Physics 7A - Lectures 2/3 Midterm 2

Problem 1

Answers should be a short paragraph only, perhaps with a drawing, and very little, if any, math.

a) A Physics Professor entertains his students by sitting in a wheeled chair and discharging a fire extinguisher to the rear to propel himself forward. Can you explain what causes this propulsion? [5 pts.]

Same concept as rocket propulsion, thrust from expelling mass. Force of Thrust = $v_{rel}\dfrac{dM}{dt}$.

I accepted two answers:

1) Using Newton's third law if you adequately explained where the force comes from.

2) Using approximate conservation of momentum since I think it is okay if you assumed the chair being wheeled (and moving at all) could mean friction was negligible.

b) If you jump off of a wall onto the ground, staying on your feet (not rolling), what can you do to reduce the force on your legs? Please explain in terms of physics concepts. [5 pts.]

$J = \Delta p = \int F dt$. **We can achieve the same change in momentum with a smaller force if we increase the time over which the force acts. If you bend your knees as you land you will distribute the force over the time it takes to squat down. Many people claimed it would reduce the impulse, this is not correct, you still have the same change in momentum, but have achieved it with a smaller force Gave partial credit for saying bend your knees, full credit if you accurately explained how that will reduce the force.**

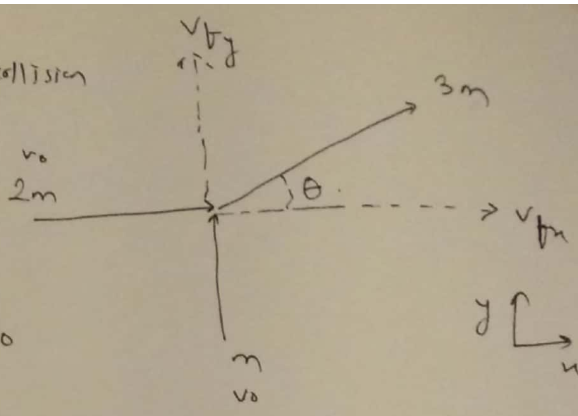
c) Usually friction is considered a non-conservative force and gravity is considered a conservative force, but some would argue that all forces are fundamentally conservative. Please explain both points of view. [5 pts.]

Conservative forces are independent of the path taken and only depend on start and end state. Feynman argued in his lectures at CalTech that there are no non-conservative forces. Friction for example is considered non-conservative because we say that the energy "lost" depends on the path taken. However, that is because we are considering our system to be the box sliding down the hill and only looking at macroscopic translational kinetic energy. If we consider the universe as our system and consider the kinetic energy gained by atoms in the box, hill, air, etc. (in the form of heat, light, sound, etc.) energy is not lost and the state of the system is not defined by the location of the box alone, but also the path, so taking two different paths to the same location would not considered the same end state.

Full credit given if a discussion of path dependence of conservative/non-conservative forces and of energy conservation in terms of universe vs system, partial credit if only one of these was discussed adequately.

27 If 2 objects stick together after collision, the collision is said to be <u>completely</u> <u>inelastic</u>.

In inelastic collision, though K.E is not conserved the total energy is always conserved and the ~~vector~~ total vector momentum is also conserved.



change in momentum along x dirⁿ = 0. $\Rightarrow \Delta P_x = 0$

$\Rightarrow 2m(v_0) + m(0) - 3mv_{fx} = 0$

$\Rightarrow 2mv_0 = 3mv_{fx}$

$\Rightarrow \boxed{v_{fx} = \frac{2}{3} v_0}$

Change in momentum along y dirⁿ = 0 $\Rightarrow \Delta P_y = 0$

$\Rightarrow 2m(0) + mv_0 - 3mv_{fy} = 0$

$\Rightarrow mv_0 = 3mv_{fy}$

$\Rightarrow \boxed{v_{fy} = \frac{1}{3} v_0}$

$\tan\theta = \frac{v_{fy}}{v_{fx}} \Rightarrow \theta = \tan^{-1}\left(\frac{v_{fy}}{v_{fx}}\right) \Rightarrow \theta = \tan^{-1}\left(\frac{1/3\, v_0}{2/3\, v_0}\right) \Rightarrow \boxed{\theta = \tan^{-1}\frac{1}{2} \text{ or } \theta = 26.565}$

(b) As explained in the beginning, K.E of system is not conserved but total energy is conserved.

$\Delta E = ?$

$v_f = \sqrt{v_{fx}^2 + v_{fy}^2} \Rightarrow \sqrt{\left(\frac{2}{3}v_0\right)^2 + \left(\frac{1}{3}v_0\right)^2} = \sqrt{\frac{5}{9}v_0^2}$

$KE(\text{initial}) = K.E(\text{final}) + \Delta E$

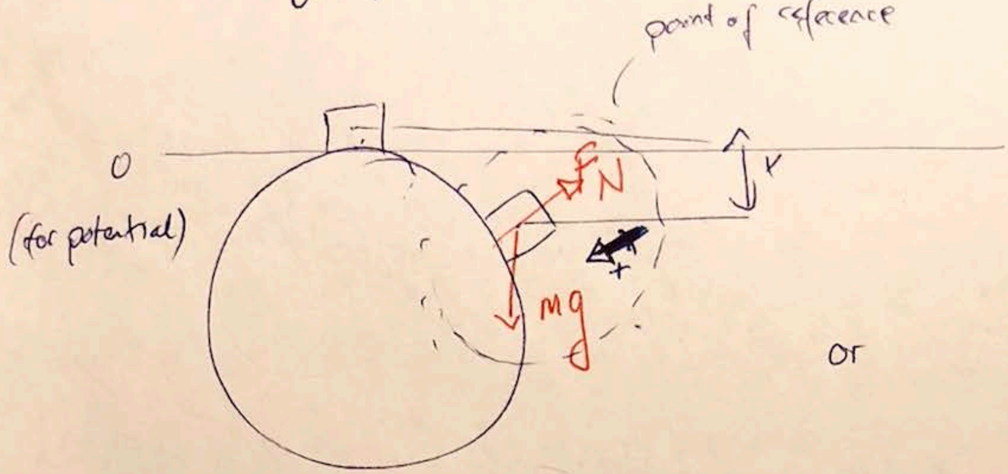
$\Delta E = KE(\text{ini}) - KE(\text{fin})$

$= \underbrace{-\frac{1}{2}(3m)(v_f)^2}_{\text{final}} + \underbrace{\left(\frac{1}{2}(2m)v_0^2 + \frac{1}{2}m(v_0)^2\right)}_{\text{initial}}$

$= -\frac{5}{6}v_0^2 m + mv_0^2 + \frac{mv_0^2}{2}$

$\boxed{\text{loss}/\Delta KE = \frac{2}{3}mv_0^2}$

Pb#3 - Falling off the world



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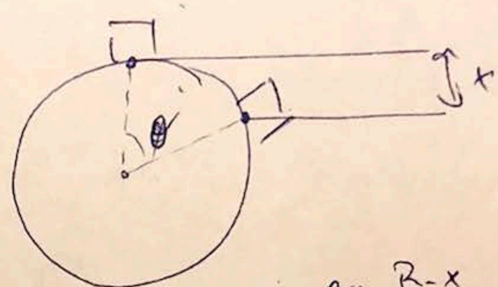


$$\cos\theta = \frac{R-x}{R}$$

Newton's 2nd law - radial motion

$$\Sigma F = m a_R = \frac{m v^2}{R} = mg\cos\theta - F_N$$

block will lose contact with sphere when $F_N = 0$

$$\frac{mv^2}{R} = mg\cos\theta = mg\,\frac{R-x}{R}$$

$$\frac{mv^2}{R} = mg\frac{(R-x)}{R} \implies \frac{mv^2}{R} = \frac{\cancel{m}\,2\cancel{g}x}{\cancel{R}} = \cancel{m}\cancel{g}\frac{(R-x)}{\cancel{R}}$$

obtain v from Conservation of Energy:

$$\Delta K + \Delta U = 0$$

$$\left(\frac{1}{2}mv^2 - \cancel{0}\right) + \left(mg(-x) - \cancel{mg(0)}\right) = 0$$

$$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gx$$

$$\boxed{v^2 = 2gx}$$

$$2x = R - x$$

$$3x = R$$

$$\boxed{x = \frac{R}{3}}$$

Lee's midterm 2 P4

Points

a) Define $U(r=\infty)=0$ 1'

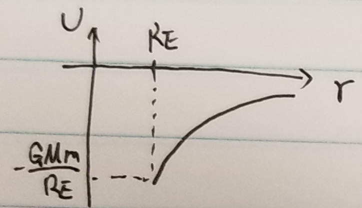
We know for $r>R_E$, $\vec{F} = -\frac{GMm}{r^2}\hat{r}$

$$U(r)-U(\infty) = -W_{\infty\to r} = -\int_\infty^r \vec{F}\,dr$$

$$= \int_\infty^r \frac{GMm}{r^2}\hat{r}\,dr$$

$$= -\frac{GMm}{r}$$

Thus $U(r) = U(\infty) - \frac{GMm}{r} = -\frac{GMm}{r}$ 6'



3'

(1' for not drawing $r<R_E$)

b) In order to escape from earth, we need

$v(r=\infty)=0$ 1'

$E(r=R_E) = \frac{1}{2}mv^2 + U(R_E) = \frac{1}{2}mv^2 - \frac{GMm}{R_E}$

$E(r=\infty) = 0$

From energy conservation

$E(r=R_E) = E(r=\infty)$ 6'

$\frac{1}{2}mv^2 - \frac{GMm}{R_E} = 0$

$v = \sqrt{\frac{2GM}{R_E}}$ 3'

c) Yes

Suppose the satellite is on the orbit with radius r

$E_p = -\frac{GMm}{r}$ 3'

From Newton's 2nd law, $\frac{GMm}{r^2} = \frac{mv^2}{r}$

$v = \sqrt{\frac{GM}{r}}$ 3'

$E_k = \frac{1}{2}mv^2 = \frac{GMm}{2r} = \frac{1}{2}|E_p|$ 4'

Physics 7A MT2 P5 Solution

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1 Center of Mass Solution

The center of mass travels along the original trajectory and lands at a distance $2L$ from the launch site. Since the smaller piece lands at $x = 0$, the larger piece needs to land at a position to keep the center of mass at $x = 2L$. This means that $3mD = 4m(2L)$ or $D = \frac{8/3}{L}$.

2 Kinematics solution

If you forgot about center of mass, you can use kinematics. The time it takes for either piece to land is the same. The initial horizontal velocity is $v_0 = L/t$. The smaller piece must have a velocity $-v_0$. This means that the larger piece, in order to conserve momentum, must have $3mv - mv_0 = 4mv_0$. So $v = \frac{5}{3}v_0$. This also means that it travels a distance $\frac{5}{3}L$ in the same time, from the initial point at L, so the final impact site is at $x = \frac{8L}{3}$.