FINAL EXAM (v1) [v2]

PHYS 201 (Spring 2007), 05/04/07

Name: Solutions

students: 79

509	510	511	512
20	17	22	20

Lab-Sect. no.:

Signature:

Duration: 120 minutes

Show all your work for full/partial credit!

Include the correct units in your final answers for full credit!

Unless otherwise stated, quote your results in SI units!

1.) *Multiple Choice* *(14 pts.)*

For each statement below, circle the correct answer (TRUE or FALSE, no reasoning required).

(a) In projectile motion, the acceleration of the object keeps changing.
TRUE FALSE

(b) If the speed of an object changes, a nonzero net force is acting on that object.
TRUE FALSE

(c) If the speed of an object is constant, there is no net force acting on the object.
TRUE FALSE

(d) A potential energy must be based on a conservative force.
TRUE FALSE

(e) If in a 2-body collision momentum is conserved, kinetic energy must also be conserved.
TRUE FALSE

(f) In the 1. law of thermodynamics, positive work done by a gas requires the gas to expand.
TRUE FALSE

(g) If the internal energy of an ideal gas increases, the average speed of the gas molecules decreases.
TRUE FALSE

No.	Points
1	WG
2	KR
3	KR
4	WG
5	RR
6	LN
7	LN
8	JV
9	JV
Sum	

2.) *Projectile Motion* (12 pts.)

A boy is throwing a baseball with initial speed of $22 m/s$ toward a tall vertical building which is $38 m$ away. [44] The baseball hits the building after $2.8 s$. Ignore air resistance and assume the baseball to be launched from ground level.

(4) (a) What is the launch angle of the baseball?

(4) (b) What is the maximal height reached by the ball, and what is it's acceleration at that point?

(4) (c) How high above the ground does the ball strike the building and how fast is the ball at that moment?

(a) x-comp.

$x = V_{ox} t \quad V_{ox} = V_o \cos\theta_o$

$\Rightarrow V_{ox} = \frac{x}{t} \quad \Rightarrow \cos\theta_o = \frac{x}{V_o t}$

$\Rightarrow \boxed{\theta_o = 51.9°}$ [44.4°]

(b) $V_y^2 = V_{oy}^2 - 2gy \stackrel{!}{=} 0$

$\Rightarrow \boxed{y_{max} = \frac{V_{oy}^2}{2g} = \frac{V_o^2 \sin\theta_o^2}{2g} = 15.3 m}$ [12.1 m]

$a_y = -g$

(c) $\boxed{y_f = y_o + V_{oy} t - \frac{1}{2} g t^2 = 10.1 m}$ [4.7 m]

$V_y^f = V_{oy} - gt = -10.1 m/s$ (-12.05)

$\boxed{V_f = \sqrt{v_y^{f2} + v_x^{f2}} = \sqrt{13.57^2 + 10.1^2} = 16.9 m/s}$ [19.8 m/s]

3.) *Newton's 2. Law of Motion* (*12 pts.*)

A truck is carrying a cargo box placed on its loading deck. The coefficient of static friction between the box and the bed surface is 0.45. On a horizontal road, the truck starts from rest and accelerates uniformly to $65mph$. [0.35] ($1m/s$=$2.25mph$).

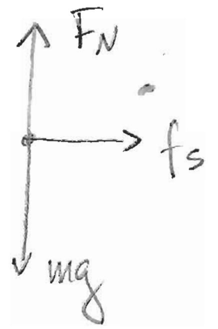
28.9 m/s

4 (a) Draw a free-body diagram of the box during the acceleration process.

4 (b) What is the maximal acceleration the truck can have without the box starting to slide?

4 (c) What is the shortest time for the truck to reach $65mph$ without the box starting to slide?

(a)



(b) $f_s^{max} = m a_{max} \Rightarrow a_{max} = \frac{f_s^{max}}{m} = \frac{\mu_s mg}{m} = \mu_s g$

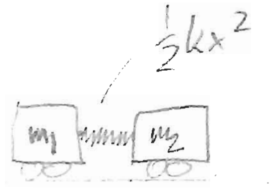
$$\boxed{a_{max} = 4.41 \, m/s^2} \quad [3.43 \, m/s^2]$$

(c) $V_f = V_0 + a_{max} t_{min}$

$$\Rightarrow \boxed{t_{min} = \frac{65/2.25}{4.41} = 6.55 \, s} \quad [8.42 s]$$

4.) *Energy and Momentum Conservation* (10 pts.)

A cart of mass $2.2kg$ is pressed against another cart of mass $1kg$ with a spring in between them compressed by $25cm$ [45] from its relaxed state. The spring constant is $9.1N/m$. The carts are released on a horizontal frictionless table. Calculate the speed of each cart once it has moved free from the spring.



energy conservation: $\frac{1}{2}kx^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$

$x = 0.25m$

$k = 9.1\ N/m$

9.1

momentum conservation: $0 = m_1 v_1 + m_2 v_2$

$\Rightarrow v_2 = \frac{m_1}{m_2} v_1$ insert above →

$\frac{1}{2}kx^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2\left(\frac{m_1}{m_2}v_1\right)^2 = \frac{1}{2}v_1^2\left(m_1 + \frac{m_1^2}{m_2}\right)$

$\Rightarrow \boxed{v_1 = \left(kx^2/\left(m_1 + \frac{m_1^2}{m_2}\right)\right)^{1/2} = 0.28\ \frac{m}{s}}$ [0.51 m/s]

$\boxed{v_2 = \frac{m_1}{m_2} v_1 = 0.63\ m/s}$ [1.13 m/s]

5.) *Angular Momentum Conservation* (*12 pts.*)

A professor is sitting on a frictionless rotating stool. He holds a pair of dumbbells at a distance of $1.1m$ [0.9m] from the axis of rotation. The dumbbells have a mass of $6kg$ each. and the moment of inertia of the professor is $7kg\,m^2$. The initial rotation frequency is $0.75Hz$.

(a) Calculate the initial angular momentum of the system.

(b) Now the professor pulls the dumbbells closer to the axis. to a distance of $0.25m$ [0.3] (assume the moment of inertia of the professor to be constant). What is the final angular speed of the system?

(c) Calculate the initial and final kinetic energy of the system. If they are different. why?

(a) $I_o = I_{prof} + 2(mr_o^2) = 21.52\ kg\,m^2$ $[16.72\ kg\,m^2]$

$L_o = I_o \omega_o$, $\omega_o = 2\pi f_o$ $\Rightarrow L_o = 101.4\ \frac{kg\,m^2}{s}$ $[78.8\ \frac{kg\,m^2}{s}]$

(b) $L_o = L_f$

$I_o \omega_o = I_f \omega_f$ $\qquad \omega_o = 2\pi f_o = 4.71\ \frac{rad}{s}$

$I_f = I_{prof} + 2(mr_f^2) = 7.75\ kg\,m^2$ $[8.08\ kg\,m^2]$

$\Rightarrow \omega_f = \frac{I_o}{I_f}\omega_o = 13.1\ \frac{rad}{s}$ $[9.75\ rad/s]$

(c) $K_o = \frac{1}{2} I_o \omega_o^2 = 239\ J$ $[185\ J]$

$K_f = \frac{1}{2} I_f \omega_f^2 = 665\ J$ $[384\ J]$

final is larger because professor did work!

6.) *Interference* [650] *(8 pts.)*

Two small loudspeakers are each emitting a pure tone of frequency $800 Hz$ in phase (or in step). Originally, the speakers are at the same position, $6.5m$ away from the ear of a person. Then, one of the speakers is slowly moved away from the person, by an increasing distance d. $V_{sound} = 343 \frac{m}{s}$

(a) At what distance d does the sound first produce a destructive interference at the position of the person's ear?

(b) At what distance $d > 0$ does the sound produce again a constructive interference at the position of the person's ear?

(a) first destructive interference $\Delta L = \frac{\lambda}{2} = d$

$\lambda = \frac{v}{f} = 0.43m$ [0.53] $\Rightarrow$ $d_{min} = 0.214\ m$ [0.26m]

(b) first constructive interference. $d = \Delta L = \lambda$

$\Rightarrow$ $d_{max} = 0.43m$ [0.53m]

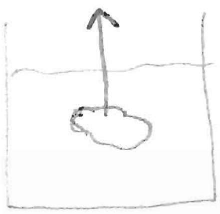
7.) *Archimedes' Principle* [3.1] (*10 pts.*)

An ore sample which looks like gold from the outside has a mass of $2.5kg$. The sample is suspended by a light and thin cord and completely immersed into water. The tension in the cord is measured to be $21.1N$. ($\rho_{water} = 1000kg/m^3$, $\rho_{gold} = 19300kg/m^3$)

(a) What is the volume of the sample?

(b) What is the density of the sample? Is it solid gold?

(a) $T = 21.1\ N$



$$F_B = \rho_w V_{ore}\, g = mg - T$$

$$\Rightarrow V_{ore} = \frac{mg - T}{\rho_w g} = 3.47 * 10^{-4} m \quad [9.37 * 10^{-4} m^3]$$

(b) $F_W^{ore} = \rho_{ore} V_{ore}\, g = M_{ore}\, g$

$$\Rightarrow \rho_{ore} = \frac{M_{ore}}{V_{ore}} = 7200 \frac{kg}{m^3} \quad [3300\ kg/m^3]$$

no gold!

8.) *Heat Transfer* (10 pts.)

A cooking pot with a circular steel bottom of radius 18cm and thickness 0.7cm rests on a hot stove plate. The water inside the pot is at the boiling point ($T = 100°C$) and evaporates at a rate of $0.12 kg/min$. → 2×10^{-3} kg/s (latent heat of vaporization for water: $L_V = 2.256 \times 10^6$)

[0.18] → 3×10^{-3} kg/s

thermal conductivity of steel: $K_{steel} = 50.2\ W m^{-1} K^{-1}$

(a) How much thermal power flows into the water?

(b) What is the temperature at the lower surface of the pot (which is in contact with the stove plate)?

(a) $P = \frac{Q}{t} = \frac{m L_V}{t} = \frac{m}{t} L_V$: 4512 W [6768 W]

270720 J/min 406080 J/min

(b) $P = \frac{Q}{t} = KA \frac{\Delta T}{L}$ $A = \pi r^2 = 0.1018\ m^2$

$\Rightarrow \Delta T = PL/KA = 6.2\ C°$ [9.2 C°]

$\Rightarrow T = T_W + \Delta T = 106.2\ °C$ [109.2 °C]

9.) *First Law of Thermodynamics and Ideal Gas* [$3.3 * 10^5$ Pa] (*12 pts.*)

120 moles of an ideal gas are held in a cylinder at a constant pressure of $2.7 \times 10^5 Pa$. The gas is cooled and compressed from $2.1 m^3$ to $1.6 m^3$.

(a) By how much did the internal energy of the gas change (include the correct sign!)?

(b) How much work has been done by/on the gas?

(c) How much heat has been extracted from/added to the gas?

(a) $pV = nRT \Rightarrow T_0 = \frac{pV_0}{nR} = 569\,°K$ [$695°K$]

$T_f = \frac{pV_f}{nR} = 433\,°K$ [$529°K$]

$\Delta U = \frac{3}{2} nR\Delta T = -2.03 * 10^5\,J$ [$-2.48 * 10^5\,J$]

(b) $W = P\Delta V = -1.35 * 10^5\,J$ [$-1.65 * 10^5\,J$]

(c) $\Delta U = Q - W$ $Q = C_p n \Delta T$ ($C_p = \frac{5}{2}R$)

$\Rightarrow Q = \Delta U + W = -3.38 * 10^5$ [$-4.13 * 10^5\,J$]