P113 University of Rochester NAME Soln key SM
S. Manly Fall 2002

# Exam 2 (November 5, 2002)

***Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given.***

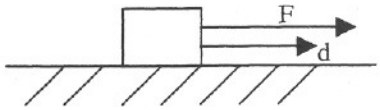
**Problem 1 (16 pts):**

**Over a period of three seconds, a person exerts a force of 20 N on a box as it slides along the floor. The direction of the force is as shown in the diagrams (vector F). The box slides a distance of 2 m (vector d). The force and movement are as shown in the diagrams.**

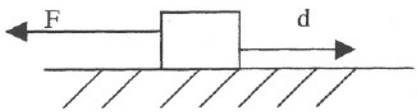
**a) Evaluate the amount of work done by the person in each case. Write your answer beside the appropriate diagram.**

**b) What is the power exerted by the person in each case? Write your answer beside the appropriate diagram.**

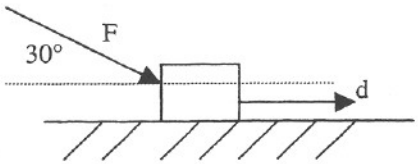
$W = \vec{F} \cdot \vec{d}$ $\quad P = \Delta W / \Delta t$



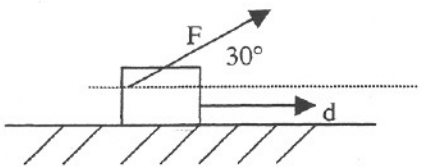

$W = (20\,N)(2\,m) = 40\,N\cdot m = 40\,J$ $\quad P = \frac{40\,J}{3\,s} = 13.3\,Watts$




$W = -(20\,N)(2\,m) = -40\,J$ $\quad P = -13.3\,Watts$ $= \frac{-40}{3}$




$W = (20\,N)(2\,m)\cos 30 = 34.6\,J$ $\quad P = 11.5\,Watts$ $= \frac{34.6}{3}$




$W = (20\,N)(2\,m)\cos 30 = 34.6\,J$ $\quad P = \frac{34.6}{3} = 11.5\,Watts$

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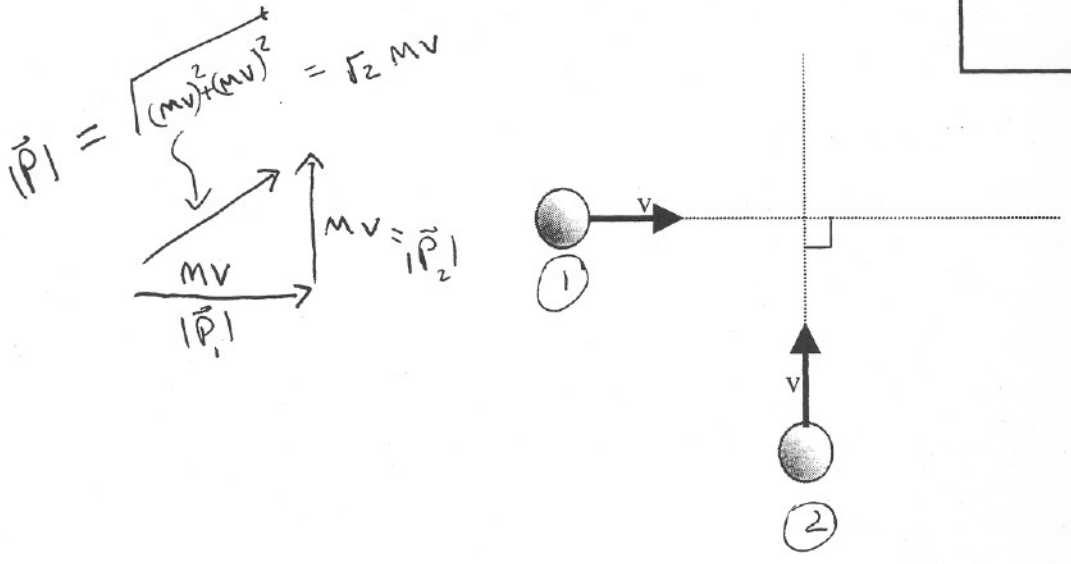
| | |
|---|---|
| 1) | /16 |
| 2) | /16 |
| 3) | /16 |
| 4) | /20 |
| 5) | /12 |
| 6) | /20 |
| tot | /100 |

**Problem 2 (16 pts, show your work):**

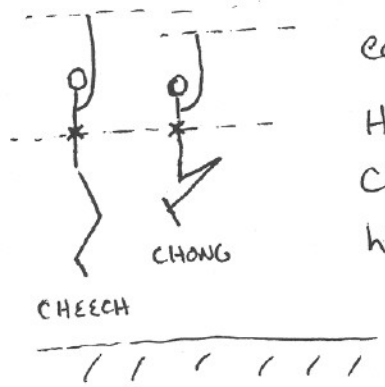
**Two identical bodies of mass M move with equal speeds v. The direction of their velocities is illustrated in the figure. The magnitude of the linear momentum of the system is**

a) 2Mv
b) Mv
c) 4Mv
d) $\sqrt{2}$Mv
e) $4\sqrt{2}$Mv




**Problem 3 (16 pts):**

**Two identical twin boys, named Cheech and Chong, play for the UR basketball team. Cheech and Chong are physically identical. The coach has noticed that when Cheech jumps, he keeps his legs extended and points his toes, while Chong bends his legs and at the hips and knees and tucks his legs up underneath his body while he is in the air. Whose fingertips reach the highest point on the backboard during a jump, those of Cheech or Chong? Explain your answer using concepts you have learned recently in this course. Feel free to make and refer to a diagram if you wish.**




Due to energy conservation the center of mass of each player reaches the same height during a jump. However the position of the center of mass ~~within~~ within Chong's body must ~~be higher in~~ further up in his body (relative to that of cheech) because he bends his legs. Therefore Chong's fingertips cannot reach as high as cheech's fingertips.

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**Problem 4 (20 pts):**

**It is a little known (and probably untrue) fact that the late Jam Master Jay's stellar career as a hip-hop disc jockey started when he was a young kid playing around with his parent's turntable. Fictitious legend has it that he was fascinated by rotational kinematics and often made numerous physics measurements using his turntables while preparing for concerts. Let us assume young JMJ observed that his turntable took 5 s to reach its final angular velocity of 45 RPM (revolutions per minute) starting from rest.**

a) **(6 pts) Calculate the angular acceleration of JMJ's turntable, assuming constant angular acceleration. Show your work.**

$45\ \text{rpm} = \frac{4.5(2\pi)}{60\ s} = 4.7\ \frac{\text{rad}}{s} = \omega_{final}$

$\alpha = \frac{\Delta\omega}{\Delta t} = \left(\frac{(4.7-0)\ \text{rad/s}}{5\ s}\right) = 0.94\ \frac{\text{rad}}{s^2}$

b) **(6 pts) Through what angle does the turntable turn during this initial 5 s period? Show your work.**

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$ ($\theta_0 = 0$, $\omega_0 = 0$)

$\theta = \frac{1}{2}(0.94)\,5^2 = 11.75\ \text{rad}$

c) **(8 pts) Suppose JMJ placed a penny on the turntable at a radius of 3 cm from the center before starting the turntable. If the coefficient of static friction between the penny and the turntable is 0.05, does the penny slide off the turntable? If so, how long after the start of the motion (i.e., the start of the rotation of the turntable) before the penny begins to slide? Show your work.**

For penny to NOT slip $F_{friction} = \frac{mv^2}{R}$ ← Newton's 2ND law applied to Penny in radial direction

At moment of slipping (Threshold)

$F_{fric.} = \mu_s N = \mu_s mg = \frac{mv^2}{R}$ or $v^2 = R\mu_s g$

$v^2 = (.03\ m)(.05)(9.8)$

$v = 0.12\ m/s$

$\omega = \frac{v}{R} = \frac{0.12\ m/s}{.03\ m} = 4\ \frac{\text{rad}}{s}$

$\omega_{Threshold} < \omega_{Final}$ (4.0 < 4.7)

∴ Penny MUST slide

To Determine time penny slides

$\omega = \omega_0 + \alpha t$

$4.0 = 0 + (.94)t$ ⟩ $t = 4.25$ seconds

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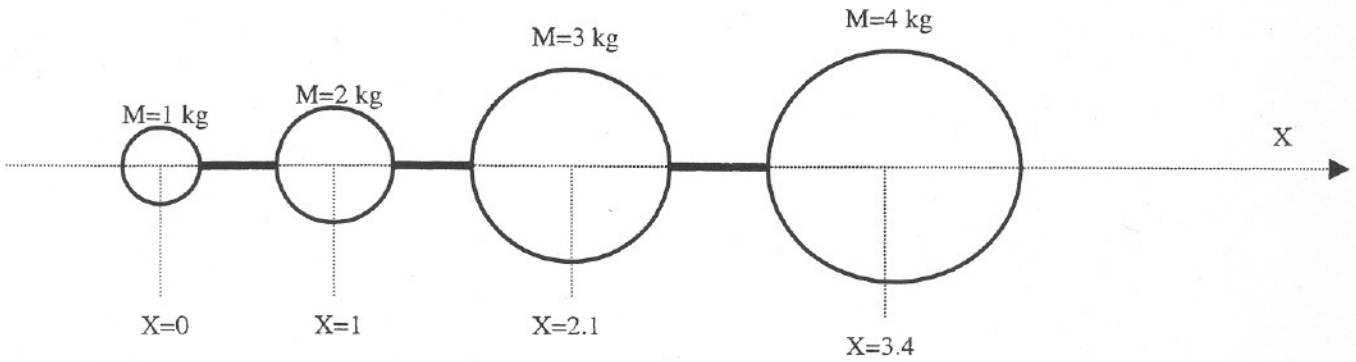
**Problem 5 (12 pts):**

**Consider the uniform spherical masses pictured below connected by thin, weightless rods. Where is the center of mass of this system in x? Show your work.**




$$X_{CM} = \frac{(0)(1) + (1)(2) + (2.1)(3) + (3.4)(4)}{1 + 2 + 3 + 4}$$

$$= \frac{\sum x_i m_i}{\sum m_i} = \frac{21.9}{10} = 2.19 \text{ units of } x$$

x unit was unspecified

Sorry

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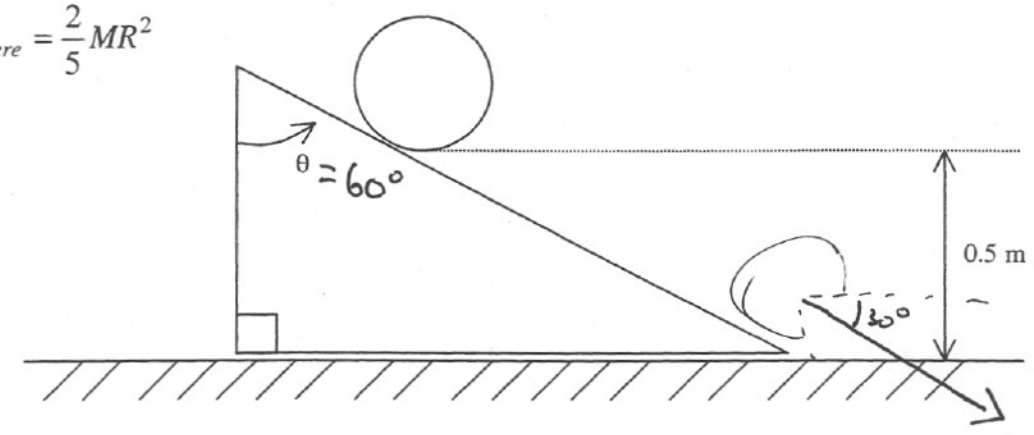
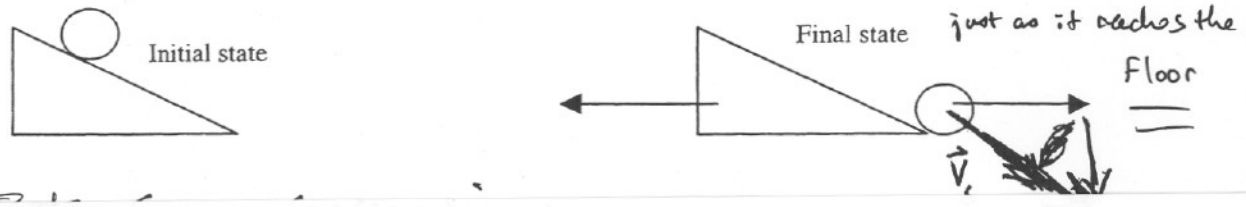
**Problem 6 (20 pts):**

**Consider a uniform, solid sphere placed on a block shaped like an inclined plane as shown below. Let the sphere have a mass of 2 kg and a radius of 5 cm and let the inclined plane/block have a mass of 1.5 kg. The block moves without friction across the floor. With both the block and sphere starting from rest, the sphere is allowed to roll down the plane without slipping from a height of 0.5 meters. What are the velocities of the block and sphere when the sphere reaches the bottom of the inclined plane?**

$I_{sphere} = \frac{2}{5}MR^2$




Threw out Problem