161 Spring 2022 Test 1B 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.

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

Prefix	**Abbreviation**	$\mathbf{10^?}$		**Prefix**	**Abbreviation**	$\mathbf{10^?}$
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}

Name:____

1) The energy density of a fuel is $20.2\,\frac{\mathrm{GJ}}{\mathrm{m}^3}$. Assume $1\ \mathrm{J} = 9.47\underline{8} \times 10^{-4}$ BTU where BTU stands for *British thermal unit*. Convert the energy density of butane to units of $\frac{\mathrm{BTU}}{\mathrm{cm}^3}$. **Write your answer in scientific notation.

1

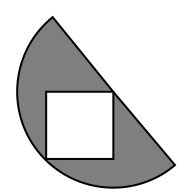
**2) Suppose you are told a force equation is given by

$$F = \sqrt{\frac{\alpha x^5}{v^3} - \frac{\beta v^2}{x^4}}$$

In this equation x represents horizontal position, v represents speed, and α & β are positive constants. Determine the units required for the constant α. Write your final answer in terms of $\mathrm{kg}, \mathrm{m}, \&\ \mathrm{s}$. Note: it is possible for some or all of the units cancel out.

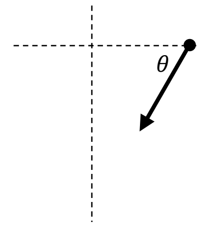
2

**3) A metal disk of diameter D is machined into the shape shown at right.
You may assume the main diagonal of the square is equal to the disk's radius.
Determine an algebraic expression for the surface area of the final shape (gray area, top surface only).
Answer as a decimal number with three sig figs times D^2 for credit.



3

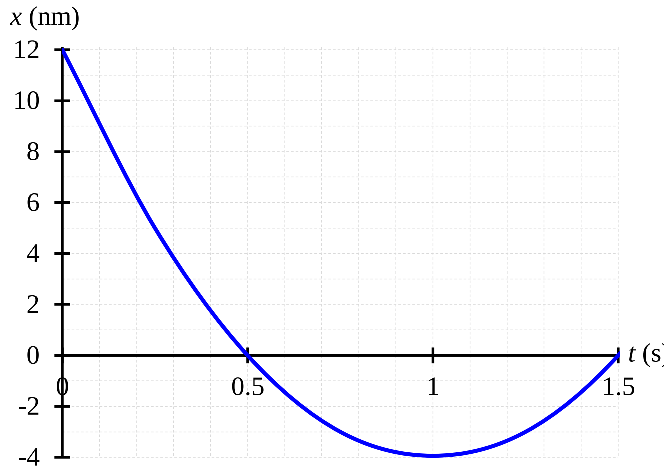
A spaceship (shown by black dot in the figure) is in deep space. Because it is far from any stars or planets, you may assume there is zero gravitational force acting on the spaceship. At the instant shown in the figure, the ship is distance d from the origin moving with speed v at angle θ (figure not to scale). Based on the coordinate system shown, the ship accelerates to the left with constant rate a.



*****4) Determine the time required to cross the vertical axis.

4	

An object travelling in 1D motion is visualized with the plot of position versus time shown at right.



**5a) Determine *distance traveled* for the entire time interval shown.

**5b) Determine *velocity* at 0.50 s.

5c) Over what time interval(s), or at what instant(s) in time, is this object *moving backwards*. If this doesn't occur in the time interval shown, state "doesn't occur).

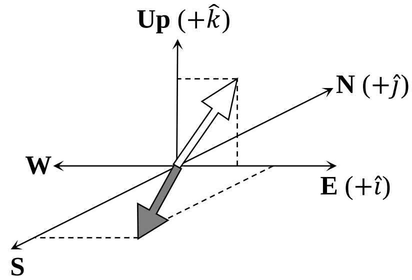
5d) Over what time interval(s), or at what instant(s) in time, is this object *moving forwards* and *slowing down*. If this doesn't occur in the time interval shown, state "doesn't occur).

Qui runs a 200.0 m race in 32.25 s.
She accelerates from rest at rate $2.75\,\frac{\text{m}}{\text{s}^2}$ until reaching her top speed.
She then finishes the race at that speed.

*****6) Determine Qui's speed for the second stage of the race.

6	

A drone and a boat are initially located at the origin. At time $t = 0$, the drone and the boat leave the origin. For exactly one hour the boat and the drone each travel at constant speed. The drone has velocity $\vec{v}_d = (5.55\hat{\imath} + 8.88\hat{k})\,\frac{\text{m}}{\text{s}}$ relative to the earth while the boat is heading $22.2°$ east of south with speed $v_b = 17.77\,\frac{\text{m}}{\text{s}}$ (relative to the earth). Figure not to scale.



***7a) Determine $\vec{v}_b \times \vec{v}_d$. Answer in Cartesian form.
**7b) Determine the angle between the two velocity vectors.
***7c) Determine distance between the boat & drone after the hour of travel.

7a	
7b	
7c	

**8) From kinematics we know

$$v_f^2 = v_i^2 + 2a\Delta x$$

A data table is shown at right. Compute Δx in units of meters.
Use correct sig figs in engineering notation with appropriate prefix.

$v_f\ \left(\frac{\mathrm{m}}{\mathrm{s}}\right)$	$v_i\ \left(\frac{\mathrm{m}}{\mathrm{s}}\right)$	$a\ \left(\frac{\mathrm{m}}{\mathrm{s}^2}\right)$
7.65×10^{-2}	-80.0	7.00

8	

A particle moves in one dimensional motion with velocity described by

$$v_x = \frac{k}{x^4}$$

where k is a constant, and x is position. At time $t = 0$ the particle is located distance d to the right of the origin.

****9) Determine the particle's position as a function of time.

9	

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