Physics 2101
Final Exam

December 2009

Name: SOLUTIONS

ID#: _____

Section: (Circle one)

1 (Chastain, MWF 8:40 AM)

2 (Chastain, MWF 10:40 AM)

3 (Rupnik, MWF 12:40 PM)

4 (Plummer, TTh 9:10)

5 (Adams, TTh 12:10)

- 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. A 0.5 kg projectile is fired from ground level at angle of $\theta = 30°$ as shown below. The
initial velocity of the projectile has a *y-component* value of 20 m/s.

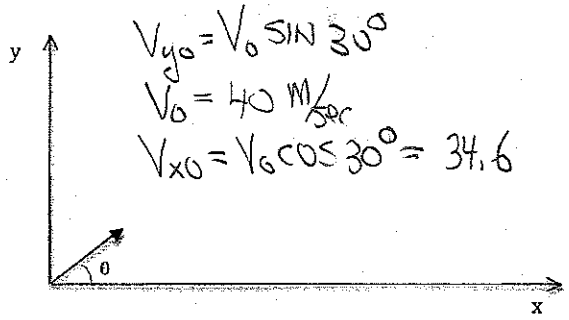
(A) (10pts) At what time will the projectile's *x-coordinate* be 100 m?

(a) 9.8 s
(b) 3.2 s
(c) 2.9 s
(d) 1.4 s
(e) 0.5 s

$\Delta x = V_{x0} t$

$100 = 34.6 t$

$t = 2.89$ sec



$V_{y0} = V_0 \sin 30°$

$V_0 = 40$ m/sec

$V_{x0} = V_0 \cos 30° = 34.6$

(B) (10pts) What will be the kinetic energy of the projectile just before it hits the ground?

(a) 80 J
(b) 400 J
(c) 1960 J
(d) 2500 J
(e) 4460 J

SAME AS IT STARTED WITH

$E_K = \frac{1}{2} m V_0^2 = \frac{0.5}{2}(40)^2$

$E_K = 400$ J

3. (10pts) A 0.25 kg mass is attached to a spring with spring constant k = 25 N/m. If the spring-mass system undergoes simple harmonic motion with a maximum kinetic energy of 50 J, what is the amplitude of the motion?

(a) 0.1 m
(b) 0.3 m
(c) 1.0 m
(d) 2.0 m
(e) not enough information given

$E_m = \frac{1}{2} k x_m^2$

$50 = \frac{25}{2} x_m^2$

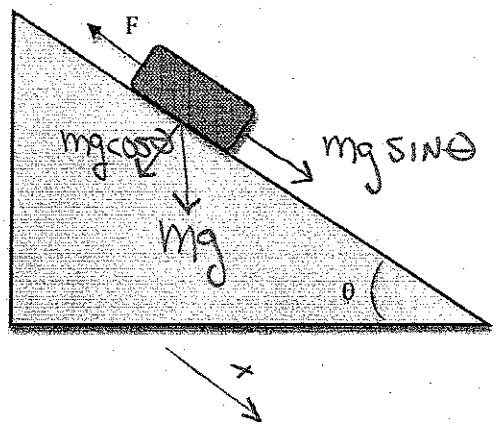
$x_m = 2$ m

4. As shown below, a 2 kg block is placed at rest on a 60° incline that has equal coefficients of static and kinetic friction, $\mu_s = \mu_k = 0.5$. In addition, an external force F = 5 N is applied to the block along the plane as shown.

(A) (5pts) What is the normal force on the block?

(a) 19.6 N
(b) 17.0 N
(c) 9.8 N
(d) 0.7 N
(e) 0.2 N

$F_N = mg\cos\theta$
$= 2(9.8)(0.5)$



(B) (10pts) What is the magnitude and direction of the acceleration of the block?

(a) 9.8 m/s^2; down the plane
(b) 3.5 m/s^2; down the plane
(c) 3.5 m/s^2; up the plane
(d) 1.0 m/s^2; up the plane
(e) 1.0 m/s^2; down the plane

$mg\sin\theta - F - \mu_k F_n = ma$
$mg\sin\theta - 5 - 0.5(9.8) = ma$
$16.97 - 5 - 4.9 = 2a$
$a = 3.54 \frac{m}{sec^2}$

5. A 0.2 kg projectile moving at a speed of 5 m/s strikes and imbeds itself into a 0.8 kg block of wood that is initially at rest on a frictionless surface.

(A) (5pts) What is the speed of the block of wood after impact?

CONSERVATION of MOMENTUM

(a) zero
(b) 1 m/s
(c) 2 m/s
(d) 5 m/s
(e) not enough information provided

$m_1 v_1 = (m_1 + m_2) v_f$
$(0.2)(5) = 1\, v_f \quad v_f = 1 \frac{m}{sec}$

(B) (5pts) How much kinetic energy was *lost* in the collision?

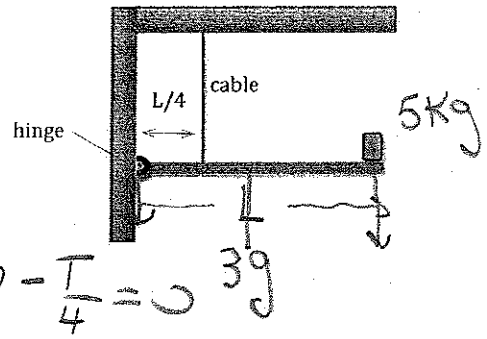
(a) 5 J
(b) 2.5 J

2J

$\Delta E_K = \frac{1}{2} m_1 v_1^2 - \frac{1}{2}(m_1 + m_2) v_f^2$
$= \frac{(0.2)}{2} 5^2 - \frac{1}{2} 1^2 = 2.5 - 0.5 = 2J$

(c) 2.0 J
(d) 0.5 J
(e) zero

6. (Show your work) A uniform 3 kg beam of length L has 5 kg box placed on one end and is supported in a horizontal position by a hinge and a cable as shown below.



(A) (10pts) Find the tension in the cable.

$\Sigma T = 0 = 5gL + 3 \cdot \frac{Lg}{2} - T\frac{L}{4}$

$0 = 5g + \frac{3g}{2} - \frac{T}{4} \quad = 49 + 14.7 - \frac{T}{4} = 0$

$T = 254.8\,N$

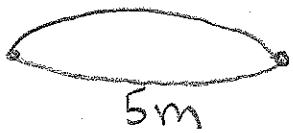
(B) (10pts) Find the direction (up or down) and magnitude of the *vertical* component of the force of the hinge on the beam.

$\Sigma F = 0 = F_y - T + 5g + 3g = 0$

$F_y = 176.4\,N$ down

7. (10pts) A string fixed on both ends is 5 m long. If the lowest possible frequency for a standing wave on the string is 10 Hz what is the speed of a transverse wave on the string?

(a) 100 m/s
(b) 50 m/s
(c) 10 m/s
(d) 1 m/s
(e) zero



$\lambda = 2L = 10\,m$

$\omega = 2\pi f \qquad v = f\lambda = f\,2L = 10 \times 10$

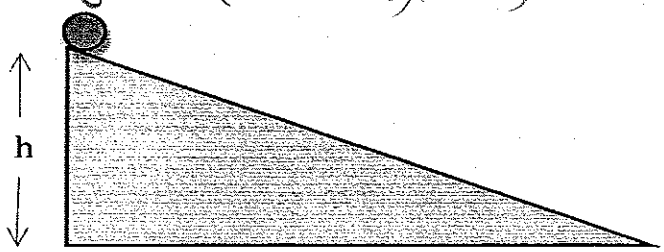
$= 100$

8. (10pts) A solid 20.4 kg sphere with radius R = 0.2 m rolls without slipping down an incline with h = 2 m, as shown below. What is the total kinetic energy of the sphere when it reaches the bottom of the inline?

(a) 10 J
(b) 100 J
(c) 250 J
(d) 400 J

$E_T = U + K \qquad K = ROT + TRANS$

$U = mgh = (20.4\,kg)(9.8)2 = 399.8\,J$

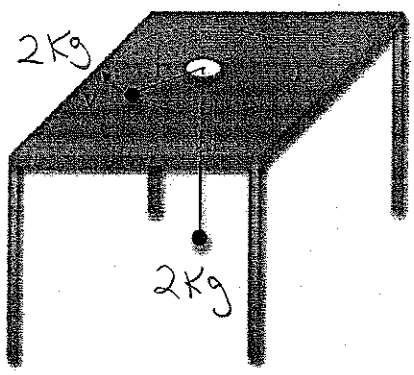


(e) none of the above

9. (*Show your work*) A 2 kg mass slides uniformly in a circle of radius *r* on a frictionless table while attached to an identical mass by a cord through a hole in the table, see figure below.

(A) (10pts) What is the tension in the cable?

$T = mg = 2kg(9.8)$
$= 19.6\ N$



(B) (10pts) If the speed of the mass is 2 m/s, then what is the radius of the circular motion, *r*?

$T = ma_c = m\frac{v^2}{R} = 19.6$
$R = \frac{mv^2}{T} = \frac{2 \cdot 4}{19.6} = 0.4m$

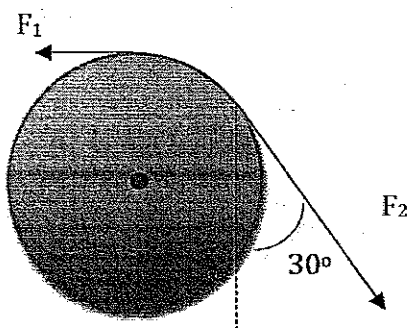
10. (5pts) Which of the following quantities is conserved in an *elastic* collision?

(a) Only potential energy
(b) Only momentum
(c) Only kinetic energy
(d) Both kinetic energy and momentum
(e) Both acceleration and force

11. (10pts) A solid disk with a pivot at its center has a mass of 4 kg and radius 0.5 m. The disk is acted upon by two tangential external forces as shown below. The magnitude of the forces are $F_1 = 5$ N and $F_2 = 20$ N. What is the angular acceleration of the disk?

(a) $\pm 15.0\ rad/s^2$
(b) $-15.0\ rad/s^2$
(c) $-12.3\ rad/s^2$
(d) $-5.0\ rad/s^2$
(e) zero

$\tau = I\alpha = \Sigma F_i r_i$
$I = \frac{1}{2}mR^2$
$\alpha = \frac{20(0.5) - 5(0.5)}{\frac{1}{2}4(0.5)^2}$
$\alpha = 15\ \frac{rad}{sec}$ INTO PAPER $= -15$



12. (5pts) If the net angular momentum of a system is *not* changing, then what must be true?

$\frac{dL}{dt} = \tau$

$\tau = 0$

(a) It has *internal* frictional forces.
(b) It has no *internal* forces.
(c) The net *external* torque acting on the system is zero.
(d) It is not rotating.
(e) none of the above

13. (*Show your work*) The pulley shown in the figure has a radius R and a mass M and can be assumed to be a solid disk. The block has the same mass as of that of the pulley and moves on a frictionless surface. The block is initially pulled a distance d so that the spring stretches by an amount d from its un-stretched position. The block is then released.

(A) (10pts) Calculate the acceleration of the block immediately after it is released assuming that the cable does not slip on the pulley. Your answer should be in terms of M, k, and d.

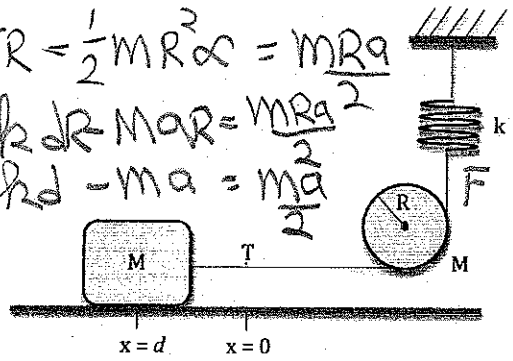
$I = \frac{1}{2}MR^2$

$\tau = I\alpha = \Sigma F_i \cdot R = FR - TR = \frac{1}{2}MR^2\alpha = \frac{MRa}{2}$

$T = Ma \quad F = kd \Rightarrow kdR - MaR = \frac{MRa}{2}$

$kd - ma = \frac{ma}{2}$

$a = \frac{kd2}{M3}$



(B) (10pts) Find the tension in the section of the cable between the block and the pulley in terms of k and d.

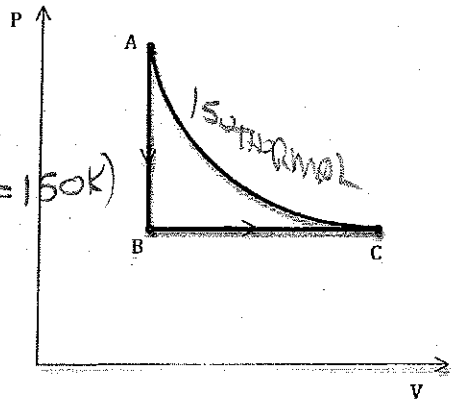
$T = Ma = \frac{2kd}{3}$

14. (*Show your work*) A monoatomic ideal gas at point A in the diagram below has a temperature of 150 K and is at pressure of 1.5 x 10^5 Pa and occupies a volume 2.0 m^3. The pressure and volume at point C are 1.0 x 10^5 Pa and 3.0 m^3 respectively. The system is brought from A to C by the two-step process shown in the diagram (A->B, B->C).

(A) (5pts) What is the temperature the gas at point C?

$P_A V_A = nRT_A \quad P_C V_C = nRT_C$

$\frac{T_C}{T_A} = \frac{P_C V_C}{P_A V_A} = \frac{1.0\times10^5\ 3.0}{(1.5\times10^5)\ 2.0} = 1 \quad (T_C = 150K)$



(B) (5pts) How much work was done by the gas in going from A->B? (explain)

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

(C) (5pts) How much heat was removed from the gas in going from A->B?

ISOCHORIC

$Q = \Delta E_{INT} = nC_V\Delta T$

$= \frac{3}{2}nR\Delta T = \frac{3}{2}\Delta PV$

$= \frac{3}{2}(1.5-1.0)\times10^5\ 2 = -1.5\times10^5\ J$

(D) (5pts) How much heat was absorbed by the gas in going from B->C?

$Q = nC_P\Delta T = \frac{5}{2}nR\Delta T = \frac{5}{2}P\Delta V = \frac{5}{2}(1\times10^5)\ 1$

$Q = 2.5\times10^5\ J$

15. (5pts) A gasoline engine performs 2000 J of mechanical work and discards 3000 J of heat in each cycle. What is the efficiency of the engine?

(a) 100%
(b) 67%
(c) 50%

$Q_H = Q_L + W \quad W = 2000\ J \quad Q_L = 3000\ J$

$\varepsilon = \frac{W}{Q_H} = \frac{2000}{5000} = 40\%$

(d) 40%
(e) 10%

16. (*Show your work*) A thermally isolated cup contains 1.5 kg of water at an initial temperature of 50 °C. Ignore the specific heat of the cup.

(A) (10pts) How much ice with an initial temperature of -10 °C should be combined with the water so that the final temperature of the system is +10 °C?

$Q_{IN} = Q_{OUT} = Q_{WATER}$ $\Delta T = 40°C$ $C = 4187$ $m = 1.5\,kg$

$Q_W = -251220$

$Q_{ice} = m(2220)(10) + m(3.33\times10^5) + m(4187)|10$

$= m(3.97\times10^5)$

$m = 0.63\,kg$

(B) (10pts) What is the total change in entropy of the water-ice mixture as it reaches a final temperature of +10 C?

$\Delta S_1(WATER) = (1.5)(4187)\ln\frac{283}{323} = -830.3\ J/K$

$\Delta S_2(ice) = (0.63)(2220)\ln\frac{273}{263} = 52.4\ J/K$

$\Delta S_3(melt) = \frac{0.63\times3.33\times10^5}{273} = 772.1\ J/K$

$\Delta S_4(Heat\ ice) = 0.63(4187)\ln\frac{283}{273} = 95.35\ J$

$\Delta S_T = 89.5\ \frac{J}{K}$