Name

Nine-digit Tech ID

Fall 2018 **Physics 2211 AB** Quiz #

2D

- Put *nothing* other than your name and nine-digit Tech ID in the spaces above.
- Free-response problems are numbered I–VII. Show all your work clearly, including all steps and logic. Write **darkly**. Blue or black ink is recommended. Do not make any erasures in your free-response work. Cross out anything you do not want evaluated. Box your answer.
- Multiple-choice questions are numbered 1–5. For each, select the answer most nearly correct, circle it on your quiz, and fill the bubble for your answer on this front page.
- Initial the odd pages in the top margin, in case the pages of your quiz get separated.
- The standard formula sheet is on the back of this page, which may be removed from the quiz form if you wish, but it must be submitted.
- If the page for a free-response problem has insufficient space for your work, ask a proctor for an additional sheet. If you wish this work to be evaluated, put your name on the sheet and make a note on the problem page, so graders know where to find your work.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next is given.

Fill in bubbles for your Multiple Choice answers darkly and neatly.

1 ⓐ ⓑ ⓒ ⓓ ⓔ

2 ⓐ ⓑ ⓒ ⓓ ⓔ

3 ⓐ ⓑ ⓒ ⓓ ⓔ

4 ⓐ ⓑ ⓒ ⓓ ⓔ

5 ⓐ ⓑ ⓒ ⓓ ⓔ

Quiz & Final Exam Formulæ & Constants

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{\omega} = \frac{d\vec{\theta}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt}$$

$$v_{\mathrm{sf}} = v_{\mathrm{si}} + a_{\mathrm{s}}\,\Delta t$$

$$\omega_{\mathrm{f}} = \omega_{\mathrm{i}} + \alpha\,\Delta t$$

$$s_{\mathrm{f}} = s_{\mathrm{i}} + v_{\mathrm{si}}\,\Delta t + \tfrac{1}{2}a_{\mathrm{s}}\,(\Delta t)^2$$

$$\theta_{\mathrm{f}} = \theta_{\mathrm{i}} + \omega_{\mathrm{si}}\,\Delta t + \tfrac{1}{2}\alpha\,(\Delta t)^2$$

$$s = r\theta$$

$$v = r\omega$$

$$a_{\mathrm{t}} = r\alpha$$

$$\sum \vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$

$$\sum \vec{F}_{\mathrm{ext}} = M\vec{a}_{\mathrm{cm}} = \frac{d\vec{P}}{dt}$$

$$\sum \vec{\tau}_{\mathrm{ext}} = I\vec{\alpha} = \frac{d\vec{L}}{dt}$$

$$f_{\mathrm{s,max}} = \mu_{\mathrm{s}} n$$

$$f_{\mathrm{k}} = \mu_{\mathrm{k}} n$$

$$a_{\mathrm{r}} = \frac{v^2}{r}$$

$$\vec{w} = m\vec{g}$$

$$|\vec{F}_{\mathrm{G}}| = \frac{Gm_1m_2}{|\vec{r}|^2}$$

$$D = \tfrac{1}{2}C\rho A v^2$$

$$\vec{\tau} = \vec{r}\times\vec{F}$$

$$W = \int \vec{F}\cdot d\vec{s}$$

$$W_{\mathrm{ext}} = \Delta K + \Delta U + \Delta E_{\mathrm{th}}$$

$$K = \tfrac{1}{2}mv^2$$

$$K = \tfrac{1}{2}I\omega^2$$

$$U_{\mathrm{g}} = mgy$$

$$U_{\mathrm{s}} = \tfrac{1}{2}k\,(\Delta s)^2$$

$$U_{\mathrm{G}} = -\frac{Gm_1m_2}{r}$$

$$P = \frac{dE_{\mathrm{sys}}}{dt}$$

$$P = \vec{F}\cdot\vec{v}$$

$$\vec{J} = \int \vec{F}\,dt = \Delta\vec{p}$$

$$\vec{p} = m\vec{v}$$

$$\vec{r}_{\mathrm{cm}} = \frac{\sum \vec{r}_i m_i}{\sum m_i}$$

$$\vec{r}_{\mathrm{cm}} = \frac{\int \vec{r}\,dm}{\int dm}$$

$$I = \sum m_i r_i^2$$

$$I = \int r^2\,dm$$

$$I = I_{\mathrm{cm}} + Md^2$$

$$\vec{L} = \vec{r}\times\vec{p}$$

$$\vec{L} = I\vec{\omega}$$

$$x = A\cos(\omega t + \phi_0)$$

$$\vec{a}_{\mathrm{x}} = -\omega^2\vec{x}$$

$$\omega = \sqrt{k/m}$$

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

Physical Constants:

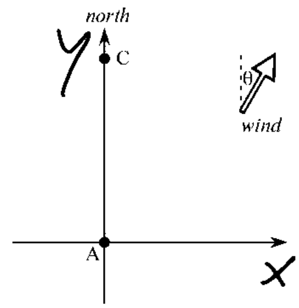
Universal Gravitation Constant $G = 6.673\times10^{-11}\,\mathrm{N{\cdot}m^2/kg^2}$
Gravitational Acceleration at Earth's Surface $g = 9.81\,\mathrm{m/s^2}$

Unless otherwise directed, drag is to be neglected and all problems take place on Earth, use the gravitational definition of weight, and all springs, ropes and pulleys are ideal.

You may remove this sheet from your Quiz or Exam

I. (10 points) You are the pilot of a plane flying 601 km due north from Atlanta to Cincinnati. Your plane is capable of maintaining a steady airspeed $v_a = 225\,\text{km/hr}$. As your plane leaves the runway, the weather report indicates a wind blowing with a speed of 64.0 km/hr at an angle $\theta = 30.0^\circ$ east of north.

Assuming that the wind remains constant throughout your flight, in what direction (relative to due north) should you point the nose of the plane?



Be $\vec{V}_p$ the velocity of the plane relative to the ground.

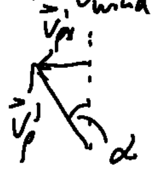
$\Rightarrow V_{px} = 0$

Atmosphere is the reference system in motion with velocity $\vec{V}_{wind}$ and $\vec{V}_p'$ the velocity of the plane in the moving system

$\vec{V}_p = \vec{V}_{wind} + \vec{V}_p'$

$x: 0 = V_{windx} + V_{px}' = V_{wind} \cdot \sin\theta + V_{px}' \Rightarrow V_{px}' = -V_{wind} \cdot \sin\theta$

heading of plane



$\sin\alpha = \frac{V_{px}'}{V_p} = \frac{V_{wind} \cdot \sin\theta}{V_p} \Rightarrow \alpha = \sin^{-1} \frac{V_{wind} \cdot \sin\theta}{V_p}$

$= 8.18^\circ$ W of N

II. (10 points) In the problem above, how long after leaving Atlanta will you arrive in Cincinnati?

need speed relative to the ground

$V = \sqrt{V_{px}^2 + V_{py}^2} = \sqrt{0 + V_{py}^2} = V_{py}$

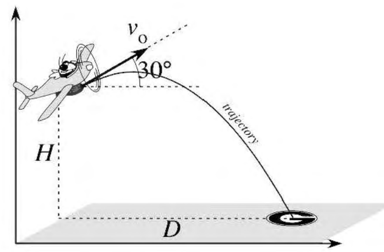
with α from above

$V_{py} = V_{windx} + V_{py}' = V_{wind} \cdot \cos\theta + V_p \cdot \cos\alpha$

$t = \frac{D}{V_{py}} = \frac{D}{V_{wind} \cdot \cos\theta + V_p \cdot \cos\alpha} = \frac{601\,\text{km}}{65\,\text{km/h} \cdot \cos 30^\circ + 225\,\text{km/h} \cdot \cos 8^\circ}$

$= 2.15\,\text{hrs}$

III. (10 points) Buzz has acquired a large stink-bomb, and plans to drop it on the big "G" on the 50-yard-line at Sanford Stadium during the UGA Homecoming game. Being something of a showoff, he decides to "lob" the bomb into the stadium while in a shallow 30.0° climb. He releases the bomb at an altitude $H = 175\,\text{m}$, while traveling at a speed $v_0 = 35\,\text{m/s}$.



Determine the elapsed time that the bomb will be in flight before it hits the ground. What horizontal distance D should Buzz be in front of the "G" at the moment he releases the bomb? (Use $g = 9.80\,\text{m/s}^2$).

Kinematics in y determines flight time

I $g = \frac{v_f - v_i}{t_f}$ $t = 0$ when bomb is released

II $v_f^2 - v_i^2 = 2g \cdot H \Rightarrow v_f = \sqrt{v_i^2 + 2 \cdot g \cdot H}$ $v_i = v_0 \cdot \sin 30°$

II in I $t_f = \frac{\sqrt{v_i^2 + 2 \cdot g \cdot H} - v_i}{g} = \underline{\underline{8\,s}}$

$D = v_0 \cdot \cos 30° \cdot t = \underline{\underline{242\,m}}$

IV. (10 points) In the problem above, With what **velocity** will the bomb impact the target?

$\vec{v}_f = ?$ $\vec{v}_f = v_{0x}\,\hat{i} + v_{fy} \cdot \hat{j}$

$v_{fy}^2 - v_{0y}^2 = 2 \cdot g \cdot H \Rightarrow v_{fy} = \sqrt{2 \cdot g \cdot H + v_{0y}^2} = \sqrt{2 \cdot g \cdot H + (v_0 \sin 30°)^2}$

$\vec{v}_f = v_0 \cdot \cos 30°\,\hat{i} + \sqrt{2 \cdot g H + (v_0 \cdot \sin 30°)^2}\,\hat{j}$

$= 30.3\,\frac{m}{s}\,\hat{i} + 61.1\,\frac{m}{s}\,\hat{j}$

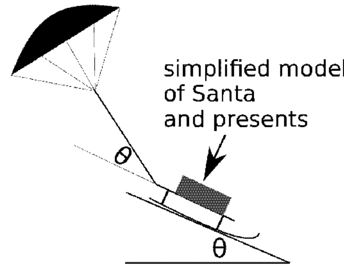
V. (2 points extra credit!) Suppose Buzz launches the bomb from the same height H with the same speed v_0, but in a 60.0° climb instead of a 30.0° climb. How will the bomb's impact speed in this second situation compare to the impact speed in the original situation? *Justify your answer with reasoning or calculations!*

$v_f^2 = (v_0 \cdot \cos 30°)^2 + 2 \cdot g h + (v_0 \cdot \sin 30)^2$

$= v_0^2 + 2 \cdot g \cdot h$ independent on angle

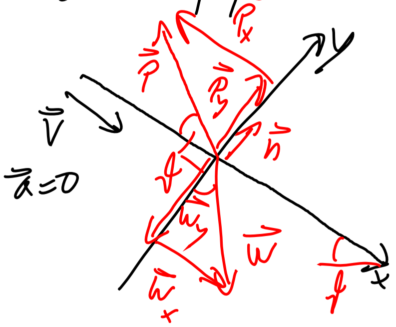
$\Rightarrow$ impact speed is the same for 30° as 60°

VI. (10 points) Santa experiences a catastrophic failure of the antimatter propulsion unit while in flight delivering presents. She manages to deploy the emergency parachute and comes to ground somewhere in the Rockies. The sleigh lands on a snowy and icy patch and slides down a slope with constant velocity while the parachute is still connected to the sleigh. The weight of the sleigh plus payload is W. The slope makes an angle $\theta = 22.0°$ relative to the horizontal and the parachute an angle $\theta = 22.0°$ relative to the slope.



Draw a free body diagram for the sleigh, identifying only **relevant** forces acting and labeling them symbolically. Argue which forces (if any) you can neglect. Choose and draw an appropriate coordinate system, and then decompose each force into appropriate components along those axes. Finally, write out Newton's 2nd law in component form along the chosen axes. (Your work will be graded for clarity, as well as accuracy!)

friction can be neglected compared to the pulling force exerted by parachute



2nd law

x: $W_x - P_x = 0$

$W \cdot \sin\theta - P\cos\theta = 0$

y: $-W_y + n + P_y = 0$

$-W\cos\theta + n + P\cdot\sin\theta = 0$

VII. (10 points) Use the equations you found above to determine the magnitude of each unknown force in your diagram. Express each answer as a numerical multiple of the weight W.

from 2nd law in x

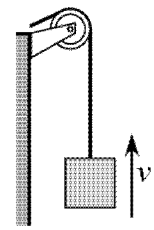
$P = W\cdot\tan\theta = 0.4\ W$

from 2nd law in y

$-W\cos\theta + n + W\cdot\tan\theta = 0$

$n = W(\cos\theta - \tan\theta) = 0.78\cdot W$

1. (10 points) A heavy crate is lifted from ground level to the roof of a building by a cable attached to a winch. While the crate is ascending at constant speed the forces acting on the crate are:



   (a) an upward tension force, the upward motion force of the crate, and a downward gravitational force, with the sum of the tension and motion forces equal in magnitude to the gravitational force.
   (b) an upward tension force and a downward gravitational force of equal magnitudes, plus the upward motion force of the crate.
   (c) an upward tension force, a downward normal force, and a downward gravitational force, with the sum of the normal and gravitational forces equal to the tension force.
   (d) an upward tension force and a downward gravitational force, with equal magnitudes.
   (e) an upward tension force and a downward gravitational force, with the magnitude of the tension force greater than the magnitude of the gravitational force.

2. (5 points) Suppose you press a book against a wall with your hand, so the book is not moving. The forces on the book are that of your push, a normal force, static friction, and the force of gravity. Now suppose that you increase the magnitude of the force of your push. How does the normal force change?
   (a) The normal force increases.
   (b) The normal force decreases.
   (c) The normal force remains the same.

3. (5 points) In the problem above, how does the static friction force change?
   (a) The static friction force decreases.
   (b) The static friction force increases.
   (c) The static friction force remains the same.

4. (10 points) When block 1 experiences a force of magnitude F_0, its resulting acceleration has a magnitude a_0. When block 2 experiences a force of the same magnitude F_0, its resulting acceleration has a magnitude $4a_0$. Blocks 1 and 2 are then glued together. If the combined blocks are subject to a force of magnitude F_0 along the x-axis plus a force of magnitude $2F_0$ along the y-axis, what will be the magnitude of the resulting acceleration?

   (a) $2.40\,a_0$
   (b) $1.34\,a_0$
   (c) $0.447\,a_0$
   (d) $1.67\,a_0$
   (e) $1.79\,a_0$

$\vec{a}_0 \rightarrow$

$\boxed{1} \xrightarrow{F_0}$ $\quad F_0 = m_1 \cdot a_0 \quad m_1 = \frac{F_0}{a_0}$

$\boxed{2} \xrightarrow{F_0}$ $\quad F_0 = m_2 \cdot 4 \cdot a_0 \quad m_2 = \frac{F_0}{4a_0}$

$4\vec{a}_0 \longrightarrow$

combining the two blocks

2nd law

$x: \quad a_x = \frac{F_0}{m_1 + m_2} = \frac{F_0}{\frac{F_0}{a_0} + \frac{F_0}{4a_0}} = a_0 \frac{4}{5}$

$y: \quad a_y = \frac{2F_0}{m_1 + m_2} = a_0 \cdot \frac{8}{5}$

$a = \sqrt{a_x^2 + a_y^2}$
$= a_0 \sqrt{80}/5$
$= 1.79 \cdot a_0$

5. (10 points) A jet fighter pilot is trained to withstand up to $4.0\,g$'s of acceleration without blacking out. Suppose that a plane in level flight at Mach 1.0 (i.e. at the speed of sound, 340 m/s) has a minimum turn radius given by R_1. Given the same "blackout acceleration" of $4.0\,g$'s, what will be the minimum turn radius $R_{3.3}$ of the same plane, when flying at Mach 3.3?

   (a) $R_{3.3} = 18 \cdot R_1$
   (b) $R_{3.3} = 3.3 \cdot R_1$
   (c) $R_{3.3} = R_1$
   (d) $R_{3.3} = 1.8 \cdot R_1$
   (e) $R_{3.3} = 11 \cdot R_1$

centripetal acceleration

$a_c = \frac{v^2}{R} = 4g$

$\frac{v_1^2}{R_1} = \frac{v_{3.3}^2}{R_{3.3}}$

$R_{3.3} = R_1 \, 3.3^2$
$= R_1 \cdot 11$