KEY

PHYS 1311 Spring 2017 Test 1
Jan. 31, 2017

Name ______________ **Student ID** ______________ **Score** ______

Note: This test consists of one set of conceptual questions, five problems, and a bonus problem. For the problems, you *must show all* of your work, calculations, and reasoning clearly to receive credit. Be sure to include units in your solutions where appropriate. An equation sheet is provided on the last page.

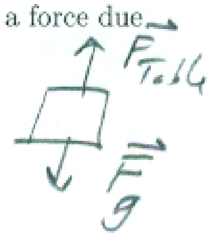
Problem 1. Conceptual questions. State whether the following statements are *True* or *False*. (10 points total, no calculations required)

(a) According to contemporary understanding of physics, there are only four fundamental forces.

True

1. Gravity
2. Electromagnetism
3. Weak Nuclear
4. Strong Nuclear

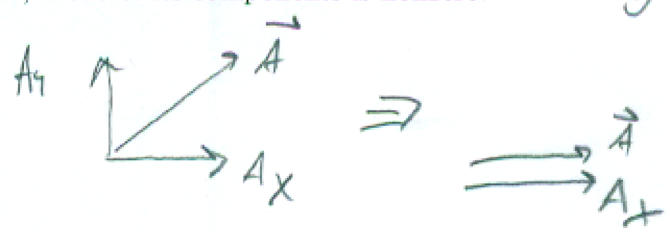
(b) If a book at rest on a table experiences both a force due to the table and a force due to gravity, the two forces are related by Newton's 3rd law of motion.



False $\rightarrow$ Newton's 2nd Law

(c) A vector can have zero magnitude, if one of its components is nonzero.

False



Problem 2. A bowling ball of mass m is dropped from a height h with zero initial velocity. Prove that the time it takes to hit the ground and its final velocity on impact are $\sqrt{2h/g}$ and $< 0, -\sqrt{2gh}, 0 >$, respectively. (15 points total)

$t_i = 0$

$y_i = h$ $v_i = 0$

$y_f = 0$ $v_f = ?$

$$y_f = y_i + v_i t_f - \frac{1}{2} g t_f^2$$

$$0 = h + 0 - \frac{1}{2} g t_f^2$$

$$\boxed{t_f = \sqrt{\frac{2h}{g}}}$$

$$v_f = v_i - g t_f$$

$$= 0 - g\sqrt{\frac{2h}{g}}$$

$$= -\sqrt{\frac{g^2 2h}{g}} = \boxed{-\sqrt{2gh}}$$

Problem 3. Josephine is climbing a 3.00 m long ladder that leans against a wall 2.50 m above the ground. Her weight is 500 N. What are the components of Josephine's weight parallel and perpendicular to the ladder? (15 points total)

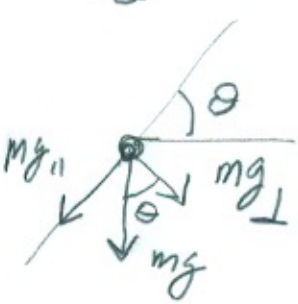
$r = 3.00\,m,\quad y = 2.50\,m$

$$\theta = \sin^{-1}\left(\frac{y}{r}\right) = \sin^{-1}\left(\frac{2.5}{3}\right) = 56.44^\circ$$

$$F_\perp = mg\cos\theta = (500N)\cos(56.44^\circ)$$

$$= \boxed{276.4\,N}$$

$F_\parallel = mg_\parallel$



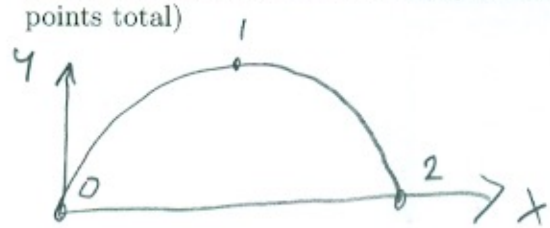
$mg_\perp = F_\perp$

$$F_\parallel = mg\sin\theta = (500N)\sin(56.44^\circ)$$

$$= \boxed{416.7\,N}$$

$// x_2 \quad // t_2$

Problem 4. A golf ball is struck with a golf club on level ground. It lands 85.0 m away 4.00 s later. What was the initial velocity of the golf ball? Give in vector component notation. (15 points total)



$$X_2 = V_{x2} t_2 = V_{x0} t_2$$

$$V_{x0} = \frac{X_2}{t_2} = \frac{85.0\,m}{4.00\,s} = 21.25\,m/s$$

$$Y_2 = Y_0 + V_{y0} t_2 - \frac{1}{2} g t_2^2$$

$$0 = 0 + V_{y0} t_2 - \frac{1}{2} g t_2^2$$

$$V_{y0} = \frac{g t_2}{2} = \frac{(9.8\,m/s^2)(4.0s)}{2}$$

$$= 19.6\,m/s$$

$$\boxed{\vec{V}_0 = \langle 21.25, 19.6, 0 \rangle \frac{m}{s}}$$

Problem 5. (a) Starting with Newton's 2nd law, $\vec{F}_{\text{net}} = m\vec{a}$, derive the momentum principle with $\gamma = 1$. (b) If a handball of mass 5.00 g hits a wall with initial velocity $< 100.0, 5.00, 0 >$ m/s and experiences an impulse of $< -1.00, 0, 0 >$ Ns, what is its final velocity and momentum? (c) If the impact occurred over a duration of 0.50 ms, what was the force vector experienced by the handball? (15 points total)

a) $\vec{F}_{net} = m\vec{a} = m\frac{d\vec{V}}{dt} = \frac{d(m\vec{V})}{dt} = \frac{d\vec{p}}{dt}$

$$\int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}_{net}\, dt$$

$$\vec{p}_f - \vec{p}_i = \vec{F}_{net}(t_f - t_i)$$

for $\vec{F}_{net}$ = constant

or

$$\boxed{\vec{p}_f = \vec{p}_i + \vec{F}_{net} \Delta t}$$

b) $\vec{p}_f = m\vec{V}_i + \vec{I}$

$= (5 \times 10^{-3}\,kg)\langle 100, 5, 0 \rangle \frac{m}{s} + \langle -1, 0, 0 \rangle Ns$

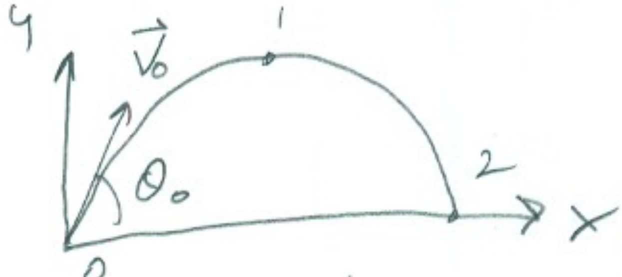
$= \boxed{\langle -0.5, 0.025, 0 \rangle Ns}$

$\vec{V}_f = \frac{\vec{p}_f}{m} = \boxed{\langle -100, 5, 0 \rangle \frac{m}{s}}$

c) $\vec{I} = \vec{F}_{net} \Delta t$

$\vec{F}_{Net} = \frac{\vec{I}}{\Delta t} = \boxed{\langle -2000\,N, 0, 0 \rangle}$

Problem 6. You kick a soccer ball with a speed of v_0 at an angle of θ_0 with respect to the horizontal. It lands down field a distance x_2 away. Starting with the appropriate kinematic equations in the $x-$ and y-directions determine in terms of v_0, θ_0, and g, the (a) total time the ball is in the air t_2, (b) the maximum height the ball reaches y_1, and (c) the total range x_2. (d) Show by taking a derivative with respect to θ_0 of the result in part (c) that the maximum range occurs when $\theta_0 = 45°$. Remember $2\sin\theta\cos\theta = \sin(2\theta)$. (30 points total)



$$V_{0x} = V_0 \cos\theta_0 = V_{1x} = V_{2x}$$

$$V_{0y} = V_0 \sin\theta_0 = -V_{2y}$$

$$V_{1y} = 0 \quad , \quad y_0 = y_2 = 0$$

a) $V_{1y} = V_{0y} - g t_1$

$$0 = V_0 \sin\theta_0 - g t_1$$

$$t_1 = \frac{V_0 \sin\theta_0}{g}$$

$$t_2 = 2t_1 = \boxed{\frac{2 V_0 \sin\theta_0}{g}}$$

b) $V_{1y}^2 = V_{0y}^2 - 2g(y_1 - y_0)$

$$0 = (V_0 \sin\theta_0)^2 - 2g y_1$$

$$y_1 = \boxed{\frac{V_0^2 \sin^2\theta_0}{2g}}$$

c) $X_2 = V_{2x} t_2 = V_{0x} 2t_1$

$$= V_0 \cos\theta_0 \frac{2 V_0 \sin\theta_0}{g}$$

$$= \frac{2 V_0^2 \cos\theta_0 \sin\theta_0}{g}$$

$$= \boxed{\frac{V_0^2 \sin(2\theta)}{g}}$$

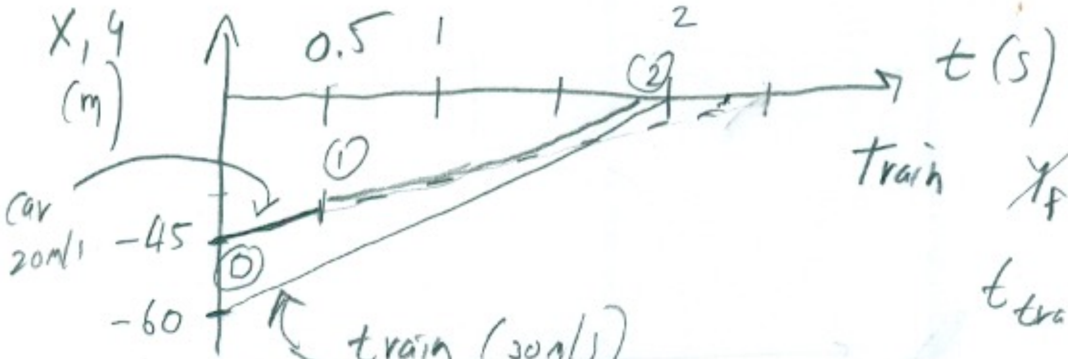
d) $\frac{dX_2}{d\theta_0} = 0$ to get maximum

$$\frac{d}{d\theta_0}\left(\frac{V_0^2}{g}\sin(2\theta)\right) = \frac{V_0^2}{g}\cos(2\theta)(2)$$

or $\cos 2\theta = 0$

or $2\theta = \frac{\pi}{2}$ or $\boxed{\theta = \frac{\pi}{4} = 45°}$

Bonus Problem. I was driving along at 20.0 m/s, trying to change a CD (I don't text and drive) and not watching the road. When I looked up, I found myself 45.0 m from a railroad crossing, and wouldn't you know it, a train moving at 30.0 m/s was only 60.0 m from the crossing. In a split second, I realized that the train was going to beat me to the crossing and that I didn't have enough time to stop. My only hope was to accelerate enough to cross the tracks before the train arrived. If my reaction time before starting to accelerate was 0.50 s, what minimum acceleration did my car need for me to beat the train and be here today giving this test? (5 points total)



train $\cancel{y_f}^{\,0} = y_i + V_{train}\, t_{train}$

$t_{train} = \frac{-y_i}{V_{train}} = \frac{+60\,m}{30\,m/s}$

$= \boxed{2.0\,s}$

time for train to get to crossing

If I drove at constant speed I would get to the crossing

at $t_{car} = \frac{-x_i}{V_{car}} = \frac{45.0\,m}{20\,m/s}$

$= 2.25\,s$ ← crash into train

at 0.5 secs, car travels to $x_1 = x_0 + V_{car}\, t_1$

$x_1 = -45 + (20\,m/s)(0.5\,s) = -35\,m$

to accelerate from x_1 to crossing (x_2) in 1.5 s

$$x_2 = x_1 + V_1(t_2 - t_1) + \frac{a}{2}(t_2 - t_1)^2$$

$$\frac{x_2 - x_1 - V_1 \Delta t}{\Delta t^2/2} = a = \frac{(0-35)-(20)(1.5)}{(1.5)^2/2} = \boxed{4.44\,\frac{m}{s^2}}$$