110 Fall 2023 Test 2A Once the exam has officially started, remove the top sheet. The remaining sheets comprise your exam. It is each student's individual responsibility to ensure the instructor has received her or his completed exam. Any exams not received by the instructor earn zero points. Smart watches, phones, or other devices (except scientific calculators) are not permitted during the exam.

$V_{sphere} = \frac{4}{3}\pi R^3$	$V_{box} = LWH$	$V_{cyl} = \pi R^2 H$	$\rho = \frac{M}{V}$
$A_{sphere} = 4\pi R^2$	$V = (A_{base}) \times (height)$	$A_{circle} = \pi R^2$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$C = 2\pi R$	$A_{rect} = LW$	$A_{CylSide} = 2\pi RH$	
$160\underline{9}\text{ m} = 1\text{ mi}$	$12\text{ in} = 1\text{ ft}$	$60\text{ s} = 1\text{ min}$	$1000\text{ g} = 1\text{ kg}$
$2.54\text{ cm} = 1\text{ in}$	$1\text{ cc} = 1\text{ cm}^3 = 1\text{ mL}$	$60\text{ min} = 1\text{ hr}$	$100\text{ cm} = 1\text{ m}$
$1\text{ cm} = 10\text{ mm}$	$1\text{ yard} = 3\text{ ft}$	$3600\text{ s} = 1\text{ hr}$	$1\text{ km} = 1000\text{ m}$
$1\text{ furlong} = 220\text{ yards}$	$528\underline{0}\text{ ft} = 1\text{ mi}$	$24\text{ hrs} = 1\text{ day}$	$1\text{ rev} = 2\pi\text{ rad} = 360°$
$g = 9.8\ \frac{\text{m}}{\text{s}^2}$	$G = 6.67 \times 10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$	$P_0 = 1.0 \times 10^5\text{ Pa}$	$1\text{ eV} = 1.60\underline{2} \times 10^{-19}\text{ J}$
$1\text{ N} = 1\frac{\text{kg}\cdot\text{m}}{\text{s}^2}$	$1\text{ J} = 1\text{ N}\cdot\text{m}$	$1\text{ Pa} = 1\ \frac{\text{N}}{\text{m}^2}$	
$x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2$	$v_{fx}^2 = v_{ix}^2 + 2a_x(\Delta x)$	$v_{fx} = v_{ix} + a_x t$	$r = \sqrt{x^2 + y^2}$
$\vec{A}\cdot\vec{B} = AB\cos\theta_{AB}$	$\lVert\vec{A}\times\vec{B}\rVert = AB\sin\theta_{AB}$	$\sin(A \pm B)$ $= \sin A\cos B \pm \cos A\sin B$	$\cos(A \pm B)$ $= \cos A\cos B \mp \sin A\sin B$
$\vec{v}_{ae} + \vec{v}_{eb} = \vec{v}_{ab}$	$\hat{r} = \cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath}$	$\hat{\theta} = -\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath}$	
$a_{tan} = r\alpha$	$a_c = \frac{v^2}{r} = r\omega^2$	$\vec{a} = a_r\hat{r} + a_{tan}\hat{\theta}$	$\vec{a} = a_c(-\hat{r}) + a_{tan}\hat{\theta}$
$\Sigma\vec{F} = m\vec{a}$	$f \le \mu n$		

Prefix	Abbreviation	$10^?$		Prefix	Abbreviation	$10^?$
Giga	G	10^9		milli	m	10^{-3}
Mega	M	10^6		micro	μ	10^{-6}
kilo	k	10^3		nano	n	10^{-9}
centi	c	10^{-2}		pico	p	10^{-12}
				femto	f	10^{-15}

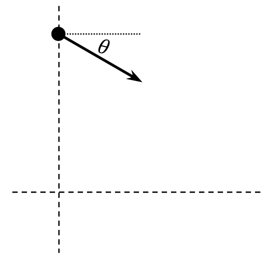
$[\text{M}] = \frac{\text{units of}}{\text{mass}} = \text{kg}$ $[\text{L}^2] = \frac{\text{units of}}{\text{area}} = \text{m}^2$ $[\text{T}] = \frac{\text{units of}}{\text{time}} = \text{s}$ $\left[\frac{\text{L}}{\text{T}^2}\right] = \frac{\text{units of}}{\text{acceleration}} = \frac{\text{m}}{\text{s}^2}$

$[\text{L}] = \frac{\text{units of}}{\text{length}} = \text{m}$ $[\text{L}^3] = \frac{\text{units of}}{\text{volume}} = \text{m}^3$ $\left[\frac{\text{L}}{\text{T}}\right] = \frac{\text{units of}}{\text{velocity}} = \frac{\text{m}}{\text{s}}$ $\left[\frac{\text{L}\cdot\text{M}}{\text{T}^2}\right] = \frac{\text{units of}}{\text{force}} = \frac{\text{kg}\cdot\text{m}}{\text{s}^2} = \text{N}$

Name:____

NOTE: allow yourself 95 minutes for this test since problem 6 was added after the fact.

In deep space a particle is initially 14.44 m from the origin travelling with speed $22.2\,\frac{\text{m}}{\text{s}}$ at angle $\theta = 33.3°$ as indicated by the figure. The particle accelerates *to the left* with constant magnitude $5.55\,\frac{\text{m}}{\text{s}^2}$.



**1a) How much time is required to reach the horizontal axis?

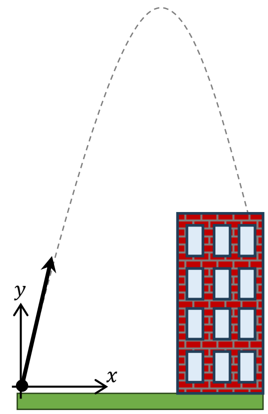
**1b) What is the speed of the particle when it reaches the horizontal axis?

1c) How far from the origin is the particle when it crosses the horizontal axis?

**1d) At what time does the particle begin travelling down and to the left (instead of down and to the right? If this never occurs, state "`never occurs`" in the box.

1a	
1b	
1c	
1d	

A projectile of negligible size is launched from the ground with speed v_0 and impacts the top of a building with speed v_f exactly 2.0 s later. The sketch at right shows an approximate trajectory. Assume air resistance is negligible and use the standard coordinate system shown.



2a) Which best describes the components of *acceleration* at max height? Circle the best answer.

$a_x < 0$ & $a_y = 0$	$a_x = 0$ & $a_y = 0$	$a_x > 0$ & $a_y = 0$	Impossible to determine without more info
$a_x < 0$ & $a_y > 0$	$a_x = 0$ & $a_y > 0$	$a_x > 0$ & $a_y > 0$	
$a_x < 0$ & $a_y < 0$	$a_x = 0$ & $a_y < 0$	$a_x > 0$ & $a_y < 0$	

2b) Which best describes the components of *velocity* at max height? Circle the best answer.

$v_x < 0$ & $v_y = 0$	$v_x = 0$ & $v_y = 0$	$v_x > 0$ & $v_y = 0$	Impossible to determine without more info
$v_x < 0$ & $v_y > 0$	$v_x = 0$ & $v_y > 0$	$v_x > 0$ & $v_y > 0$	
$v_x < 0$ & $v_y < 0$	$v_x = 0$ & $v_y < 0$	$v_x > 0$ & $v_y < 0$	

2c) Which best describes the time to reach max height (t_{max}) for this 2.00 s flight? Circle the best answer.

$t_{max} = 2.0$ s	1.0 s $< t_{max} <$ 2.0 s	$t_{max} = 1.0$ s	0.0 s $< t_{max} <$ 1.0 s	Impossible to determine without more info

2d) Which best describes the relationship between impact speed (v_f) and launch speed (v_0)? Circle the best answer.

$v_f > v_0$	$v_f = v_0$	$v_f < v_0$	Impossible to determine without more info

2e) Which best describes the relationship between *the sizes* of the impact velocity's horizontal component (v_{fx}) and the launch velocity's horizontal component (v_{0x})? Circle the best answer.

$\lvert v_{fx}\rvert > \lvert v_{0x}\rvert$	$\lvert v_{fx}\rvert = \lvert v_{0x}\rvert$	$\lvert v_{fx}\rvert < \lvert v_{0x}\rvert$	Impossible to determine without more info

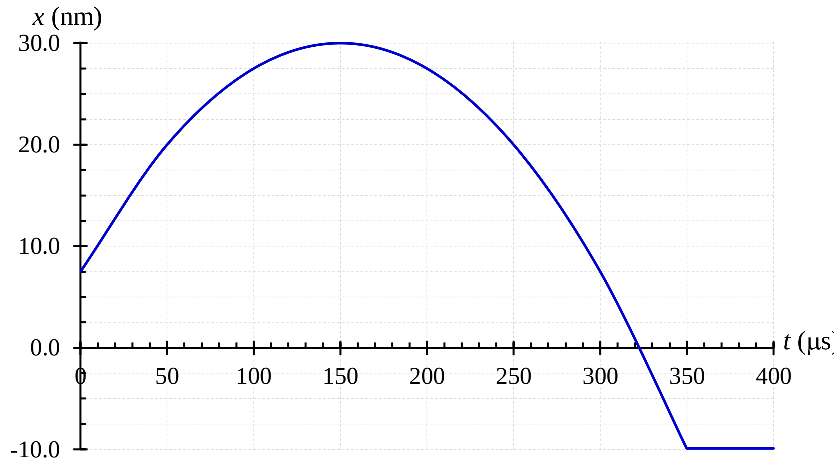
2f) Which best describes the relationship between *the sizes* of the impact velocity's vertical component (v_{fy}) and the launch velocity's vertical component (v_{0y})? Circle the best answer.

$\lvert v_{fy}\rvert > \lvert v_{0y}\rvert$	$\lvert v_{fy}\rvert = \lvert v_{0y}\rvert$	$\lvert v_{fy}\rvert < \lvert v_{0y}\rvert$	Impossible to determine without more info

2g) Which best describes the vertical displacement for this 2.0 s flight? Circle the best answer.

positive	zero	negative	Impossible to determine without more info

At right is an xt-plot for an object moving in one dimension. As usual, you need not include a unit vector for vector results as long as you include the appropriate $\pm$ sign.



3a) During which time intervals (or at what times) is the object *moving to the left*?

3b) During which time intervals (or at what times) is the object *speeding up*?

3c) What does the symbol x represent? Circle the best answer.

Speed	Distance	Acceleration	None of the other answers is correct
Velocity	Displacement	Acceleration *Magnitude*	

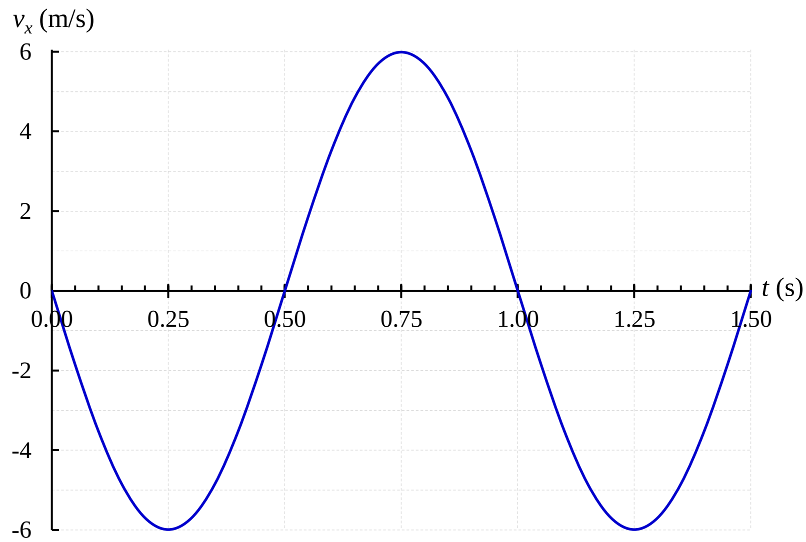
3d) What is the *distance traveled* over the entire time interval shown?

3e) What is the *displacement* over the entire time interval shown?

3f) Estimate *average speed* for the entire time interval shown. **Answer in scientific notation in units of $\frac{m}{s}$.**

3g) Estimate *velocity* at 250 µs. **Answer in scientific notation in units of $\frac{m}{s}$.

At right is plot for an object moving horizontally in one dimension. As usual, you need not include a unit vector for vector results as long as you include the appropriate $\pm$ sign.



4a) During which time intervals (or at what times) is the object *moving to the left*?

4b) During which time intervals (or at what times) is the object *speeding up*?

4c) Which best describes total displacement for the entire time interval shown.

To the left	To the right	No displacement	Impossible to determine without more info

4d) Estimate acceleration at $t = 0.50$ s.

A robot is constrained to move horizontally.
The robot is initially distance d to the left of the origin moving left.
The robot accelerates with constant magnitude a.
The robot reaches the origin in time t.

5a) What direction is the robot accelerating? Circle the best answer.

To the left	To the right	No acceleration	Impossible to determine without more info

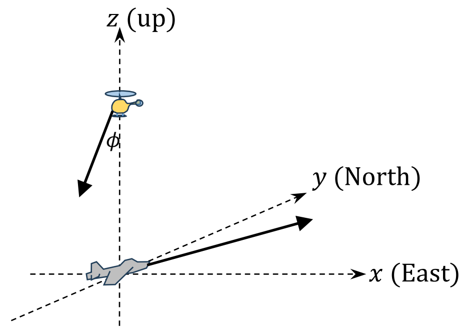
**5b) Determine the initial *velocity* of the robot.
Answer in terms of $\boldsymbol{a}$, $\boldsymbol{d}$, & $\boldsymbol{t}$.

****5c) How far has the robot moved by the time it reaches the origin?
Your answer must be algebraic (in terms of $\boldsymbol{a}$, $\boldsymbol{d}$, & $\boldsymbol{t}$) for credit.
It should also be simplified as much as possible to earn full credit.
This part is probably the hardest on the test (the simplifying was tedious).
If you are clever it isn't that bad, but you can still get it right with brute force.
HOWEVER, as a *check* on your *algebraic result*, I will tell you this answer should be 6.5 m when you use:

- $a = 2\,\frac{\text{m}}{\text{s}^2}$
- $t = 3\text{ s}$
- $d = 6\text{ m}$

5b	
5c	

At one instant in time a plane flies past the origin at $100.0\,\frac{\text{m}}{\text{s}}$ heading $32.25°$ east of north relative to the earth. At the same instant, the plane's radar detects a helicopter 47.5 m directly above the plane. Relative to the plane itself, the helicopter moves in the xz-plane with speed $50.0\,\frac{\text{m}}{\text{s}}$ at angle $\phi = 17.25°$ to the z-axis as shown. **Note:** the numbers in this problem are not based on realistic helicopter & plane speeds. Nothing in this problem is drawn to scale.



****6a) Determine the speed of the helicopter *relative to earth*.

6b) Determine the direction of the helicopter's motion relative to earth. **Answer as a unit vector.

6a	
6b	

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