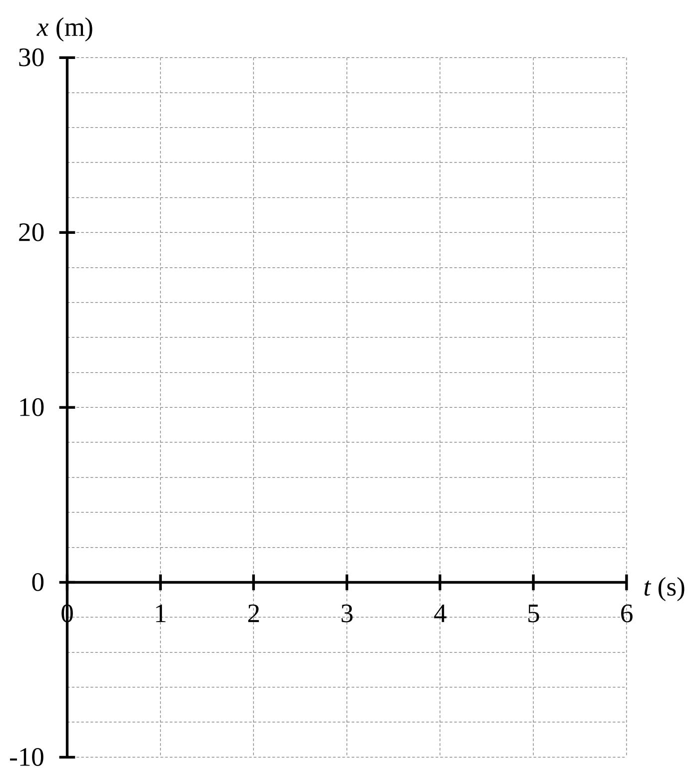
161 Spring 2023 T1A Once the exam has officially started, remove the top sheet. The remaining sheets comprise your exam. It is each student's individual responsibility to ensure the instructor has received her or his completed exam. Any exams not received by the instructor earn zero points. Smart watches, phones, or other devices (except scientific calculators) are not permitted during the exam.

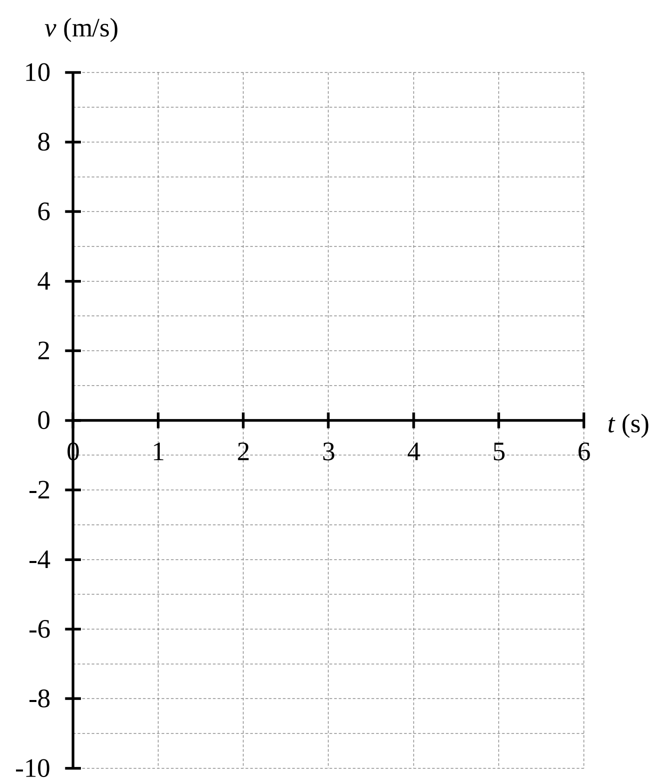
$V_{sphere} = \frac{4}{3}\pi R^3$	$V_{box} = LWH$	$V_{cyl} = \pi R^2 H$	$\rho = \frac{M}{V}$
$A_{sphere} = 4\pi R^2$	$V = (A_{base}) \times (height)$	$A_{circle} = \pi R^2$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$C = 2\pi R$	$A_{rect} = LW$	$A_{CylSide} = 2\pi RH$	
$160\underline{9}$ m = 1 mi	12 in = 1 ft	60 s = 1 min	1000 g = 1 kg
2.54 cm = 1 in	1 cc = 1 cm^3 = 1 mL	60 min = 1 hr	100 cm = 1 m
1 cm = 10 mm	1 yard = 3 ft	3600 s = 1 hr	1 km = 1000 m
1 furlong = 220 yards	$528\underline{0}$ ft = 1 mi	24 hrs = 1 day	1 rev = 2π rad = 360°
$g = 9.8 \frac{\text{m}}{\text{s}^2}$	$G = 6.67 \times 10^{-11} \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$	$P_0 = 1.0 \times 10^5$ Pa	1 eV = $1.60\underline{2} \times 10^{-19}$ J
$1\text{ N} = 1 \frac{\text{kg}\cdot\text{m}}{\text{s}^2}$	$1\text{ J} = 1\text{ N}\cdot\text{m}$	$1\text{ Pa} = 1 \frac{\text{N}}{\text{m}^2}$	
$x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2$	$v_{fx}^2 = v_{ix}^2 + 2a_x(\Delta x)$	$v_{fx} = v_{ix} + a_x t$	$r = \sqrt{x^2 + y^2}$
$\vec{A}\cdot\vec{B} = AB\cos\theta_{AB}$	$\lVert\vec{A}\times\vec{B}\rVert = AB\sin\theta_{AB}$	$\sin(A \pm B)$ $= \sin A\cos B \pm \cos A\sin B$	$\cos(A \pm B)$ $= \cos A\cos B \mp \sin A\sin B$
$\vec{v}_{ae} + \vec{v}_{eb} = \vec{v}_{ab}$	$\hat{r} = \cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath}$	$\hat{\theta} = -\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath}$	
$a_{tan} = r\alpha$	$a_c = \frac{v^2}{r} = r\omega^2$	$\vec{a} = a_r\hat{r} + a_{tan}\hat{\theta}$	$\vec{a} = a_c(-\hat{r}) + a_{tan}\hat{\theta}$
$\Sigma\vec{F} = m\vec{a}$	$f \le \mu n$	$F_G = \frac{GmM}{r^2}(-\hat{r})$	$U_G = -\frac{GmM}{r}$
$TKE = \frac{1}{2}mv^2$	$RKE = \frac{1}{2}I\omega^2$	$U_S = SPE = \frac{1}{2}kx^2$	$U_G = GPE = mgh$
$E_i + W_{non-con \text{ or } ext} = E_f$	$\Delta KE = W_{ext.\&\,non-con}$	$W = Fd\cos\theta = F_{\parallel}d$	$W = \int F_x dx$
$\Delta U = -W = -\int_i^f \vec{F}\cdot d\vec{s}$	$F_x = -\frac{d}{dx}U(x)$	$\mathcal{P}_{inst} = \frac{dE}{dt} = \vec{F}\cdot\vec{v}$	$\mathcal{P}_{avg} = \frac{\Delta E}{\Delta t} = \frac{Work}{time}$
$\vec{J} = \Delta\vec{p} = \vec{F}\Delta t$	$\vec{p} = m\vec{v}$	$x_{CM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$	$x_{CM} = \frac{\int x\,dm}{\int dm}$
$\vec{\tau} = \vec{r}\times\vec{F}$	$\Sigma\vec{\tau} = I\vec{\alpha}$	$L = I\omega = mvr_{\perp}$	$\mathcal{P}_{inst} = \vec{\tau}\cdot\vec{\omega}$
$s = r\Delta\theta$	$v = r\omega$	$a_{tan} = r\alpha$	$a_c = \frac{v^2}{r} = r\omega^2$
$I_{\parallel axis} = I_{CM} + md^2$	$I_{zz} = I_{xx} + I_{yy}$	$I = \int r^2 dm$	$\frac{F}{A} = E\frac{\Delta L}{L_0}$
$P = \frac{F}{A}$	$P_{gauge} = P_{abs} - P_{ambient}$	$B = \rho_f V_{disp} g$	$A_1v_1 = A_2v_2$
$P(h) = P_0 + \rho gh$	$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$	$R = \frac{\pi r^4\Delta P}{8\eta L}$	$F = \eta A\frac{\Delta v_x}{\Delta y}$

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}

A robot moves horizontally in 1D motion.
The robot is initially 30.0 m *to the right* of the origin.
During the first 2.00 s of motion, the robot moves *to the left* with constant speed 8.00 $\frac{\text{m}}{\text{s}}$.
During the next 4.00 s the robot slows down at a constant rate until it comes to rest.
*1a) How far does the robot travel during the first 2.00 s of motion?
*1b) Is acceleration positive or negative during the last 4.00 s of motion?
*1c) What acceleration *magnitude* is required during the final 4.00 s of motion?
*1d) What is the robot's *displacement* during the final 4.00 s of motion?
****1e&1f) Sketch a plots of *position* versus time & *velocity* versus time for the robot.
I will give 1 point for the first 2.00 s and 1 point for the last 4.00 s (on each graph).
The last 4.00 s of the position graph are time consuming for 1 point.

1a	
1b	
1c	
1d	





A physics equation is

$$ca = U + \beta q^2$$

Associated data is shown in the table below.

c (kg · m)	a $\left(\frac{\text{mm}}{\text{s}^2}\right)$	U $\left(\frac{\text{kg} \cdot \text{m}^2}{s^2}\right)$	β $\left(\frac{\text{kg}}{\text{s}^2}\right)$
21.25	30.0	0.555	6.00×10^7

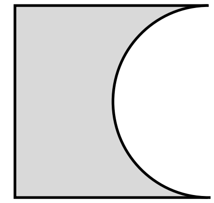
*2a) Solve this equation algebraically for q.

****2b) Compute a numerical value for q using:

- correct engineering notation
- best choice of prefix with correct units
- rounding to the appropriate number of sig figs

2a	
2b	

A metal plate has density ρ and thickness t. The plate was created by removing a semi-circular segment from the left half of a square plate (figure drawn to scale). The mass of the plate (after the ½-circle chunk was removed) is m.

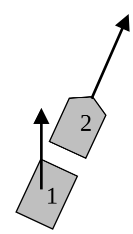


****3) Determine the side length of the original square plate in terms of known quantities. Simplify your work for credit. The final answer must be written as a decimal number (in the numerator) with 3 sig figs times an algebraic expression using the stated parameters.

3	

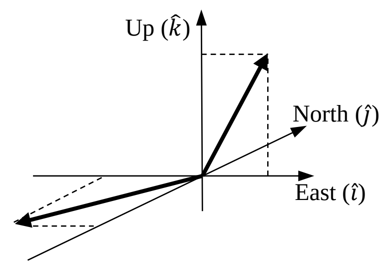
A multi-stage rocket is observed just after the instant of separation (se figure at right). The spacecraft (labeled 2) moves with speed $222\,\frac{\text{m}}{\text{s}}$ at an angle of $77.7°$ *relative to earth*. The booster stage (labeled 1) moves straight up with speed $155.5\,\frac{\text{m}}{\text{s}}$ *relative to the earth*.

***4) How fast is the booster moving *relative to the spaceship* at this instant?



4	

A drone travels in two straight line displacements. The first displacement covers 5.75 m directed $32.1°$ *west of south*. After the second displacement, the drone's final position is 4.25 m from the origin angled $65.4°$ *above the east axis* (in the xz-plane).
*5a) Write the *first displacement* vector in Cartesian form.
**5b) Write a Cartesian form unit vector for the direction of the *final position* vector.
**5c) Determine the *angle between* the first displacement and the final position.
***5d) Determine the *magnitude* of the second displacement.

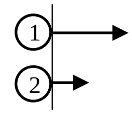


5a	
5b	
5c	
5d	

At time $t = 0$, two objects at the origin move to the right. Object 1 has velocity described by

$$v_1(t) = v_0 - kt^2$$

where k is a positive constant. Object 2 moves with constant rate $\frac{2}{5}v_0$.



6a) Is object one experiencing to constant acceleration?

Yes	No	Impossible to determine without more information

**6b) Determine the position of object 1 as a function of time.

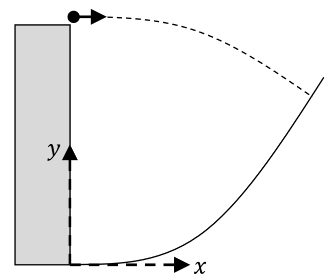
**6c) How far does object 1 travel before reversing direction?

Answer as a decimal number with 3 sig figs times $\sqrt{\frac{v_0^3}{k}}$.

****6d) Determine the *velocity* of object 1 when object 2 catches up to it (after $t = 0$)? **Answer as a decimal number with 3 sig figs times v_0.**

6b	
6c	
6d	

A ball of negligible size is placed on the edge of a building of height h. The ball is kicked horizontally with speed v_0 towards a parabolic ramp. Using the coordinate system shown in the figure, the height (y) of the parabolic ramp is given by



$$y = \frac{\alpha x^4}{2}$$

*7a) Determine the units assumed for the constant α. Assume the 2 is dimensionless.
*****7b) Determine horizontal displacement between launch and impact positions.
This answer ends up looking exceptionally ugly.
Simplify it as best you can after all other work on the test is done.

7a	
7b	

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