is the velocity of the block?
(b)(7) How much does spring compress (the maximum compression)?
~~(c)(4)~~ What is the period of the subsequent oscillations? → 108
~~(d)(7)~~ When the block has compressed by half the distance in part (b), what is its speed? 108

a) $m_{bullet} v_{bullet} = (M_{block} + m_{bullet}) v_f$

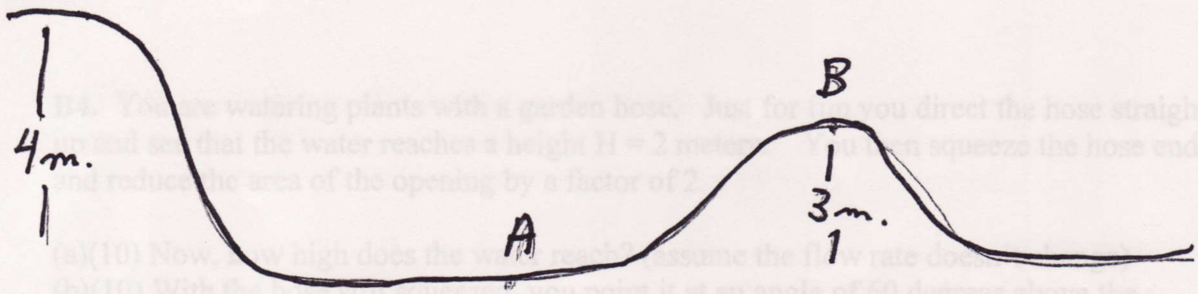
$$(.003)(700) = (.300 + .003) v_f$$

$$\boxed{v_f = 7 \text{ m/sec}}$$

b) $E_i = \frac{1}{2} m v^2 = \frac{1}{2}(.303)(7)^2$

$E_f = \frac{1}{2} k x^2 = \frac{1}{2}(500)(x^2)$

$$\boxed{x = .17 \text{ m}}$$

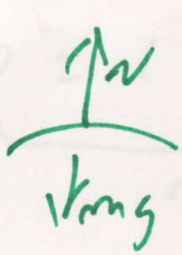


B3. A sledder slides on a sled which has a mass of 10 kg. She starts at rest at the top of a hill 4 meters high, slides down and ascends a hemispherical bump with a radius of curvature of 3 meters. The sledder has a mass of 50 kg and is 26 years old. Ignore friction and air resistance.

(a)(5) What is the speed of the sled at the bottom of the hill (point A)?
(b)(5) What is the speed of the sled at the top of the hill (point B)?
(c)(10) What is the normal force at the top of the hill? Does the sled maintain contact with the snow?
(d)(5) How much work is done by gravity (on the sled-sledder system) as she ascends the bump? How much is done by the normal force?

a) $\left.\begin{array}{l} E_i = mgh \\ E_A = \frac{1}{2} m v_A^2 \end{array}\right\}$ $v_A^2 = 2gh \Rightarrow \underline{v_A = 8.9 \text{ m/sec}}$

b) $\left.\begin{array}{l} E_i = mgh \\ E_f = \frac{1}{2} m v_B^2 + mg(3) \end{array}\right\}$ $v_B^2 = 2g(h-3) \Rightarrow v_B = \underline{4.5 \text{ m/sec}}$

c) 

$N - mg = -\frac{m v_B^2}{R}$ $\boxed{N = 167 \text{ Newtons}}$

yes, maintains contact

d) $W_{grav.} = mgh = (60)(10)(3) = \boxed{1800 \text{ J}}$

$W_{normal} = 0$

B4. You are watering plants with a garden hose. Just for fun you direct the hose straight up and see that the water reaches a height H = 2 meters. You then squeeze the hose end and reduce the area of the opening by a factor of 2.

(a)(10) Now, how high does the water reach? (assume the flow rate doesn't change)
(b)(10) With the hose still squeezed, you point it at an angle of 60 degrees above the horizontal. The hose opening is 1 meter above the ground. How far away from you (horizontally) does the water hit the ground? (Hint: the water behaves as a projectile).

a) initially, v? $\frac{1}{2}mv^2 = mgh$

$$v^2 = 2gh$$

$$v = \sqrt{2gh} = \sqrt{2(10)(2)} = 6.3 \text{ m/sec}$$

now: $A_1 v_1 = A_2 v_2 \qquad A_2/A_1 = 1/2$

$$v_2 = 2v_1 = 12.6 \text{ m/sec}$$

$$\frac{1}{2}mv^2 = mgh \Rightarrow h = \frac{v^2}{2g} = \boxed{8 \text{ m}}$$

b) $y = y_i + v_{y_i} t - \frac{1}{2}gt^2 \qquad x = x_i + v_{x_i} t$

$$\underbrace{0 = 1 + (12.6)\sin 60\, t - \tfrac{1}{2}(9.8)t^2}_{\text{solve quadratic}} \qquad x = (12.6)\cos 60\, t$$

$t = .44$ sec $\rightarrow \boxed{x = 2.7 \text{ m.}}$

B5. The blood pressure in your vein is 15.00 mm-Hg. The viscosity of blood (at body temperature) is 0.002 Pa-sec, and its density is 1.06 times that of water. A needle with a length of 2.5 centimeters and an inner radius of 0.3 millimeters is inserted.

(a)(10) How long will it take for a unit of blood (450 cubic centimeters) to drain out through the needle? (Assume the blood goes out into the open air at the same height as the vein.)
(b)(8) Suppose that instead, the blood follows a tube down to the floor into a bag, 1 meter below (the bag is at atmospheric pressure). What is the pressure difference between the exit at the needle and the bag below? (assume the velocity of the blood doesn't change as it flows through the tube.)
(c)(7) In this case, how long does it take to drain a unit of blood? (This is why the bag is put low to the ground when you donate blood.)

a) $\frac{\Delta V}{\Delta t} = \frac{\pi \Delta P r^4}{8 \eta L} = \frac{\pi \left(15 \text{ mm-Hg} \cdot \frac{10^5 \text{ Pa}}{760 \text{ mm-Hg}}\right)(.0003)^4}{8(.002)(.025)}$

$= 1.25 \times 10^{-7} \text{ m}^3/\text{sec}$

$= .125 \text{ cm}^3/\text{sec}.$

$t = \frac{450 \text{ cm}^3}{.125 \text{ cm}^3/\text{sec}} = \underline{3600 \text{ sec}}$

b) $\Delta P = \rho g h = (1060)(9.8)(1) = 10400 \text{ Pa}$

c) $\Delta P_{\text{vein-bag}} = 10400 + 15 \text{ mm-Hg} \cdot \frac{10^5 \text{ Pa}}{760 \text{ mm-Hg}} = 12370 \text{ Pa}$

same as part (a) = $\boxed{t = 570 \text{ sec}}$

A. The following short answer questions are five points each.

1. An ideal gas is in a closed box at a temperature of 27 °C. Heat is added until the pressure doubles. What is the final temperature?

$$T_f = 2T_i = 2(300\,K) = 600\,K$$
$$= 327°C$$

2. How much heat (in calories) would you need to add to 10 grams of ice at -20 °C in order to first melt and then boil it?

$$Q = (10)(.5)(20) + (10)(80) + (10)(1)(100)$$
$$+ (10)(540) = \underline{7300 \text{ cal.}}$$

3. A glass windowpane that measures 20 cm by 15 cm is 0.32 cm thick. The temperature outdoors is -15 °C and indoors is 22 °C. What is the rate of heat loss through the window? The thermal conductivity of glass is 0.63 W/(m-K).

$$\frac{Q}{t} = \frac{k A \Delta T}{d} = \boxed{220W}$$

$A = .03$

$\Delta T = 37°C$

$d = .0032$

B1. An ideal gas is in a closed box with a volume of 50,000 cubic centimeters, a temperature of 25 degrees Celsius and is at atmospheric pressure (10^5 Pa).

(a)(10) How many moles are in the box? How many molecules?
(b)(15) the gas is then heated to 100 degrees Celsius by putting 3140 Joules of heat into the box. Is the gas monatomic, diatomic or neither? Show how you determine the answer.

$$vol = 50{,}000\,cm^3 \times \frac{1^3\,m^3}{100^3\,cm^3} = 0.05\,m^3$$

$$T = 25^\circ C = 298.15\,K$$

$$P = 10^5\,Pa$$

a) $PV = nRT$

$$n = \frac{PV}{RT} = \frac{(10^5)(0.05)}{(8.31)(298.15)} = \boxed{2.02\,mol}$$ 10

$$N = \frac{PV}{KT} = \frac{(10^5)(0.05)}{(1.38e{-}23)(298.15)} = \boxed{1.22 \times 10^{24}\text{ molecules}}$$

b) $Q = 3140\,J$

$T = 100^\circ C = 373.15\,K$

$Q = n C_V \Delta T$

monatomic $C_V = 3/2\,R = 12.465$
diatomic $C_V = 5/2\,R = 20.775$
$\Delta T = 373.15 - 298.15 = 75$

monatomic: $Q = (2.02)(12.465)(75) = 1888.4475\,J$
diatomic: $Q = (2.02)(20.775)(75) = 3147.4125\,J$
matches 3140J

$\boxed{\text{Diatomic}}$ 15

use $5/2 R$ for C_V

25