Midterm # 1: Physics 131

(Winter 2005, 8:30 Section)

Name: **SOLUTIONS** _
Recitation Instructor: ________________________

The duration of the midterm is 48 min.

There are four problems to the midterm.

Put you name on all sheets of paper.

Use the back of the sheets for extra space (label your work clearly).

A formula sheet is attached as the last page. You may remove this for ease of use. Do NOT put any work on the sheet and turn it in with your test.

GOOD LUCK!

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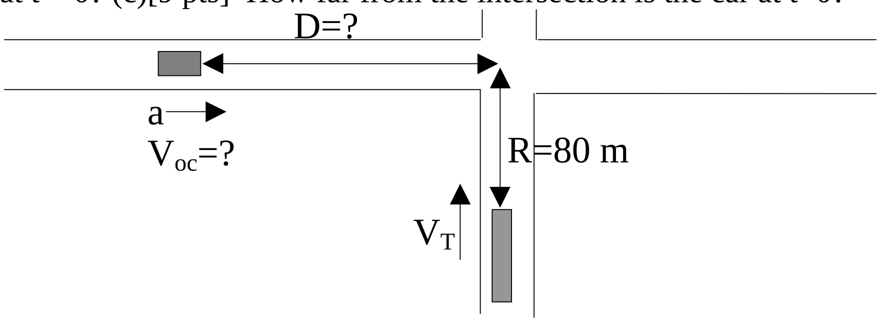
Problem 1 [25 pts] A truck is traveling down a straight road with a constant velocity of 20 m/s. A car is traveling down another straight road which is perpendicular to the first road. The car is accelerating with a constant 1 m/s^2 (forward). At t = 0 the truck is 80 m from the intersection. Neither driver notices the other and the car and the truck collide in the center of the intersection. At the moment of the collision the car is traveling 15 m/s. (a) [8 pts] At what time, t, does the collision occur? (b)[8 pts] What is the speed of the car at t = 0? (c)[9 pts] How far from the intersection is the car at t=0?



a) **The time is just the time that it takes the truck to reach the intersection which is given by:**

$$t = R/V_T = (80\text{ m})/(20\text{ m/s}) = 4\text{ s.}$$

b) **The velocity of the car at t=0 can be determined from**

$$V_c = V_{oc} + a\,t \Rightarrow V_{oc} = V_c - a\,t = 15\text{ m/s} - (1\text{m/s}^2)(4\text{ s}) = 11\text{ m/s}^2$$

c) **The distance that the car was from the intersection can be determined from**

$$D = V_{oc}t + \tfrac{1}{2} at^2 = (11\text{ m/s})(4\text{ s}) + \tfrac{1}{2}(1\text{ m/s}^2)(4\text{ s})^2 = 52\text{ m}$$

or another approach is

$$V_c^2 = V_{0c}^2 + 2a(D)$$
$$D = (V_c^2 - V_{0c}^2)/2a = 52\text{ m}$$

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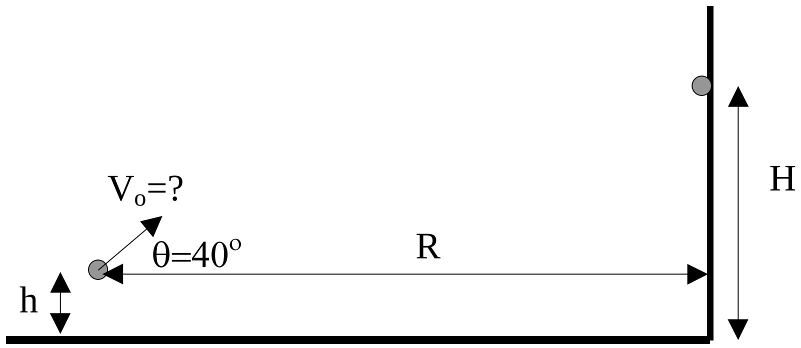
Problem 2 [25 pts] A ball is thrown at a vertical brick wall. The ball is initially 1.5 m above the horizontal ground, 10 m from the wall and is thrown toward the wall at an angle of 40^o with respect to the ground. It takes 1.0 second for the ball to reach the wall. (a)[7 pts] What is the initial speed of the ball? (b)[7 pts] At what distance above the ground does the ball hit the wall? (c) [7 pts] What is the ball's velocity (magnitude and direction) when the ball hits the wall? (d) [4 pts] Did the ball reach its maximum height before it hit the wall?



a) We can get the velocity from

$$R = V_o \cos 40^o\, t \;\rightarrow\; V_o = R/(\cos 40^o\, t) = 13 \text{ m/s}$$

b) Once we have the initial velocity

$$H = h + V_o \sin 40^o\, t - \tfrac{1}{2} g t^2 = h + R \tan 40^o - \tfrac{1}{2} g t^2 = 5.0 \text{ m}$$

c) The velocity when the ball hits the wall can be determined by components

$$V_x = V_{ox} = V_o \cos 40^o = R/t = 10 \text{ m/s}$$
$$V_y = V_{oy} - gt = V_o \sin 40^o - g\, t = -1.4 \text{ m/s}$$

The magnitude of the of the velocity is

$$V = [\,(V_x)^2 + (V_y)^2]^{1/2} = 10.1 \text{ m/s}$$

the angle *below* the horizontal is

$$\theta = \arctan(|V_y|/|V_x|) = 8.2^o \text{ (below the horizontal)}$$

d) Since the y-component of the velocity is negative when the ball hits the wall, it must have passed its maximum height before it hits the wall.

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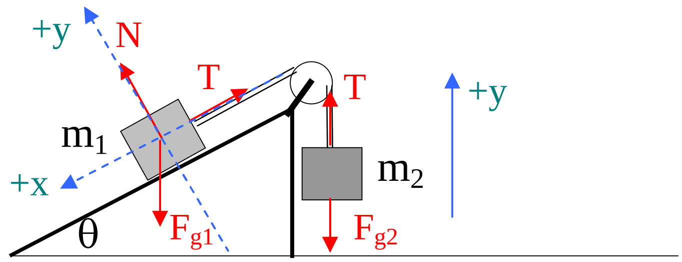
Problem 3 [25 pts] Two blocks with mass m_1 = 3.0 kg and m_2 = 5.0 kg are connected by a massless and unstretchable rope that passes over a massless pulley as shown in the diagram below. The pulley and surfaces are frictionless. The angle θ is 30°.



a) [5 pts] On the plot above, label all the forces that are acting on each block.

b) [5 pts] Write down Newton's 2nd law for each block.

Block #1: $\sum F_x = F_{g1}\sin\theta - T = m_1 a_1$

$\sum F_y = N - F_{g1}\cos\theta = 0$

Block #2: $\sum F_y = T - F_{g2} = m_2 a_2$

Note: If block #1 accelerates down the slope in its +x direction then block #2 will accelerate up with the same acceleration, therefore

$a_1 = a_2$

c) [3 pts] Determine the normal force:

$N = F_{g1}\cos\theta = m_1 g\cos\theta = 25$ N

d) [6 pts] Determine the acceleration of the blocks.

From Block #2 $T = m_2 a + F_{g2} = m_2 a + m_2 g$

substitute this in the x equation for block #1

$m_1 g\sin\theta - (m_2 a + m_2 g) = m_1 a$
$g(m_1\sin\theta - m_2) = (m_1 + m_2)a$

$a = g(m_1\sin\theta - m_2)/(m_2 + m_1) = -4.3$ m/s² ("–" means it is pointing down)

e) [6 pts] Determine the tension in the rope.

From the first equation in d) $T = m_2(a+g) = 28$ N

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Problem 4 [25 pts] (Circle your answer)

4a) [4 pts] A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown

1) upward
2) downward
3) neither - they both hit with the same speed 🡐

4b) [4 pts] An elevator is traveling downward with a constant velocity. A person in the elevator drops a coin. To the person in the elevator the magnitude of the acceleration of the coin appears to be

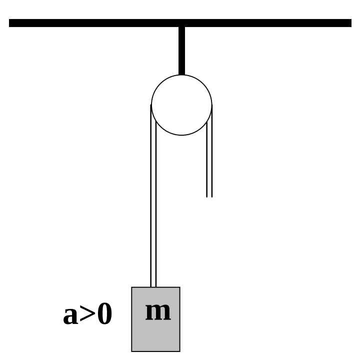
1) $a > 9.8\ m/s^2$
2) $a = 9.8\ m/s^2$ 🡐
3) $a < 9.8\ m/s^2$

4c) [4 pts] While riding in a car that is accelerating forward, you throw an egg straight up in the air. The egg will land

1) in front of you.
2) straight back down into your hand.
3) behind you. 🡐

4d) [5 pts] Shown below is a box that is accelerating upward because someone is pulling on the other end of the rope. The tension in the rope is

1) T > mg 🡐
2) T = mg
3) T < mg



4e) [4 pts] Two blocks are stacked on a table, one on top of the other. What can be said about the normal force on the bottom block due to the table?

1) It is equal to the weight of the bottom block.
2) It is equal to sum of the masses of the two blocks.
3) We must have more information.
4) It is greater that the weight of the bottom block. 🡐

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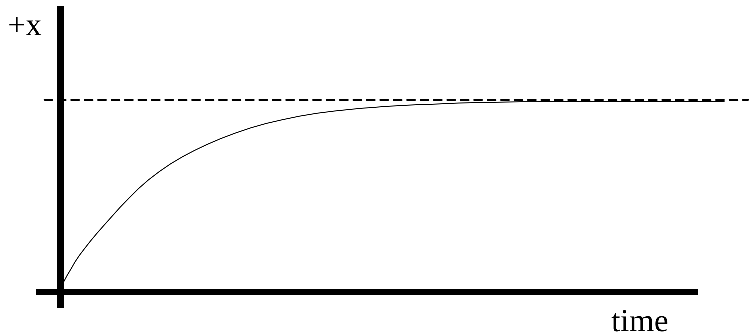
4f) [4 pts] Shown below is a position versus time plot for a particle moving in one-dimension. At no time (shown below) is the acceleration:

1) $a > 0$ 🡐
2) $a = 0$
3) $a < 0$

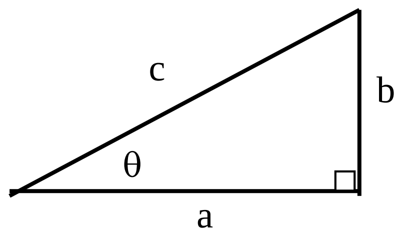


Useful Equations and Constants:

$g = 9.8\ m/s^2 = 32\ ft/s^2$

$m_e = 9.11 \times 10^{-31}$ kg (electron mass)

$m_p = 1.67 \times 10^{-27}$ kg (proton mass)



$(4/3)\pi r^3$ (Volume of a sphere)

$4\pi r^2$ (Surface area of a sphere)

$2\pi rL$ (area of the sides of a cylinder)

$\pi r^2 L$ (volume of a cylinder)

πr^2 (area of a circle)

$2\pi r$ (circumference of a circle)

$\mathbf{A}+\mathbf{B}=(A_x+B_x)\mathbf{i}+(A_y+B_y)\mathbf{j}+(A_z+B_z)\mathbf{k}$

$\mathbf{A}-\mathbf{B}=(A_x-B_x)\mathbf{i}+(A_y-B_y)\mathbf{j}+(A_z-B_z)\mathbf{k}$

$a^2+b^2=c^2$; $\sin\theta = b/c$; $\cos\theta = a/c$; $\tan\theta = b/a$; $\sin^2\theta + \cos^2\theta = 1$; $2\sin\theta\cos\theta = \sin 2\theta$

If $ax^2+bx+c=0$, then $x = \dfrac{-b \pm \sqrt{b^2-4ac}}{2a}$

$$\vec{v} = \frac{d\vec{r}}{dt} \quad \text{by components:} \quad v_x = \frac{dx}{dt} \quad v_y = \frac{dy}{dt} \quad v_z = \frac{dz}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \quad \text{by components:} \quad a_x = \frac{dv_x}{dt} = \frac{d^2x}{dt^2} \quad a_y = \frac{dv_y}{dt} = \frac{d^2y}{dt^2} \quad a_z = \frac{dv_z}{dt} = \frac{d^2z}{dt^2}$$

Equations of Motion:

$$x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x = v_{0x} + a_x t \qquad v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$$

$$\text{Horizontal Range:} \quad R = \frac{v_0^2}{g}\sin 2\theta \qquad \text{Projectile Motion:} \quad y = x(\tan\theta_0) - \frac{gx^2}{2(v_0\cos\theta_0)^2}$$

Forces:

$$\sum \vec{F} = m\vec{a} \quad \text{by components:} \quad \sum F_x = ma_x \quad \sum F_y = ma_y \quad \sum F_z = ma_z$$

$\mathbf{F_g} = \mathbf{W} = m\mathbf{g}$ (Weight)

1 N = 1 kg m/s^2

Conversion Factors:

1 mi = 1.61 km = 5280 ft   1 m = 3.28 ft   1 in = 2.54 cm