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

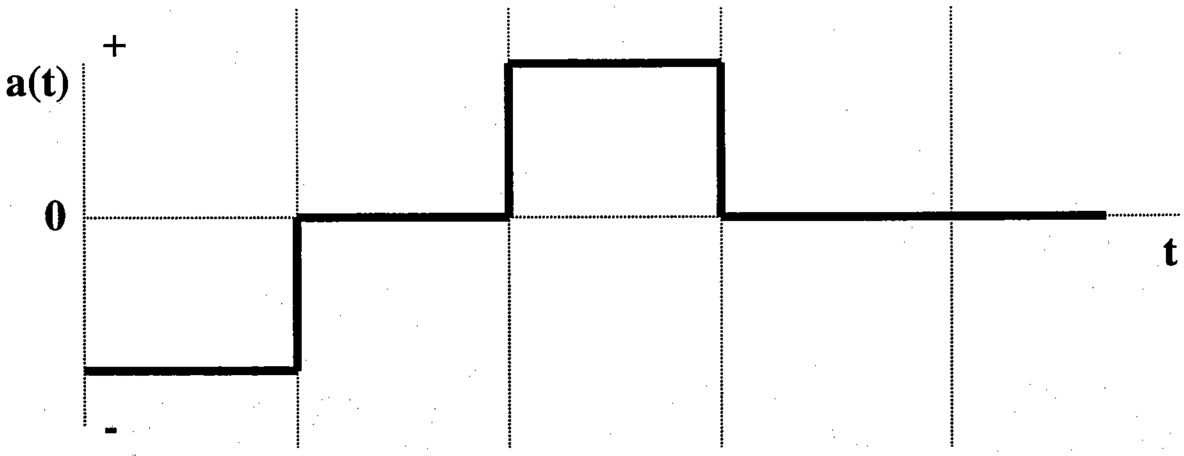
Solutions TO EXAM I

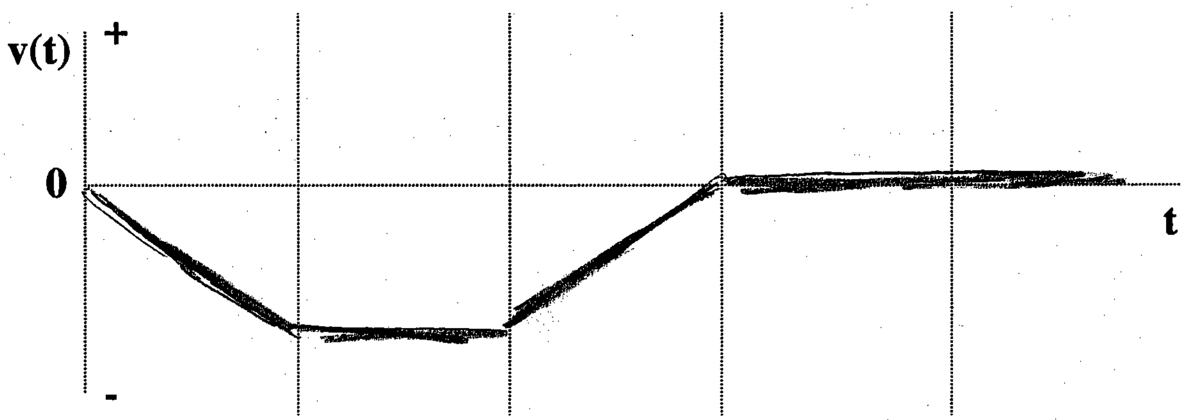
Exam 1 (October 10, 2002)

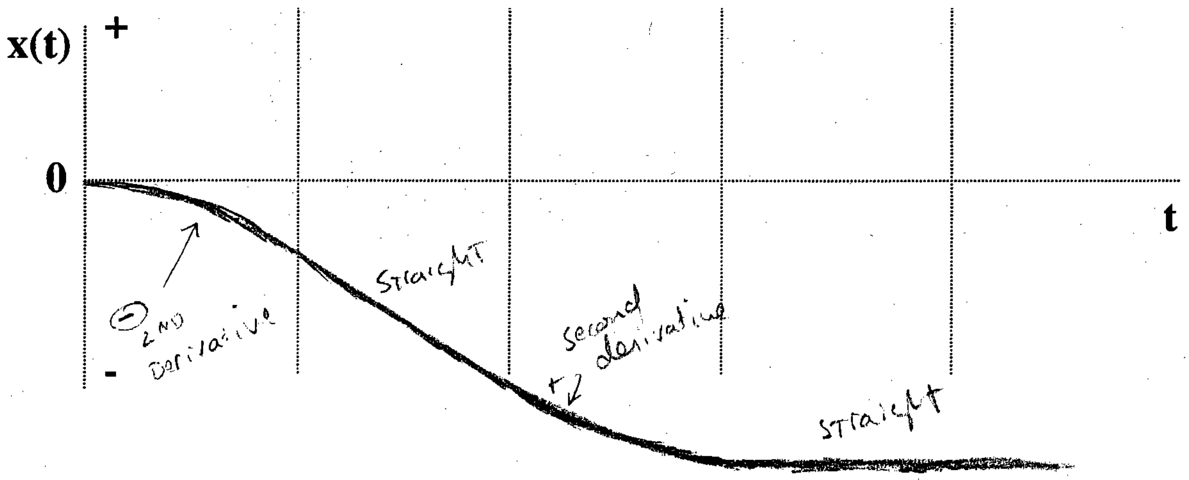
Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given.

Problem 1 (12 pts):

The 1-dimensional motion of a particle is described by the acceleration-time graph given below. Draw the appropriate qualitative velocity-time and position-time graphs for this particle. Assume the particle starts at x=0 with v=0.







1)	/12
2)	/11
3)	/10
4)	/10
5)	/10
6)	/10
7)	/10
8)	/12
9)	/15
tot	/100

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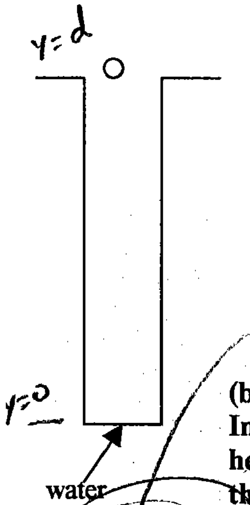
Problem 2 (11 pts):

In preparing for this exam Eggburt Lowder decided that his newly developed skill at beer pong was not going to help him solve projectile problems. So, he prayed for a while and then walked to a nearby wishing well. Eggburt dropped several coins down the well and wished to do well on his exam. Suddenly, in a fit of physics euphoria he decided to use his physics knowledge to determine the depth of the well.

Eggburt dropped a coin into the well and determined the depth of the well from the time between the release of the coin and hearing the splash of the coin in the water at the bottom. (Here "depth" is defined as the distance from the lip of the well to the top of the water surface at the bottom of the well.) He measures a time difference of 2.5 s.

(a) What is the depth of the well? (Assume the speed of sound in air is a constant 340 m/s.) Show your work.



$a_{coin\,fall} = -9.8\ m/s$

$a_{sound\,up} = 0$

$T_{TOTAL} = t_{fall} + t_{sound}$

$y = y_0 + v_{0y} t_{fall} + \frac{1}{2} a t_{fall}^2$

$\boxed{d = V_{sound}\, t_{sound}}$

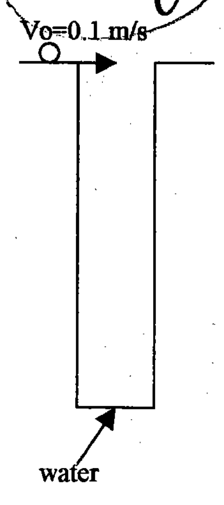
$t_{sound} = T_{tot} - t_{fall}$

$\boxed{d = \frac{1}{2} 9.8\, t_{fall}^2}$

$\frac{1}{2} 9.8\, t_{fall}^2 = V_{sound} T_{tot} - V_{sound} t_{fall}$

$t_{fall}^2 + \underbrace{\frac{2(340)}{9.8}}_{69} t_{fall} - \underbrace{\frac{(2)\,340(2.5)}{9.8}}_{172.5} = 0$

(b) Next Eggburt slides the coin off the side of the well with a horizontal velocity of 0.1 m/s. In this case, what time difference does he measure between the release of the coin and hearing the sound of the splash at the bottom of the well? Assume the well is wide enough that the coin does not hit the side of the well as it descends. Show your work and/or explain your answer.



Answer could range between 25 and 31 due to rounding

$t_{fall}^2 + 69 t_{fall} - \cancel{69}\,172.5 = 0$

$t_{fall} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$t_{fall} = \frac{-69 \pm \sqrt{69^2 + 4(69)172.5}}{2}$

Choose ⊕ root to make $t_{fall} > 0$

$t_{fall} = 2.41\ s$

$\therefore t_{sound} = 2.5 - \cancel{0.98}\,2.41 = \cancel{1.52}\,0.09\ s$

$\boxed{d = (340\ \tfrac{m}{s})(0.09\ s) = 30.6\ m}$

The time difference stays the same 2.5 s because the horizontal component of V is independent of the vertical motion

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Problem 3 (11 pts):

Circle the vector equation that describes the relationship among vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ shown in the sketch.

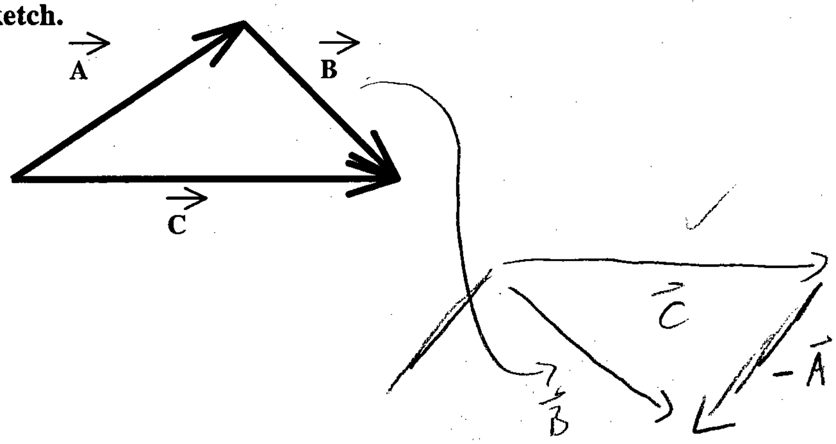
a) $\vec{B} = \vec{C} + \vec{A}$

b) $\vec{B} = \vec{C} - \vec{A}$

c) $\vec{C} = A - B$

d) $\vec{A} = \vec{B} - \vec{C}$

e) $\vec{A} = \vec{B} + \vec{C}$



Problem 4 (11 pts):

Your heart pumps 80 g of blood with each beat. The blood starts from rest and reaches a speed of 0.60 m/s in the aorta. If each beat takes 0.16 s, the average force exerted on the blood is

a) 3.0×10^2 N
b) 0.22 N
c) 0.16 N
d) 0.30 N
e) 0.98 N

$$\bar{a} = \frac{\Delta v}{\Delta s} = \frac{0.6}{0.16} = 3.75\ m/s^2$$

$$\bar{F} = m\bar{a} = (0.08\ kg)(3.75\ m/s^2) = 0.3\ N$$

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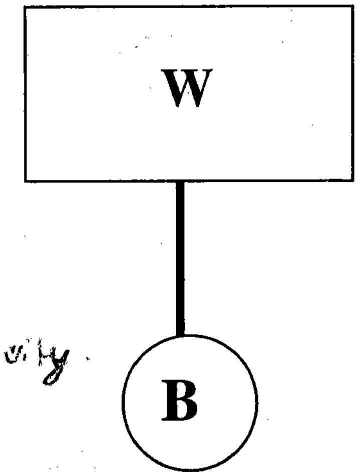
Problem 5 (12 pts):

The system in the figure consists of a steel ball attached by a cord to a large block of wood. If the system is dropped in a vacuum, the force (tension) in the cord is



a) Zero.
b) equal to the difference of the masses of B and W.
c) equal to the difference of the weights of B and W.
d) equal to the weight of B
e) equal to the sum of the weights of B and W.

The only force on either Mass is gravity.

$F = \cancel{M}a = \cancel{M}g$

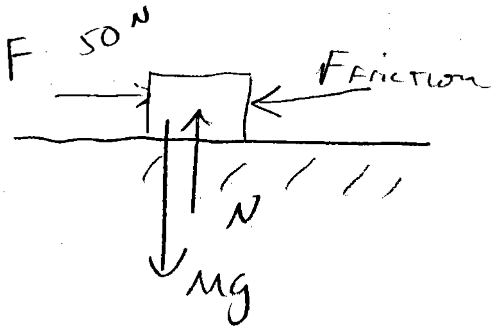
a of Both is g regardless of Mass

$\therefore$ No Tension in cord

Problem 6 (12 pts):

A 10 kg block is at rest on a level surface, where the coefficient of static friction is 0.6 and that for kinetic friction is 0.4. A 50 N horizontal force is applied. The frictional force on the block is

a) 60.0 N
b) 39.2 N
c) 98.0 N
d) 58.8 N
e) 50.0 N



Assume Moving and get 39.2 → +5

Assume STATIC and get 58.8 → +7

$F_{\substack{STATIC\\MAX}} = \mu_s N = \mu_s Mg = (0.6)(10)(\overset{9.8\ m/s^2}{9.80}) = 58.8\ N$

$58.8\ N > 50\ N$

So object does NOT Move and

$F_{\text{friction}} = 50\ N$

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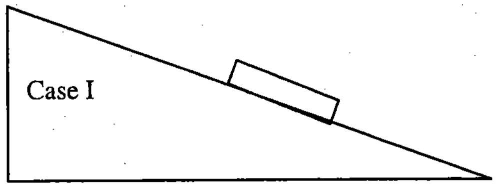
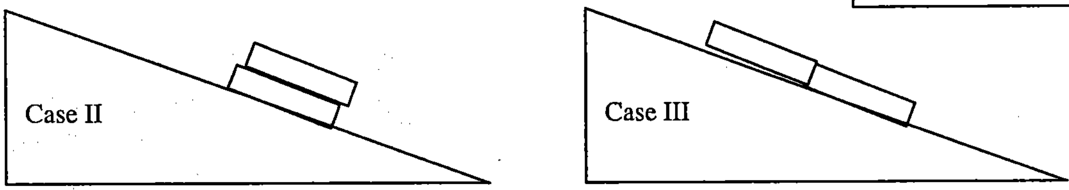
Problem 7 (12 pts):

Two identical blocks (each with a mass of 4 kg) slide down an inclined plane that makes an angle of 35° with the horizontal. Consider three cases:
In case I, a single block slides down the plane.



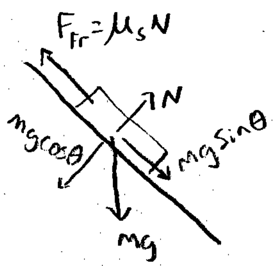
In case II, two blocks glued together with one block on top of the other slide down the plane.



In case III, two blocks glued together with one block in front of the other slide down the plane. Please ignore the sketch imperfections caused by MSWord's drawing lattice and consider all surfaces to be flush. Assume friction is present between the surface of the blocks and the surface of the inclined plane. Let the coefficient of kinetic friction be equal to 0.1.

What is the acceleration of the system down the plane in each of the three cases?

M=4kg



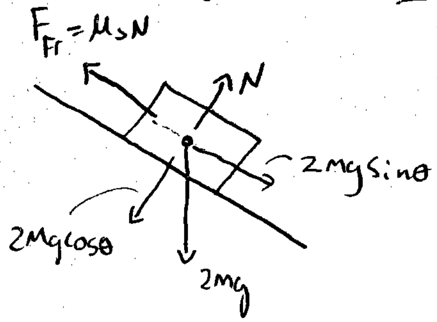
$ma_{\parallel} = Mg\sin\theta - \mu_K Mg\cos\theta$

$a_{\parallel} = g\sin\theta - \mu_K g\cos\theta$

$= (9.8)(\sin 35) - (0.1)(9.8)(\cos 35)$

$\boxed{a_{\parallel} = 4.8\ M/s^2}$ CASE I

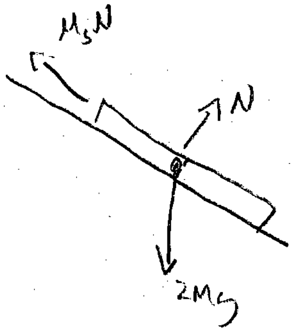
M=4kg



I set M=kg and put 2M in eqns. Could let M=8kg and put M in eqns. That does NOT make a difference

$\cancel{2}Ma_{\parallel} = \cancel{2}Mg\sin\theta - \mu_K \cancel{2}Mg\cos\theta$

$\boxed{a_{\parallel} = 4.8\ M/s^2}$ case II



SAME as case II

$\boxed{a_{\parallel} = 4.8\ M/s^2}$

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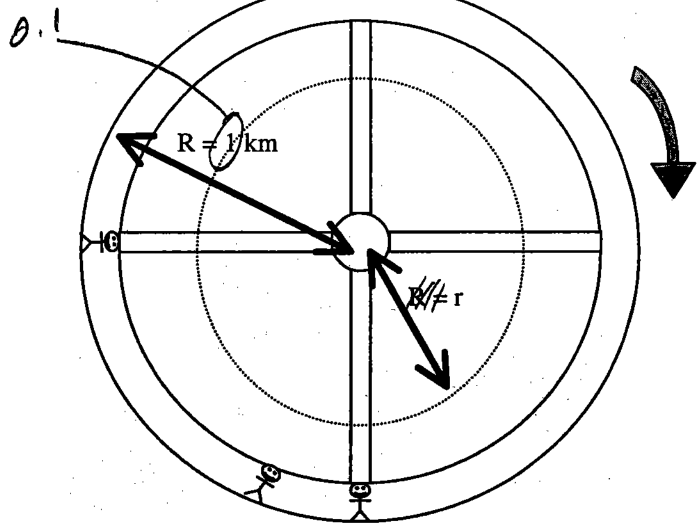
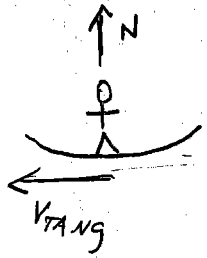
<u>Problem 8 (15 pts):</u> ***(Work on this problem after you have attempted and checked your work on all the other problems on the exam.)***

Designers of future large space stations hope to create "artificial gravity" by circular motion. Consider a space station design that appears like a large bicycle wheel. The inhabitants live and work on the interior of the outer rim of the wheel structure. That is to say, they typically can be found at a radius of 0.1 km from the center of the station. This outer rim region is shaped like a large donut or toroid. Consider such a structure, schematically pictured below, with a radius of 0.1 km.

View along axis of rotation.



a) The station must make a full rotation in what time in order for the inhabitants to feel as if they are standing on the surface of the earth (at least in terms of their apparent weight)?



$F_c = m\frac{v^2}{R} = mg$ $\qquad \frac{v^2}{R} = g$ $\qquad V_{TANG} = \frac{2\pi R}{\text{Time one Rotation}}$

$F_c = N = mg$

Normal Force provides Apparent weight

$\text{Time} = \frac{2\pi(100\,m)}{31\ m/s}$

$\boxed{\text{Time} = 20\,s}$

b) What is the magnitude of the tangential velocity of an object on the outer rim of the station?

$$\boxed{V_{TANG} = \sqrt{Rg} = \sqrt{(100\,m)\,9.8\,m/s^2} = 31\ m/s}$$

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c) Consider an object in one of the station's radial spokes at a radius, r, less than 0.1 km. Derive and circle the correct general expression giving the tangential velocity of this object as a function of r.

$v(r)=0$ $\quad v(r)=\sqrt{gR}$ $\quad v(r)=\sqrt{gr}$ $\quad v(r)=r\sqrt{\frac{g}{R}}$ $\quad v(r)=r\sqrt{\frac{R}{g}}$

$$V(r)_{TANG} = \frac{2\pi r}{\text{Time 1 rev}} = \frac{2\pi r}{\left[\frac{2\pi R}{V(R)}\right]} = \frac{2\pi r}{2\pi R} V(R) = \frac{2\pi r}{2\pi R}\sqrt{Rg} = r\sqrt{\frac{g}{R}}$$

Time is same at r as it is at R

d) Consider an object in one of the station's radial spokes at a radius, r, less than 0.1 km. Derive and circle the correct general expression giving the centripetal acceleration of this object as a function of r.

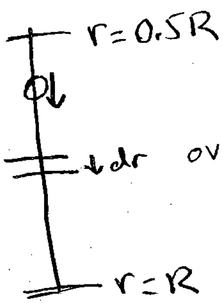
$a(r)=0$ $\quad a(r)=g$ $\quad \boxed{a(r)=g\frac{r}{R}}$ $\quad a(r)=g\frac{R}{r}$ $\quad a(r)=g\sqrt{\frac{r}{R}}$

$$a_c(r) = \frac{V(r)^2}{r} = \left[r\sqrt{\frac{g}{R}}\right]^2 \frac{1}{r} = \frac{r^2}{r}\frac{g}{R} = g\frac{r}{R}$$

e) Consider an object in one of the station's radial spokes at a radius, r, less than 0.1 km. Suppose this object is allowed to slide down a thin, straight, frictionless rod (like a bead on a string) that extends radially along one of the station's spokes. Let it start with a radial velocity of zero at a radius of 0.5R and slide frictionlessly down the rod until it reaches the outer rim at a radius of R. Derive and circle the expression for the radial velocity of the object when it reaches the rim.

$v(R)=0$ $\quad v(R)=\sqrt{gR}$ $\quad v(R)=\sqrt{g\frac{R}{2}}$ $\quad v(R)=\frac{\sqrt{gR}}{2}$ $\quad v(R)=\frac{R}{2}\sqrt{\frac{R}{g}}$

Hint: one can assume the radial velocity and acceleration are constant over a differential time dt and a differential distance dr.



$$V - \underset{0}{V_0} = \int_{r=0.5R}^{r=R} a\,dt$$ general expression

over dr, $dv = a\,dt$

and $dr = v\,dt$

$\therefore dt = \frac{dr}{V}$

Convert to integral over dr

$$V = \int_{0.5R}^{R} a(r)\frac{dr}{V(r)} = \int_{0.5R}^{R} g\frac{r}{R}\frac{1}{r}\sqrt{\frac{R}{g}}\,dr$$

$$V(R)_{radial} = \sqrt{\frac{g}{R}}\int_{0.5R}^{R} dr = \sqrt{\frac{g}{R}}\,[0.5R] = 0.5\sqrt{gR}$$