Physics 8A - JACOBSEN -
Fall 2002 - Midterm 2

University of California
Department of Pl
Physics 8A, Fall

Second Midterm Exam November 6, 2002

You will be given 100 minutes to work this exam. No books, but you may use a handwritten note sheet no larger than an 8 1/2 by 11 sheet of paper. Your description of the physics involved in a problem is worth significantly more than any numerical answer. Show all work, and take particular care to explain what you are doing. Write your answers directly on the exam, and if you have to use the back of a sheet make sure to put a note on the front. Do not use a blue book or scratch paper.

sin 45° = 0.707, cos 45° = 0.707, sin 30° = 0.500, cos 30° = 0.866

Rotational Inertias for radius R or length L:
sphere about axis: (2/5)MR^2 spherical shell about axis: (2/3)MR^2
disk about axis: (1/2)MR^2 hoop about axis: MR^2
rod about perpendicular at midpoint: ML^2/12

$$\frac{1}{2}\rho v^2 + y g \rho + P = \text{constant} \qquad F = \frac{GM_1M_2}{r^2} \quad \omega = \sqrt{\frac{k}{m}} \quad \omega = \sqrt{\frac{g}{l}} \quad \sum \vec{F} = m\vec{a}$$

Each part is worth the number of points indicated. These should sum to 100 points. Setup and explanation are worth almost all the of the points. Clearly state what you are doing and why. In particular, make sure that you explain what principles and conservation rules you are applying, and how they relate.

1 ____________________

S ____________________

I ____________________

DISCUSSION SECTION DATE/TIME: Mon, 1-2pm

3	
4	
5	
6	
total	

Read the problems carefully.
Try to do all the problems.
If you get stuck, go on to the next problem.
Don't give up! Try to remain relaxed and work steadily.

1A) (2 pts) A ladder leans against a wall. If the ladder is not to slip, which one of the following must be true?

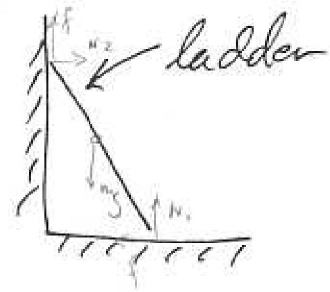
a) the coefficient of friction between the ladder and the wall must not be zero

b) the coefficient of friction between the ladder and the floor must not be zero

c) both a and b

d) either a or b

e) neither a nor b



1B) (2 pts) If a sphere is pivoted about an axis that is tangent to its surface, its rotational inertia is

a) $1/5\ MR^2$

b) $3/5\ MR^2$

c) MR^2

d) $7/5\ MR^2$

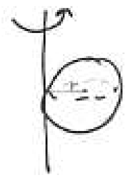
e) $9/5\ MR^2$

$I = \sum mr^2$

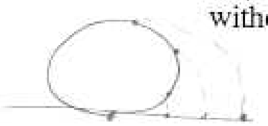
$I' = I_{cm} + mh^2$

$= \frac{2}{5}mr^2 + mr^2$

$= \frac{7}{5}mr^2$



1C) (2 pts) We may apply conservation of energy to a cylinder rolling down an incline without slipping, thus saying no work is done by friction, because



a) there is no friction present

b) the angular velocity of the center of mass about the point of contact is zero

c) the coefficient of kinetic friction is zero

d) the linear velocity of the point of contact (relative to the surface) is zero

e) the coefficients of static and kinetic friction are equal in this case

1D) (2 pts) A figure skater stands on one spot on the ice (assumed frictionless) and spins around with her arms extended. When she pulls in her arms, she reduces her rotational inertia and her angular speed increases so that her angular momentum is conserved. Compared to her initial rotational kinetic energy, her rotational kinetic energy after she has pulled in her arms must be

$K_{rot} = \frac{1}{2} I\omega^2$

a) the same.

b) larger because she's rotating faster.

c) smaller because her rotational inertia is smaller.

$\downarrow I, \omega\uparrow$

1E) (2 pts) In simple harmonic motion, the magnitude of the acceleration is greatest when the

a) velocity is maximum

b) displacement is zero

c) force is zero

d) displacement is maximum

e) none of these

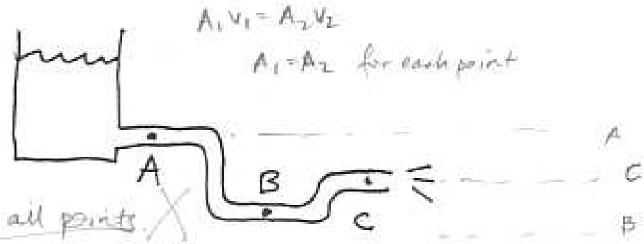
2A) (5 points) Water is flowing from a reservoir. The tube varies in height. At which of the three points labeled A, B and C is the fluid moving <u>fastest</u> when you ignore frictional loses, viscosity, etc? At which of the three points labeled A, B, C is the fluid moving <u>fastest</u> if you include the effects of friction on the fluid? As always, explain your answers.

Bernoulli's equation:

$P_0 + \frac{1}{2}\rho v^2 + \rho g h = $ a constant

$A_1 v_1 = A_2 v_2$

$A_1 = A_2$ for each point



ρ is the same, g is the same, P_0 is the same for all points. What is changing is velocity and height. For the equation to be true, if height decreases, velocity must compensate by increasing. Thus, ignoring frictional losses, the point at lowest height (B) has the fastest velocity

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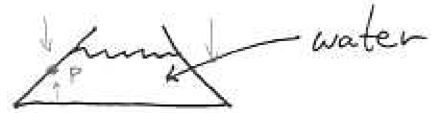
If we take into account frictional losses, then (A) would have the fastest velocity even though its height is greater (and thus has a slower velocity according to Bernoulli's ideal fluids equation), the water at point A has travelled the least through the tubing, which makes frictional losses minimal.

2B) (5 points) Water fills an oddly-shaped cup (see figure). Is the total force exerted on the bottom of the cup by the water greater than, equal to, or less than the weight of the water? As always, explain your answer.

the total force exerted on the bottom of the cup is GREATER than the weight of the water.



Only when the cup is a nice cylinder are these two values equal. The reason is because the water at point P (labeled in diagram) is exerting a force upwards. (If we were to poke a hole in the cup, water would spring out). Therefore, in order to counter this force, the odd-shaped cup must exert a force down. The total force that the bottom of the cup "feels" is the weight of the water <u>plus</u> this compensatory force

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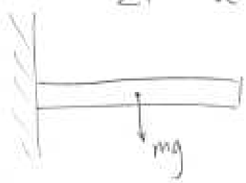
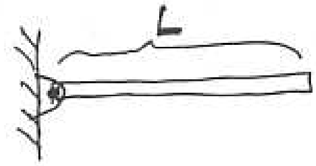
3 (20 pts) A rod of length **L** and mass **m** is attached to a wall with a hinge at one end. The center of mass of the rod is in the center. The rod is released from a horizontal position.

a) At the moment of it's release, what's it's angular acceleration $\boldsymbol{\alpha}$ about the hinge?
b) At the moment of it's release, what's the downward acceleration **a** of the center of mass?

$\Sigma F = ma$





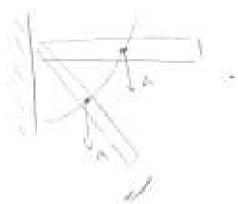
(a) $\tau = I\alpha = Fr$

$\alpha = \frac{F \cdot r}{I}$

$I \neq \frac{1}{12}ML^2$ → need to use ∥ axis thm!

$= \frac{(mg)(\frac{L}{2})}{\frac{1}{12}ML^2} = \boxed{\frac{6g}{L}}$

8 +1 = 9



(b) $\boxed{a = \alpha r \quad \text{where } r = \frac{1}{2}L, \text{ for center of mass}}$

$a = \frac{6g}{L}\cdot(\frac{1}{2}L) = \boxed{3g}$

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Energy of rod (through x_{cm})

$v = \omega r$

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$mg(\frac{L}{2}) = \frac{1}{2}mv^2 + \frac{1}{2}(\frac{1}{12}mL^2)(\frac{v}{L/2})^2$

$\frac{mgL}{2} = \frac{mv^2}{2} + \frac{mv^2}{6}$

$v = \sqrt{\frac{3}{4}gL}$

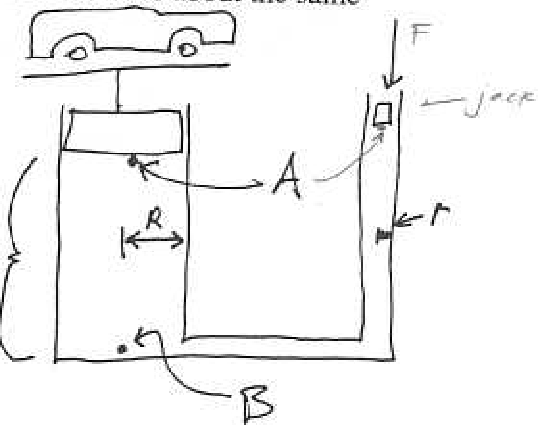
Correct answer

$\alpha = \frac{Fr}{I} = \frac{mg\cdot\frac{L}{2}}{\frac{1}{3}ML^2} = \boxed{\frac{3}{2}\frac{g}{L}}$

$a = \alpha r = \frac{3g}{2L}\cdot\frac{1}{2}L = \boxed{\frac{3}{4}g}$

4 (20 pts) A 1000 kg car is being lifted by a hydraulic jack. The large piston has radius R=10 cm, and the small piston has radius r=1cm. Hydraulic fluid has about the same density as water. See figure.

a) What is the pressure at point A?
b) What is the pressure at point B?



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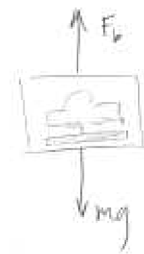
$P = \frac{F}{A}$

pressure underneath car = pressure underneath jack b/c they're at the same height (1m)

W_{done} is same for both sides of jack

$W = F d$

(a)



$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$

$\Sigma F = ma$ $\quad F_b = \rho V g$

$F_b = mg$

$R = 10\text{ cm} = 0.10\text{ m}$

$P_A = \frac{F_b}{A} = \frac{mg}{\pi R^2} = \frac{980000}{\pi}$

$\boxed{\approx 312000 \text{ kg/ms}^2}$

$\frac{\text{kg}\cdot\text{m/s}^2}{\text{m}^2} = \frac{\text{kg}}{\text{ms}^2}$

(b) Pressures add, so $P_B = P_A + P$ of water column

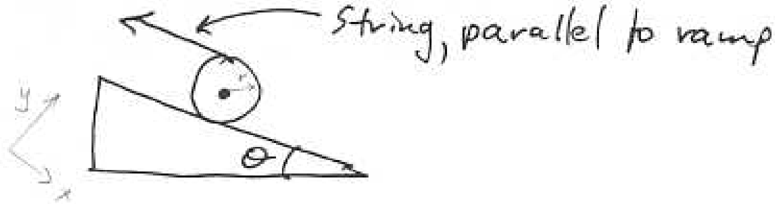
$= \frac{980000}{\pi} + \rho g h$ (assuming $P_0 = P_{atmosphere} = 0$)

$= \frac{980000}{\pi} + \left(\frac{1000\text{ kg}}{\text{m}^3}\right)\left(9.8\text{ m/s}^2\right)(1\text{m})$ $\quad \rho = \frac{1\text{g}}{\text{cm}^3} \cdot \left(\frac{100\text{cm}}{1\text{m}}\right)^3 = \frac{1000\text{kg}}{\text{m}^3}$

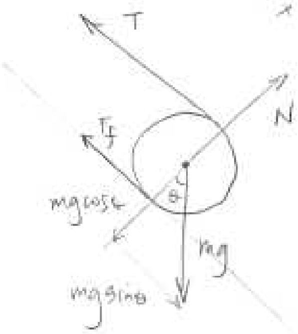
$\boxed{\approx 322000 \text{ kg/ms}^2}$

friction

5 (20 pts) A wheel of radius r and mass m would normally roll down a ramp. In this problem, it's constrained by a string, which prevents it from rolling. What's the tension in the string?



FBD:



$\Sigma F = ma$

$\Sigma F = 0$ in static equilibrium
$\Sigma \tau = 0$

$\Sigma \tau = F_f \cdot r - T \cdot r = 0$

$F_f = T$

$\Sigma F_y = 0$
$N = mg\cos\theta$

$\Sigma F_x = mg\sin\theta - F_f - T = 0$

$F_f = mg\sin\theta - T$

$F_f = F_f = T = mg\sin\theta - T$

$2T = mg\sin\theta$

$$\boxed{T = \frac{1}{2} mg\sin\theta}$$

good!

$F_f = \frac{1}{2} mg\sin\theta = \mu_s \cdot N$

$\frac{1}{2} mg\sin\theta = \mu_s \cdot mg\cos\theta$

$\mu_s = \tan\theta$

20/20

6 (20 pts) A block of mass m is attached to a spring with spring constant k. The mass is sitting at the equilibrium position when it is suddenly hit to add energy E to it. It then oscillates around the equilibrium position with a period T.

a) What are the maximum values of the position, velocity and acceleration of this motion?

b) Make a sketch showing where in the motion those maxima occur. (E.g at the center, 1/2 of the way through, or whatever)

(a)

$E_1 = KE = \frac{1}{2}mv_1^2$

$E_2 = U = \frac{1}{2}kx^2$

$E_1 = E_3 = KE = \frac{1}{2}mv_1^2$

$E_2 = E_4 = U = \frac{1}{2}kx^2$

total $E = U + KE = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

$T = \frac{2\pi}{\omega} \rightarrow \omega = \frac{2\pi}{T}$

$T = 2\pi\sqrt{\frac{m}{k}}$

period does not depend on amplitude

$T \neq$ constant $\cdot X_{max}$

Amplitude (X_{max}) depends on how much (E) is put into system

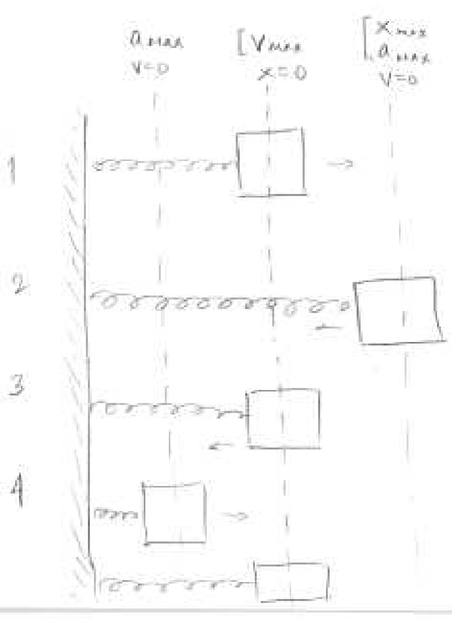
- position max when $V = 0$, $E = \frac{1}{2}kx^2 \rightarrow X_{max} = \sqrt{\frac{2E}{k}}$
- velocity max when $x = 0$, $E = \frac{1}{2}mv^2 \rightarrow V_{max} = \sqrt{\frac{2E}{m}}$
- acceleration max when $V = 0$, $X_{max} = \sqrt{\frac{2E}{k}}$ and

$$a_{max} = |-\omega^2 X_{max}| = \omega^2\sqrt{\frac{2E}{k}} = \left(\frac{2\pi}{T}\right)^2\sqrt{\frac{2E}{k}}$$

$$= \left(\frac{k}{m}\right)\sqrt{\frac{2E}{k}}$$

10

(b)



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$\left(\frac{2\pi}{2\pi\sqrt{\frac{m}{k}}}\right)^2 = \frac{k}{m}$