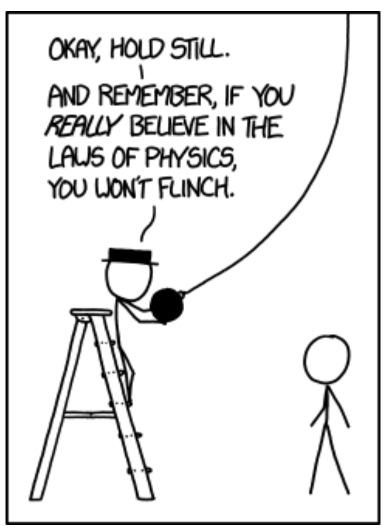
PHYS 2240 Exam II

Thursday, April 15, 2021

Instructions: *You have as much time as you need to complete this exam. Take a deep breath and relax! Read each question carefully, and let me know if anything is unclear. Partial credit may be awarded, so you are encouraged to clearly and legibly show your work for each problem. Extra paper is available at the front of the room if you need it. Write your name on every extra sheet you use, and clearly label what problem you are working on. Staple this to the back of your exam when you turn it in. You may use any information contained within this exam, as well as a calculator.*
Good luck!

Name: ______________________________________



Potentially Useful Information

$$\vec{F}_{grav} = -G\frac{m_1 m_2}{|\vec{r}|^2}\hat{r} \qquad U_{grav} = -G\frac{m_1 m_2}{|\vec{r}|}$$

$$\left|\vec{F}_{grav}\right| \approx mg \text{ near Earth's surface} \qquad \Delta U_{grav} \approx mg\Delta y \text{ near Earth's surface}$$

$$\vec{F}_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|^2}\hat{r} \qquad U_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|}$$

$$\left|\vec{F}_{spring}\right| = k_s s \text{ opposite to the stretch}$$

$$\left|\left(\frac{d\vec{p}}{dt}\right)_\perp\right| = \frac{pv}{R} \approx \frac{mv^2}{R} \text{ (if } v << c\text{) where } R = \text{radius of kissing circle}$$

$$\omega = \frac{2\pi}{T} \qquad x = A\cos\omega t \qquad \omega = \sqrt{\frac{k_s}{m}}$$

$$\hat{f} = \langle\cos\theta_x, \cos\theta_y, \cos\theta_z\rangle \text{ unit vector from angles}$$

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} $\mathrm{N \cdot m^2/kg^2}$
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 $\mathrm{N \cdot m^2/C^2}$
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} atoms/mol

milli	m	1×10^{-3}	kilo	K	1×10^{3}
micro	μ	1×10^{-6}	mega	M	1×10^{6}
nano	n	1×10^{-9}	giga	G	1×10^{9}
pico	p	1×10^{-12}	tera	T	1×10^{12}

1. (10 points) A person jumps out of an airplane above the surface of the Earth, and falls a distance h.

   (a) The work done on the person by the Earth is:

   Positive, Negative, Zero, or Insufficient Information to Answer?

   (b) The change in gravitational potential energy of the person+Earth system is:

   Positive, Negative, Zero, or Insufficient Information to Answer?

   (c) After falling a distance h, the persons parachute opens and they proceed to fall an additional distance h, albeit at a much reduced speed. During this second phase of the fall, the work done on the person by the Earth is compared to that done in part (a). The work done is:

   More Than, Less Than, The Same As, or Insufficient Information to Answer?

   (d) Explain your answer to part (c)

$$W = \vec{F} \cdot \Delta \vec{r}$$

$$\vec{F} = \langle 0, -mg \rangle$$

$$\Delta \vec{r} = \langle 0, -h \rangle$$

$$\vec{F} \cdot \Delta \vec{r} = mgh$$

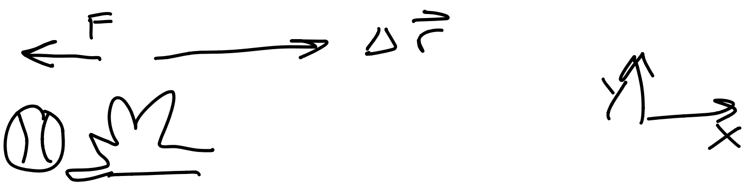
In (c) the <u>total</u> work done is less than in part (a), but work done by <u>Earth</u> is the same

2. As you catch a baseball (with a mass of 0.15 kg) which was thrown by your friend, your hand applies a constant force of 150 N as it recoils backwards slightly by 6 cm in order to bring the ball to rest.

   (a) (5 points) What is the work done by your hand on the ball?

   (b) (10 points) What was the initial speed of the ball before you caught it?

a)



$$\vec{F} = \langle -150, 0, 0 \rangle \text{ N}$$

$$\Delta\vec{r} = \langle 0.06, 0, 0 \rangle \text{ m}$$

$$W = \vec{F} \cdot \Delta\vec{r} = -(150)(0.06) \text{ Nm} = -9.0 \text{ J}$$

b) $\Delta E_{ball} = -9.0 \text{ J}$

$$-\frac{1}{2} m v_i^2 = -9.0 \text{ J}$$

$$v_i = \sqrt{\frac{(2)(9)}{0.15}} = 10.95 \text{ m/s}$$

3. An 1100 kg car is driving on a road at a constant speed of 25 m/s when it rounds a curve with radius of curvature of 150 meters.

   (a) (12 points) What is the force being exerted on the car during this turn?

$$\left|\frac{dp}{dt}\right|_{\perp} = \frac{mv^2}{r} = \frac{(1100\ \text{kg})(25\ \text{m/s})^2}{150\ \text{m}} = F_{net} = 4583.3\ \text{N}$$

   (b) (3 points) What object in the surrounding is exerting this force?

The road

4. (20 points) Your 1600 kg car has run out of gas and is coasting along at 20 m/s. You spot a gas station in the distance, but it is on the other side of a 15 meter high hill. Is your car able to make it to the gas station? Or will it get stuck on the hill? (We are ignoring friction and air resistance in this problem, so that your car can coast on flat terrain at constant speed forever).
Note: Show your work and justify your answer. You will not receive credit by simply answering "yes" or "no" without any justification

$$\Delta E_{sys} = 0$$

$$\frac{1}{2} m v_i^2 = m g h_{max}$$

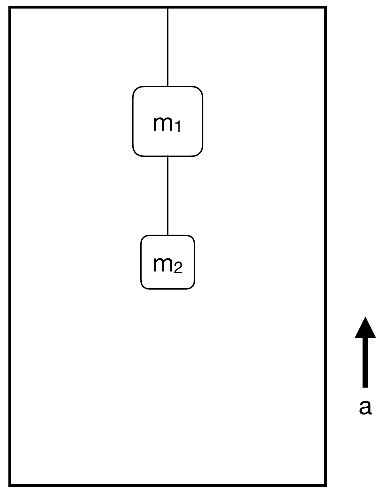
$$h_{max} = \frac{v_i^2}{2g} = \frac{(20\,m/s)^2}{2(9.8\,m/s^2)} = 20.4\ m$$

$$h_{max} = 20.4\,m > 15\,m$$

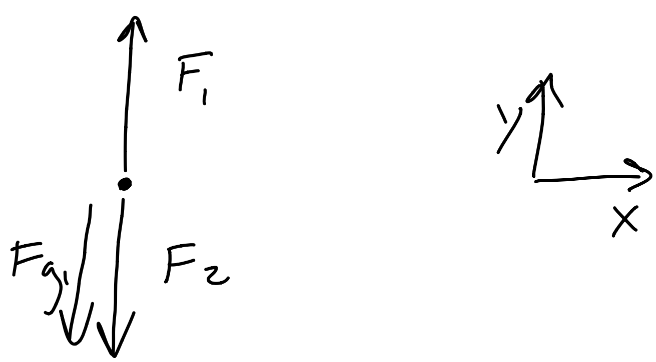
Car makes it over

5. (20 points) An elevator is accelerating upward at a rate of $a = 3.6\ \text{m/s}^2$. A block of mass $m_1 = 75$ kg hangs by a low-mass rope from the ceiling, and another block of mass $m_2 = 22$ kg hangs by a low-mass rope from the upper block.

   What are the tensions in the upper and lower ropes?



System: m_1

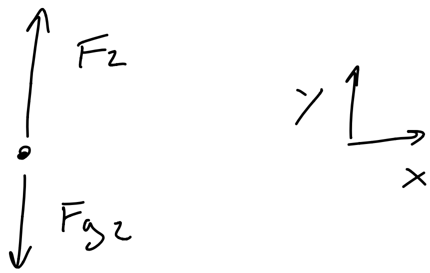


$$\frac{d\vec{p}_{1y}}{dt} = F_{net} = F_1 - F_g - F_2$$

$$\frac{dp_{1y}}{dt} = F_1 - F_2 - m_1 g$$

$$m_1 a = F_1 - F_2 - m_1 g$$

System: m_2



$$\frac{dp_y}{dt} = m_2 a = F_2 - m_2 g$$

$$F_2 = m_2(a+g)$$

$$m_1 a = F_1 - F_2 - m_1 g$$

$$F_1 = F_2 + m_1(a+g)$$

$$= m_2(a+g) + m_1(a+g)$$

$$F_1 = (m_2+m_1)(a+g)$$

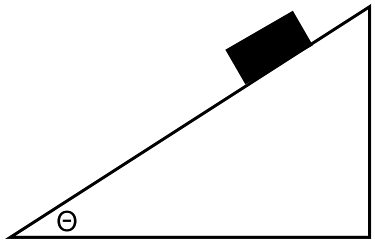
$$= (22\,kg + 75\,kg)(3.6\,\tfrac{m}{s^2} + 9.8\,\tfrac{m}{s^2})$$

$$\boxed{F_1 = 1299.8\ N}$$

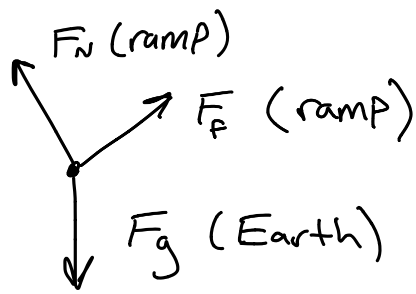
$$F_2 = m_2(a+g) = (22\,kg)(3.6+9.8)\,m/s^2$$

$$\boxed{F_2 = 294.8\ N}$$

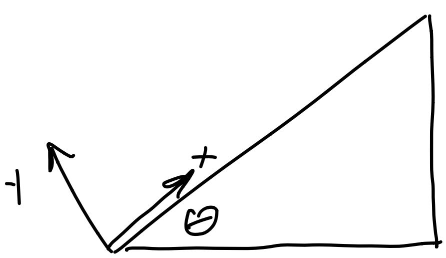
6. On the surface of the Earth, a block (mass $m = 2$ kg) slides down the surface of a ramp which is inclined at an angle of $\theta = 30°$. The block is resisted by friction as it slides, so that it moves at a constant speed of 1.6 m/s.



(a) (5 points) Draw a free body diagram representing the forces acting on the block (be sure to label the object in the surrounding which is exerting the force)

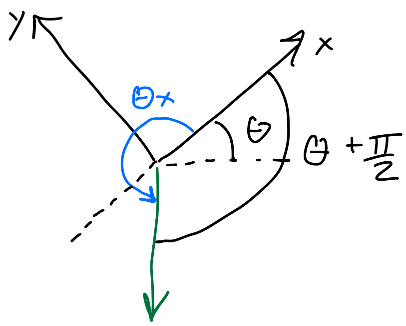


(b) (15 points) What is the coefficient of kinetic friction μ between the block and the ramp?



$$\vec{F_N} = \langle 0, F_N \rangle$$

$$\vec{F_f} = \langle F_f, 0 \rangle$$



$$\theta_x + \left(\theta + \frac{\pi}{2}\right) = 2\pi$$

$$\theta_x = \frac{3}{2}\pi - \theta$$

$$\theta_y = \pi - \theta$$

$$\vec{F}_g = F_g \langle -\sin\theta, -\cos\theta \rangle$$

$$\frac{dp_x}{dt} = 0 = F_f - mg\sin\theta$$

$$F_f = mg\sin\theta$$

$$\frac{dp_y}{dt} = 0 = F_N - mg\cos\theta$$

$$F_N = mg\cos\theta$$

$$F_f = \mu_k F_N \implies \mu_k = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \frac{1}{\sqrt{3}}$$

$$\mu_k = \frac{1}{\sqrt{3}} \approx 0.58$$

Question	Points	Score
1	10	
2	15	
3	15	
4	20	
5	20	
6	20	
Total:	100	