PHYS 124 Section A1
Final Examination
Spring 2006

Name_________________________________

Student ID Number_____________________

Instructor Marc de Montigny
Date Friday, May 26, 2006
Duration 2 hours

Instructions

- Items allowed: pen or pencil, calculator (programmable and graphic calculators are allowed). Personal digital assistants not allowed.
- Please turn off your cell phones.
- This is a closed book exam. The formula sheet provided last week, which you may have completed, is allowed. **This sheet will be collected with the exam.**
- The exam is worth a **total of 120 marks.**
- There are **7 short questions**. Each is worth 5 marks, for a **total of 35 marks**. No partial marks are allowed. Select the one best answer.
- There are **6 problems**. They are worth a **total of 85 marks**. Partial marks will be given. Show all work clearly and neatly. Please box your answers.
- You may use the back of the pages for your own calculations. They will not be marked.

Short questions (Total of 35 marks). Circle the one best answer.

S-1. (5 marks) A 10.0-g bullet is fired into a 200-g block of wood at rest on a rough horizontal surface. After impact, the block and the bullet are stuck together and slide 8.0 m before coming to rest. If the coefficient of friction is $\mu_K = 0.40$, find the speed of the bullet before impact.

A. 106 m/s
B. 166 m/s
C. 226 m/s
D. 286 m/s

S-2. (5 marks) What is the minimum angular velocity of a solid cylinder rolling on the ground at the bottom of a hill so that it will be able to roll (without slipping) to the top of the hill, which is 10.0 m long and 3.0 m high? The mass of the cylinder is 2.0 kg and its radius is 40 cm. ($I_{CYLINDER} = \frac{1}{2}MR^2$)

A. 15.7 rad/s
B. 27.1 rad/s
C. 19.2 rad/s
D. 28.6 rad/s

S-3. (5 marks) A horizontal disk with moment of inertia I_1 rotates with angular velocity ω_0 about a vertical frictionless axle. A second horizontal disk, with moment of inertia I_2 and initially not rotating, drops onto the first. Because the surfaces are rough, the two disks eventually reach the same angular velocity ω. The ratio ω / ω_0 is

A. I_1 / I_2
B. I_2 / I_1
C. $I_1 /(I_1 + I_2)$
D. $I_2 /(I_2 + I_1)$

S-4. (5 marks) A mass of 0.4 kg, hanging from a spring with constant $k = 80$ N/m, is set into an up-and-down simple harmonic motion. What is the acceleration of the mass when at its maximum displacement of 0.1 m?

A. zero
B. 5 m/s^2
C. 10 m/s^2
D. 20 m/s^2

S-5. (5 marks) If a 1000-Hz sound source moves at a speed of 50.0 m/s toward a listener who moves at a speed of 30.0 m/s away from the source, what is the apparent frequency heard by the listener, if the velocity of sound is 340 m/s?

A. 937 Hz
B. 947 Hz
C. 1060 Hz
D. 1070 Hz

S-6. (5 marks) Doubling the power output from a sound source will result in an increase of intensity level of

A. 0.5 dB
B. 2.0 dB
C. 3.0 dB
D. 20.0 dB

S-7. (5 marks) A Young's double slit has a slit separation of 3.0×10^{-5} m on which a monochromatic light beam is directed. The resultant bright fringe separation is 2.15×10^{-2} m on a screen 1.20 m from the double slit. What is the separation between the third-order bright fringe and the zeroth-order fringe?

A. 8.60×10^{-2} m
B. 6.45×10^{-2} m
C. 4.30×10^{-2} m
D. 2.15×10^{-2} m

Problems (Total of 85 marks). Show all your work and be totally clear. Please box your answers.

P-1. (15 marks) Rigid Objects in Equilibrium

A 1200-N uniform boom is supported by a cable perpendicular to the boom, as in the figure below. The boom is hinged at the bottom, and a 2000-N weight hangs from its top.

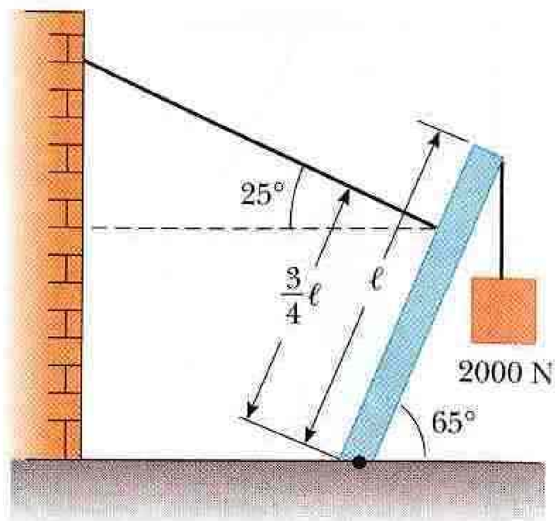
A. Draw a free-body diagram indicating all the forces acting on the boom. **(2 marks)**

B. Write down the equations $\sum F_x = 0$, $\sum F_y = 0$, $\sum \tau = 0$, using formulas for the various forces and torques. **(5 marks)**

C. Find the tension in the supporting cable. **(3 marks)**

D. Find the horizontal component of the force exerted on the boom by the hinge. **(2 marks)**

E. Find the vertical component of the force exerted on the boom by the hinge. **(3 marks)**



SOLUTION:

A. Hx : horizontal component of force by ground (assumed toward right)
Hy : vertical component of force by ground (assumed upward)
T : tension, parallel to the rope, pointing left
W_B : weight of boom, acting downward at centre i.e. length/2
W_C : weight of crate

B. Hx – T cos 25 = 0
Hy + T sin 25 – W_B – W_C = 0
½ l W_B cos 65 + l W_C cos 65 – ¾ lT = 0

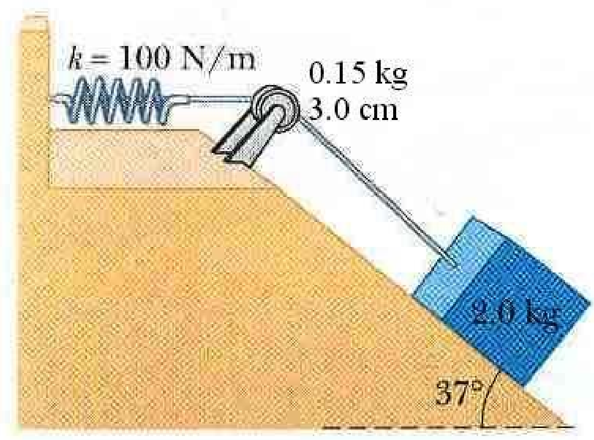
C. From third equation : T = 1465 N

D. From first equation : Hx = 1328 N

E. From second equation : Hy = 2580 N

P-2. (20 marks) Conservation of Energy

A 2.0-kg block situated on a rough incline is connected to a light spring with constant $k = 100$ N/m, as shown below. The block is released from rest when the spring is unstretched. The pulley has a mass 0.15 kg, a radius 3 cm and it is frictionless. The coefficient of kinetic friction between the block and the incline is $\mu_K = 0.1$. Find the speed of the block after it has moved down 8 cm along the incline. ($I_{PULLEY} = \frac{1}{2}MR^2$)



SOLUTION :

$$\Delta K_{block} + \Delta K_{pulley} + \Delta U_{spring} + \Delta U_{grav,block} = W_{NC}$$

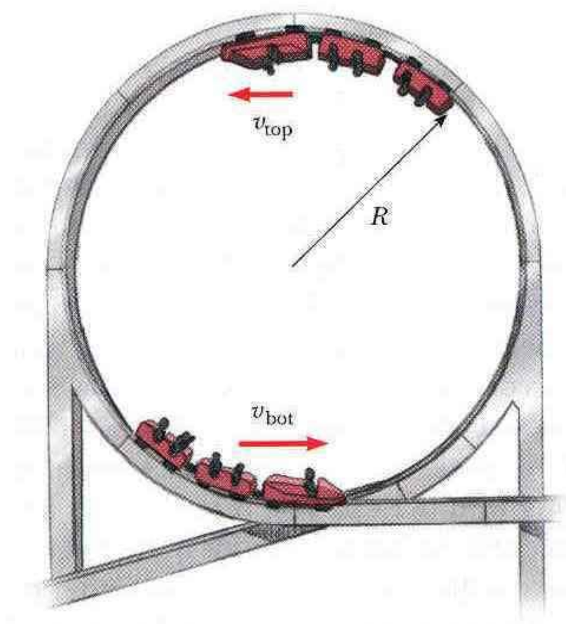
$$\frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\left(\frac{v}{R}\right)^2 - mgx\sin\theta + \frac{1}{2}kx^2 = -\mu_k mgx\cos\theta$$

$$v^2 = \frac{2mgx(\sin\theta - \mu_k\cos\theta) - kx^2}{m + \frac{1}{2}M}$$

$$v = 69.3 \text{ cm/s}$$

P-3. (10 marks) Conservation of Energy With Circular Motion

The figure below shows a roller coaster moving around a circular frictionless loop of radius *R*. What initial speed must the car have at the bottom of the track so that it will just make it over the top of the loop?



SOLUTION :

$\sum F = -N + mg = m\frac{v_{top}{}^2}{R}$, where *N* = 0, so that $v_{top}{}^2 = Rg$

From conservation of energy: $\frac{1}{2}mv_{top}{}^2 - \frac{1}{2}mv_{bottom}{}^2 + mg(2R) = 0$

so that $v_{bottom} = \sqrt{5gR}$

P-4. (10 marks) Standing Waves in a Tube

The frequencies of two consecutive harmonics in a 45-cm tube are 929 Hz and 1300 Hz, respectively.

A. Determine whether the tube is open a both ends or at one end only. **(4 marks)**

B. What is the speed of the wave in the tube? **(3 marks)**

C. Using $v \approx 20\sqrt{T[°C] + 273}$ m/s, determine the air temperature inside the tube. **(3 marks)**

SOLUTION :

A. Using $f_n = nf_1$, we find 1300/929 = 1.4 = 7/5 = f_{n+2}/f_n : TUBE OPEN AT ONE END ONLY

B. $f_5 = 5v/4L$ so that $v = 4Lf_5/5 = 334$ m/s

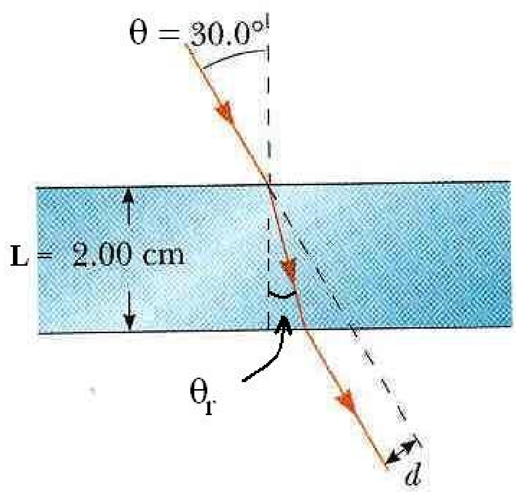
C. T = 5.89 ºC

P-5. (15 marks) Refraction

A light ray strikes a flat L-cm thick block of glass (index of refraction n) at an angle θ with the normal. As it passes through the glass block, the light ray is shifted laterally by a distance d.

A. Find an expression for d in terms of L, θ and θ_r. **(10 marks)**

B. Calculate d for $L = 2$ cm, $n = 1.50$ and $\theta = 30°$. **(5 marks)**



SOLUTION :

A. Let a be the distance of the path within the glass. From the figure, we find

$\cos\theta_r = \frac{L}{a}$ and $\sin(\theta - \theta_r) = \frac{d}{a}$, so that we find $d = \frac{L\sin(\theta - \theta_r)}{\cos\theta_r}$

B. First use $(1)\sin 30 = (1.5)\sin\theta_r$, to find $\theta_r = 19.5°$. Then d = 0.387 cm.

P-6. (15 marks) Interference and Diffraction

In a Young's double-slit experiment, the width of each slit causes a diffraction pattern which is combined with the interference pattern, in such a way that the diffraction minima annihilate some interference bright fringes. Consider two slits separated by a distance of 1 mm, with each slit being 0.25 mm wide.

A. Which maxima of interference are missing from the resulting pattern because they are annihilated by diffraction? **(8 marks)**

B. How many interference bright fringes appear in the central maximum of diffraction? **(7 marks)**

SOLUTION :

A. Interference : $d \sin\theta = m_i \lambda$

Diffraction : $W \sin\theta = m_d \lambda$ These equations have the same angle, so

$$\sin\theta = \frac{m_i \lambda}{d} = \frac{m_d \lambda}{W} \text{ and } \frac{m_i}{m_d} = \frac{d}{W} = 4.$$

Therefore the missing maxima are given by $m_i = 4 m_d = 4, 8, 12, \ldots$

B. The first missing interference maximum is at $m_i = \pm 4$, so that the central diffraction peak contains $m_i = -3, -2, -1, 0, 1, 2, 3$.

Therefore, there are SEVEN bright fringes.