Name: ______________________________

Please answer the following questions in the space provided. In the case of multiple choice questions, please circle your answer clearly. Show *all* your work, *even on multiple choice problems* for a chance at partial credit! Please refrain from using any Chapter 6 material (energy or work) on this test. Good luck!

Useful Constants and Identities
$G = 6.67 \times 10^{-11}\,\mathrm{Nm^2/kg^2}$
$\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{A^2s^4/kgm^3}$
$M_{earth} = 5.97 \times 10^{24}\,\mathrm{kg}$
$R_{earth} = 6371\,\mathrm{km}$
$\cos(90+\theta) = -\sin(\theta)$
$\cos(90-\theta) = \sin(\theta)$
$\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$
Circumference $= 2\pi r$
Area of Circle $= \pi r^2$

(2) 1. Jason hurls a 5 kg axe at his hapless target. The terrified target (65 kg) is running in the negative z-direction at 8 m/s. If the axe strikes the target moving at 20 m/s in the positive x-direction and sticks in the target, at what speed is the target/axe system moving immediately after the collision?

A. 7.4 m/s

B. 7.56 m/s

C. 12.31 m/s

D. 21.5 m/s

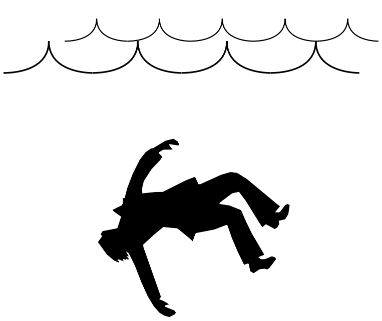
(2) 2. Seeking to dispose of the body, Jason retrieves his axe and drags the body down to the lake. The now 60 kg body has a volume of 0.0664 m^3, and the lake water has a density of 1000 kg/m^3. Obsessed with being efficient, Jason wants to add the minimum mass needed to the body (rocks stuffed into pockets) to ensure it will sink to the bottom of the lake. How much mass should he add?

A. 3.23 kg

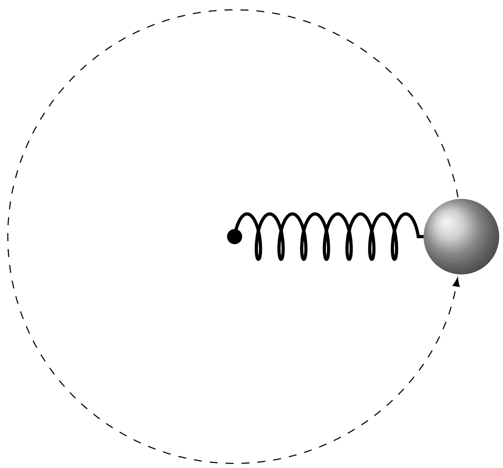
B. 6.41 kg

C. 7.38 kg

D. No extra mass is needed, the body will sink on its own



(5) 3. Climbing back up the hill to the Camp Crystal Lake Lodge, Jason notices a peculiar device spinning on the ground. A 5 kg mass is attached to a 400 N/m strong spring and is spinning in a circle of radius 2 m centered on the other end of the spring. Jason has been needing a strong spring for a special project, but he needs to know the relaxed length of the spring. Observing the setup for a bit, he notices that the mass completes one revolution every 1.25 s. What is the relaxed length of the spring?



Topdown View

Solution: Forces wise we have the force of gravity downward (into the page), the normal force upward (out of the page) and then the spring force to the left (toward the center of the circle). Since the object is moving in a circle, we know that:

$$\vec{\mathbf{F}}_\perp = \left\langle -\frac{mv^2}{r}, 0, 0 \right\rangle$$

Thus we get that

$$F_N = mg$$
$$k_s s = \frac{mv^2}{r}$$

The object is moving in a circle, so we can determine the velocity from

$$v = \frac{2\pi r}{T}$$

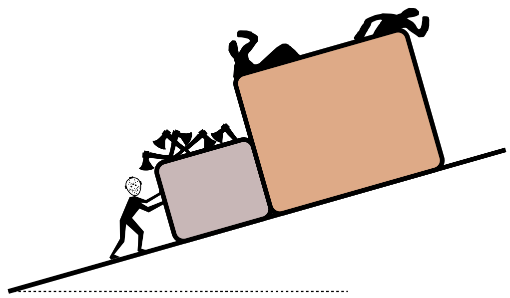
and thus

$$s = \frac{mr}{k_s}\left(\frac{2\pi}{T}\right)^2 = \frac{(5)(2)}{400}\left(\frac{2\pi}{1.25}\right)^2 = 0.63\,\mathrm{m}$$

This is the stretch distance, and the spring is currently at 2 m, so thus the relaxed length must be

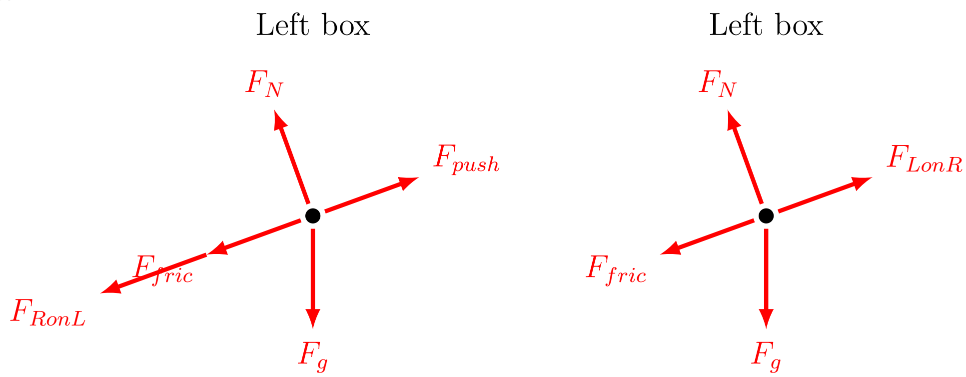
$$2 - 0.63 = 1.368\,\mathrm{m}$$

4. Jason wants to head up a hill (angle with horizontal = 20°) with a box of axes (30 kg) and a box of bodies (500 kg). Both boxes experience a coefficient of static friction of 0.82 and a coefficient of kinetic friction of 0.74.



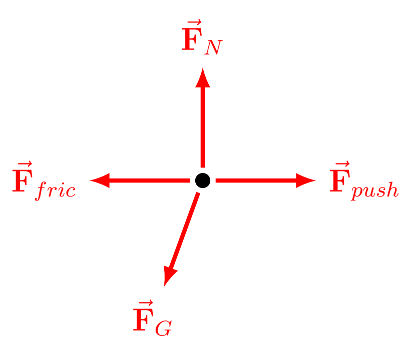
(2) (a) Sketch Free Body Diagrams for both boxes, labeling all forces and indicating relevant angles.

Solution:



(3) (b) How hard should Jason push to start the boxes moving?

Solution: Together the boxes have a FBD of (in rotated coords):



Thus we have that our sum of the forces in the y-direction:

$$F_N = F_g \cos\theta$$

And thus in the x-direction:

$$F_{push} + \mu_s mg\cos(20)\cos(180) + mg\cos(-110) = 0$$

Or

$$F_{push} = 5778.7\,\mathrm{N}$$

(4) 5. Resurrected (yet again) sometime in the distance future, Jason (85 kg) finds himself aboard a space station circling 400 km above the surface of the Earth. Striving to get to a higher portion of the station, he leaps straight up from the ground with an initial velocity of 10 m/s. How high above the space station floor does he travel?

Solution: He will be slowing from 10 m/s to 0, for a $v_{aavg} = 5\,\mathrm{m/s}$. By momentum principle:

$$\begin{aligned}
\Delta p &= F_{net}\Delta t \\
m(0-10) &= \left(\frac{-Gm_E m}{(r_E+400000)^2}\right)\Delta t \\
\Rightarrow \Delta t &= 1.15\,\mathrm{s}
\end{aligned}$$

Then to update the position:

$$y_f = y_i + v_{aavg}\Delta t = 5(1.15) = 5.757\,\mathrm{m}$$

(6) 6. In order to trip unfortunate passerby's and make an easier target for his machete, Jason tightens a trip wire across a 1 m wide door-frame. The wire has a cross-section of $3\,\mathrm{mm}^2$ and is made of titanium ($Y = 116\,\mathrm{GPa}, 47.87\,\mathrm{g/mol}, 4.507\,\mathrm{g/cm^3}$). If the wire stretches 1 cm as Jason tightens it, what is the final tension in the wire?

Solution: We need to get the atom separation first:

$$\frac{47.87}{6.022\times10^{23}} = 7.95\times10^{-23}\,\mathrm{g/atom}$$

Then

$$\frac{7.95\times10^{-23}\,\mathrm{g/atom}}{4.507\,\mathrm{g/cm^3}} = 1.76\times10^{-23}\,\mathrm{c^3m/atom}$$

Taking the cube root and converting to meters:

$$d_{atom} = 2.60\times10^{-10}\,\mathrm{m}$$

Then we can find the interatomic spring constant by

$$Y = \frac{k_{s,i}}{d_{atom}} \Rightarrow k_{s,i} = Y d_{atom} = 30.1951\,\mathrm{N/m}$$

There are

$$\frac{L}{d_{atom}} = 3.842\times10^{9}$$

springs end-to-end and

$$\frac{3 \times 10^{-6}}{d_{atom}^2} = 4.43 \times 10^{13}$$

springs side-by-side for a total spring constant of

$$k = \frac{(SbS)k_{s,i}}{E2E} = 348\,000\,\mathrm{N/m}$$

Thus a stretch of 1 cm would mean

$$T = k_s s = (348000)(0.01) = 3480\,\mathrm{N}$$

(2 (bonus)) 7. Returning to the surface of the Earth, suppose Jason wears shoes with a total charge of $5\,\mathrm{mC}$ and the floor of the lab has a charge of $3.129\,\mathrm{mC}$. How high above the floor would Jason levitate?

Solution: Levitation would mean in equilibrium, or force up must equal force down. Thus

$$\frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2} = mg$$

Solving for r then we have

$$r = \sqrt{\frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{mg}} = 13.0013\,\mathrm{m}$$

If I didn't pay this source material the respect you thought it deserved, I apologize but I've never actually seen any of these movies! (Wikipedia for the win!) Hope you have an accident free and healthiest of days and weekends!!