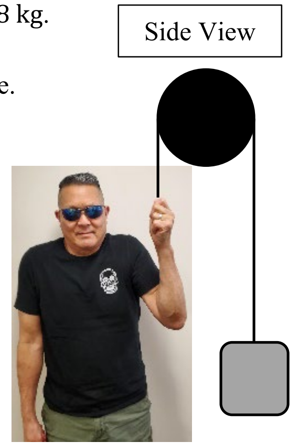
161 Spring 2024 Test 2A Once the exam has officially started, remove the top sheet. The remaining sheets comprise your exam. It is each student's individual responsibility to ensure the instructor has received her or his completed exam. Any exams not received by the instructor earn zero points. Smart watches, phones, or other devices (except scientific calculators) are not permitted during the exam.

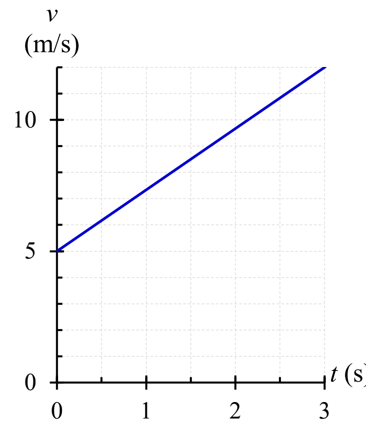
$V_{sphere} = \frac{4}{3}\pi R^3$	$V_{box} = LWH$	$V_{cyl} = \pi R^2 H$	$\rho = \frac{M}{V}$
$A_{sphere} = 4\pi R^2$	$V = (A_{base}) \times (height)$	$A_{circle} = \pi R^2$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$C = 2\pi R$	$A_{rect} = LW$	$A_{CylSide} = 2\pi RH$	
$160\underline{9}$ m = 1 mi	12 in = 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
$1\text{ N} = 1\frac{\text{kg}\cdot\text{m}}{\text{s}^2}$	$1\text{ J} = 1\text{ N}\cdot\text{m}$	$1\text{ Pa} = 1\frac{\text{N}}{\text{m}^2}$	$m_e = 9.11 \times 10^{-31}$ kg
$x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2$	$v_{fx}^2 = v_{ix}^2 + 2a_x(\Delta x)$	$v_{fx} = v_{ix} + a_x t$	$r = \sqrt{x^2 + y^2}$
$\vec{A}\cdot\vec{B} = AB\cos\theta_{AB}$	$\lVert\vec{A}\times\vec{B}\rVert = AB\sin\theta_{AB}$	$\sin(A \pm B)$ $= \sin A\cos B \pm \cos A\sin B$	$\cos(A \pm B)$ $= \cos A\cos B \mp \sin A\sin B$
$\vec{v}_{ae} + \vec{v}_{eb} = \vec{v}_{ab}$	$\hat{r} = \cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath}$	$\hat{\theta} = -\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath}$	
$a_{tan} = r\alpha$	$a_c = \frac{v^2}{r} = r\omega^2$	$\vec{a} = a_r\hat{r} + a_{tan}\hat{\theta}$	$\vec{a} = a_c(-\hat{r}) + a_{tan}\hat{\theta}$
$\Sigma\vec{F} = m\vec{a}$	$f \leq \mu n$	$F_G = \frac{GmM}{r^2}(-\hat{r})$	$U_G = -\frac{GmM}{r}$
$TKE = \frac{1}{2}mv^2$	$RKE = \frac{1}{2}I\omega^2$	$U_S = SPE = \frac{1}{2}kx^2$	$U_G = GPE = mgh$
$E_i + W_{\substack{non-con \\ or\ ext}} = E_f$	$\Delta KE = W_{ext.\&\,non-con}$	$W = Fd\cos\theta = F_{\parallel}d$	$W = \int F_x dx$
$\Delta U = -W = -\int_i^f \vec{F}\cdot d\vec{s}$	$F_x = -\frac{d}{dx}U(x)$	$\mathcal{P}_{inst} = \frac{dE}{dt} = \vec{F}\cdot\vec{v}$	$\mathcal{P}_{avg} = \frac{\Delta E}{\Delta t} = \frac{Work}{time}$
$\vec{J} = \Delta\vec{p} = \vec{F}\Delta t$	$\vec{p} = m\vec{v}$	$x_{\text{CM}} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$	$x_{\text{CM}} = \frac{\int x\,dm}{\int dm}$
$\vec{\tau} = \vec{r}\times\vec{F}$	$\Sigma\vec{\tau} = I\vec{\alpha}$	$L = I\omega = mvr_{\perp}$	$\mathcal{P}_{inst} = \vec{\tau}\cdot\vec{\omega}$
$s = r\Delta\theta$	$v = r\omega$	$a_{tan} = r\alpha$	$a_c = \frac{v^2}{r} = r\omega^2$
$I_{\parallel axis} = I_{\text{CM}} + md^2$	$I_{zz} = I_{xx} + I_{yy}$	$I = \int r^2 dm$	$\frac{F}{A} = E\frac{\Delta L}{L_0}$
$P = \frac{F}{A}$	$P_{gauge} = P_{abs} - P_{ambient}$	$B = \rho_f V_{disp} g$	$A_1v_1 = A_2v_2$
$P(h) = P_0 + \rho gh$	$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$	$R = \frac{\pi r^4\Delta P}{8\eta L}$	$F = \eta A\frac{\Delta v_x}{\Delta y}$

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:____

Len Miyahara uses a cable & pulley to lift a block of mass 8.88 kg. The cable is inextensible with negligible mass. The pulley has negligible mass and negligible axle friction. Figure not to scale. A plot of block velocity versus time is shown.





1a) Determine *initial kinetic energy* of the block.

1b) Determine *average power* delivered to the block (from all forces acting on it) over the entire time interval shown.

1c) Determine *acceleration* (magnitude) of the block.

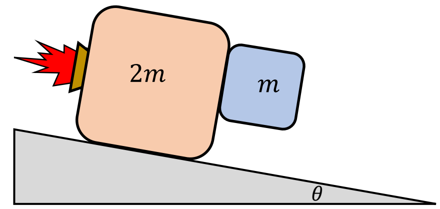
1d) Determine *tension* (magnitude) in the cable.

1e) Determine *instantaneous power* delivered to the block by the cable at $t = 3.00$ s.

1f) For the time interval shown, is gravity doing positive, negative, or zero work on the block? Write your answer in the box.

1a	
1b	
1c	
1d	
1e	
1f	

Two blocks with masses m & $2m$ are placed on an incline of angle θ.
The larger block employs a rocket thruster.
Coefficients of friction between the two blocks are μ_k & μ_s.
Friction is negligible between the floor and the larger block.



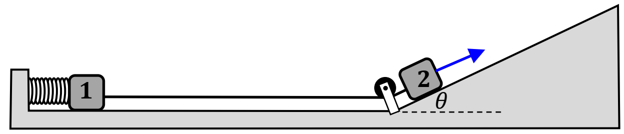
********2a) Determine the *minimum* thrust (magnitude) required to prevent m from sliding down. Simplify your work for credit.

2a	

2b) Suppose the *actual* thrust applied by the thruster is 10% larger than the minimum value found in part a. How will the actual friction force compare to the friction used in your calculations for part a?

More than 10% larger	Exactly 10% larger	Less than 10% larger	Exactly the same size as friction magnitude in the calculations for part a	Impossible to determine without more info
More than 10% smaller	Exactly 10% smaller	Less than 10% smaller		

Two blocks ($m_1 = m$ & $m_2 = 2m$) are connected by a light, inextensible string using a pulley with negligible mass & negligible axle friction. A light spring of constant k, initially unstretched, connects block 1 to the wall.

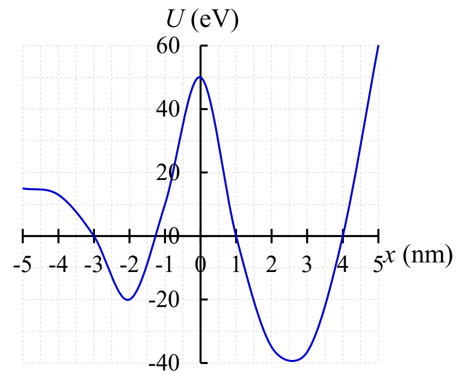


Block 1 experiences negligible friction while block 2 experiences friction with coefficients μ_s & μ_k.
Block 2 is located on a ramp of length L and angle θ.
Block 2 has negligible size compared to the ramp.
Block 2 is kicked and given some initial speed…

******3) Determine the initial speed required for block 2 to just barely reach the end of the ramp.

3	

A particle of mass 5.55×10^{-22} kg is constrained to move in one dimension under the influence of a single conservative force. A plot of potential energy versus position for this force is plotted at right. The particle is initially located at $x = -5.00$ nm and travels towards $x = +5.00$ nm.



4a) Which best describes force *direction* on the particle at $x = +1.00$ nm?

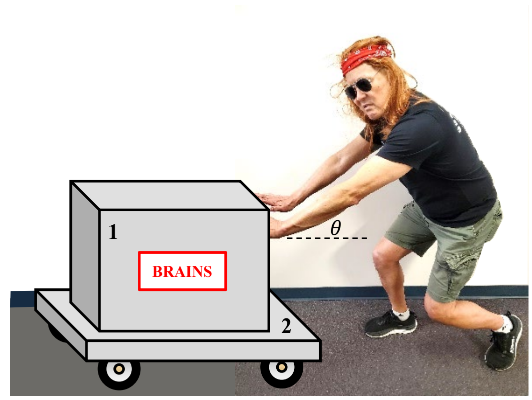
Up	Right	Up & left	Up & right	Impossible to determine without more info
Down	Left	Down & left	Down & right	

**4b) Determine force *magnitude* on the particle at $x = +1.00$ nm.

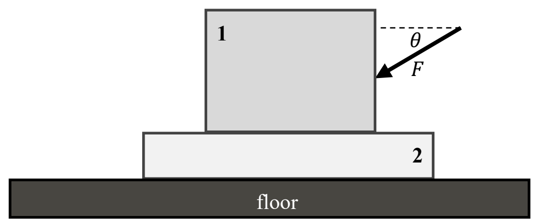
***4c) Determine the *minimum* initial speed required to reach $x = +4.50$ nm.

4b	
4c	

An Axl Rose impersonator who looks a *lot* like Len Miyahara is effectively paid a measly $4.29 an hour to move boxes of brains on a dolly for the AHC cadaver lab. Because the dolly has wheels, we may model it as *sliding* across the floor with negligible friction. Friction between the box and the dolly has coefficients μ_s & μ_k. A simplified model of the system is shown in the lower figure at right. Assume friction force between the box and the dolly has magnitude f_{12} while the normal force between them has magnitude n_{12}.
We don't know if the Len is speeding up, slowing down, or pushing with constant speed. We do know the box never slides relative to the dolly.



Simplified Model
Side View



5a) How does *size* of the normal force between the blocks (n_{12}) compare to the weight *magnitude* of the upper box ($m_1 g$)?

$n_{12} > m_1 g$	$n_{12} = m_1 g$	$n_{12} < m_1 g$	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

5b) Which of the following friction conditions most likely applies?

$f_{12} = \mu_k n_{12}$	$f_{12} < \mu_s n_{12}$	$f_{12} = \mu_s n_{12}$	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

5c) Which direction does friction act on the dolly (m_2)?

To the *right*	To the *left*	No friction	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

5d) Which best describes the work done by *friction* between the blocks as it acts on the dolly (on m_2)?

$\vec{f}_{12}$ does *zero* work on the dolly (m_2)	$\vec{f}_{12}$ does *negative* work on the dolly (m_2)	$\vec{f}_{12}$ does *positive* work on the dolly (m_2)	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

5e) Which best describes the work done by *normal force* between the blocks as it acts on the dolly (on m_2)?

$\vec{n}_{12}$ does *zero* work on the dolly (m_2)	$\vec{n}_{12}$ does *negative* work on the dolly (m_2)	$\vec{n}_{12}$ does *positive* work on the dolly (m_2)	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

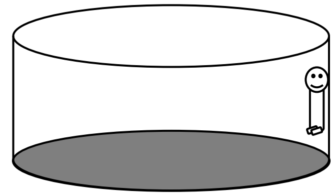
5f) Assume Len has a much larger mass than the box of brains. Which of the following statements is true?

The box exerts *more* force on Len (compared to how hard Len pushes on the box)	The box exerts *less* force on Len (compared to how hard Len pushes on the box)	The box exerts the *same* force on Len (compared to how hard Len pushes on the box)	Impossible to tell unless we know if system is accelerating	None of the other answers is correct

5g) Describe the reaction force associated with the weight **of the dolly**. Fill in the blanks below.

____________________ exerts a _________________________ force on _____________________ directed _______________________.

Object exerting force | type of force (e.g. frictional, tension, etc) | object experiencing force | direction of force



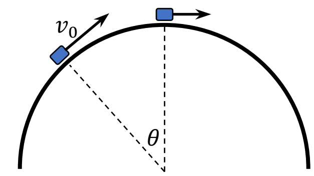
An engineer is designing an amusement park ride which involves a cylindrical room spinning with constant period $\mathbb{T}$. Once at speed, the room's floor drops but riders remain at rest (relative to the wall of the spinning room). The engineer wants to keep rider acceleration no higher than $2.34g$. Assume the rider has negligible size compared to the room's radius.

***6a) Determine the *maximum* radius of the room. **Answer as a decimal number with 3 sig figs times an expression involving g & $\mathbb{T}$.**

6b) Determine the *minimum* coefficient of friction required to prevent the rider from sliding down. **Answer as a decimal number with 3 sig figs.

6a	
6b	

A $42\underline{0}$-gram superconductor of negligible size moves along a semi-circular magnetic track of radius $R = 525$ mm. To be clear, the small block is the superconductor and the track forms a *vertical* circle (figure is side view). Block initial speed is $v_0 = 2.30\,\frac{\text{m}}{\text{s}}$ at angle $\theta = 37.5°$. You may assume frictional & drag forces are negligible.



Magnetic track can produce radially outwards *or inwards* force on the superconductor!

As a result, superconductor levitates a fixed distance from the track.

WATCH OUT: the magnetism of the track can be modeled as a normal force pushing radially outwards *or pulling radially inwards* on the superconductor. Notice this differs from a typical track which could only push radially outwards on a block.

**7a) Determine the *actual speed* of the superconductor once it reaches the *top* of the circle.

**7b) At the top of the circle, what *ideal speed* would produce *zero normal force*?

**7c) Determine the *actual* normal force at the *top of the circle* (include $\pm\hat{j}$ for direction).

7d) Determine the *initial normal force* on the superconductor (mag & dir) when it is at angle θ from the vertical. **Answer as a numerical value times $\pm\hat{\boldsymbol{r}}$.

**7e) Determine the *initial tangential acceleration* (magnitude).

7a	
7b	
7c	
7d	
7e	

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