9/20/17

* State the lens you're using & why

Problem Set # 1

1.5 1.) · Dynamics / Kinematics lens :

4

Motivation : Yes, the rocket has a large upward acceleration when it takes off, provided by the propulsion force of the high pressure air of the bike pump. After take off, the rocket continues with an acceleration, however this time provided by the constant downwards force of gravity alone. So, its acceleration should be the same as gravitational acceleration, although its velocity may be high. The downwards acceleration of gravitity slows the rocket down on its way up, then speeds it back up on its way down.

Application :

$g = 10\ m/s^2$

$V = \frac{\Delta x}{\Delta t}$. $a = \frac{\Delta V}{\Delta t}$

Frame 0 :	Frame 1 :	Frame 2 :	Frame 3 :
t = 0	t = 1	t = 2	t = 3
(0 s)	($\frac{1}{30}$ s)	($\frac{2}{30}$ s)	($\frac{3}{30}$ s)
$V_0 = 0\ m/s$	$V_1 = 45\ m/s$	$V_2 = 81\ m/s$	$V_3 = 61.5\ m/s$
$a_0 = 0\ m/s^2$	$a_1 = 1350\ m/s^2$	$a_2 = 1080\ m/s^2$	$a_3 = -585\ m/s^2$
0 m	1.5 m	4.2 m	6.25 m

$$V_1 = \frac{1.5m - 0m}{(\frac{1}{30})s - 0s} = 45\ m/s$$

$$a_{takeoff} = \frac{45\ m/s - 0\ m/s}{(\frac{1}{30})s - 0s} = 1350\ m/s^2$$

- The acceleration provided by the propulsion force was around $1350\ m/s^2$, bringing the rocket to a velocity of about $45\ m/s$ at $\frac{1}{30}$ s, traveling a measured distance of about 1.5 m. After take off, the only force is gravity, accelerating the rocket downwards at $10\ m/s^2$.

$$a = \frac{\Delta V}{\Delta t} \quad a = \frac{\left(\frac{\Delta x}{\Delta t}\right)}{\Delta t} = \frac{\Delta x}{(\Delta t)^2} \quad \frac{m}{s^2}$$

- The speed between frame 1 and 2 is : $V_{avg} = \frac{4.2m - 1.5m}{(\frac{2}{30})s - (\frac{1}{30})s} = 81\ m/s$,

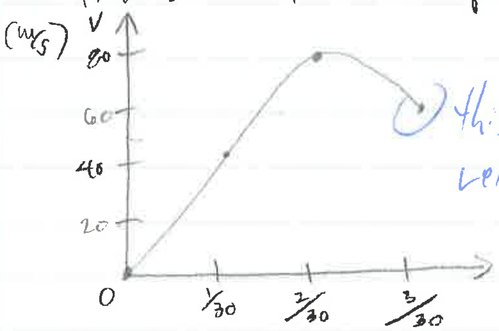
which is actually the average velocity between these points. The velocity is not constant and the rocket sped up compared to frame 1. Between the speeds I calculated, $\frac{1}{30}$ s of time had elapsed. The acceleration between these times is =

$$a_{avg} = \frac{81\ m/s - 45\ m/s}{(\frac{2}{30})s - (\frac{1}{30})s} = 1080\ m/s^2$$, which is much higher

than that of gravity ($10\,m/s^2$). At frame 3, the acceleration is:

$$a_{avg} = \frac{61.5\,m/s - 81\,m/s}{(3/30)s - (2/30)s} = -585\,m/s^2$$, which is

negative, implying the rocket is slowing down, accounting for the smaller displacement of the rocket between frames 2 & 3 compared to frames 1 & 2.



this is still a positive velocity but it's not going up

1.5 #3 2. You push a 1000 kg car from rest on smooth level ground. It takes 5 s to get the car to $1\,m/s$.

A

a) What is the car's acceleration?

I would use a kinematics lens because I can see that I'm dealing with motion (the car's speed) as a function of time. To find acceleration, we know that it is the rate at which velocity changes, therefore:

$$a_{car} = \frac{\Delta V}{\Delta t} = \frac{V_f - V_0}{t_f - t_0} = \frac{(1\,m/s - 0\,m/s)}{(5s - 0s)} = 0.2\,\frac{m/s}{s} = \boxed{0.2\,m/s^2}$$

b) What is the force you're exerting on the car?

I would use a dynamics lens for this because it's asking me to consider the force I exerted on the car, and given that we found the acceleration already, I could use the fact that force = mass × acceleration. So,

$$F = ma = (1000\,kg)(0.2\,m/s^2) = 200\,kg \cdot m/s^2 = \boxed{200\,N}$$

c) How does this force compare w/ the force of gravity on your body?
Again, I would use a dynamics lens for this since I'm still being asked to consider force (on the car and me) and acceleration (gravity). Given that the acceleration due to gravity is $10\ m/s^2$ and that I have a mass of 66 kg, the force of gravity on my body is $F = ma = (66\ kg)(10\ m/s^2) = 660\ kg\ m/s^2 = \boxed{660N}$

The force I used to push the car, 200 N, is about 1/30 the force gravity exerts on my body.

good

d) Imagine doing this in your mind. Does this seem reasonable.
Again, I would use a dynamics lens because in my mind, I'm imagining the force I'm using on the car and the acceleration that it causes. 200 N of force is about: $200\ N = ma$

$200\ N = m(10\ m/s)$

$m = 20\ kg$

$1\ kg \approx 2.2\ lbs$

$20\ kg \times \frac{2.2\ lbs}{1\ kg} = 44\ lbs$,

which seems reasonable because 44 lbs can be easily lifted by an average person.

e) Estimate the power you put out accelerating the car.
I would use an energy lens for this because it asks me to find power, which is the amount of work, or energy, in a given period of time. This involves the concept of me transferring energy from my arms and muscles onto the car to help it gain kinetic energy. The power I outputted is:

$$P = \frac{work}{time} = \frac{\frac{1}{2}mv^2}{t} = \frac{\frac{1}{2}(1000\ kg)(1\ m/s)^2}{5\ s} = \frac{500\ kg \cdot m^2/s^2}{5\ s} = 100\ kg\ \frac{m^2}{s^3}$$

$$= \boxed{100\ W}$$

1.6 #8

A

3) A 1000 kg car moving 20 m/s strikes a stationary 4000 kg truck. The two stick together and continue moving on the slippery road. Was any thermal energy produced in this collision. If so, how many Joules of thermal energy was produced? If not, how can you be sure no thermal energy was produced?

I would use an energy lens for this because I see that there's a transformation of energy when the car strikes the truck. One of the most obvious transformations is the trucks potential energy E_{PT} turning into kinetic energy E_{KT} when the car hits. Within the car-truck system, energy is conserved; the energy of the car E_{KC} was distributed post collision and is equal to the kinetic energy of the two vehicles $E_{K(C+T)}$ plus the thermal energy produced E_{th}. Obviously, not all the E_{KC} was given to the car + truck since some was converted to E_{th}. Therefore, kinetic energy alone was not conserved since the car stuck with the truck were probably moving at a much slower velocity than the car initially had alone ($E_K = \frac{1}{2}mv^2$)

9 # 1

A

4) If cart A has twice the mass & 3x the speed of cart B, what's the ratio of their kinetic energies?

I would use an energy lens for this because I see that these carts both contain kinetic energy since they're both currently at a particular velocity ($E_K = \frac{1}{2}mv^2$). To find the ratio of their kinetic energies:

$$\frac{E_{KA}}{E_{KB}} = \frac{\cancel{\frac{1}{2}} m_A (V_A)^2}{\cancel{\frac{1}{2}} m_B (V_B)^2} = \frac{2\cancel{m_B}(3V_B)^2}{\cancel{m_B}(V_B)^2}$$

$$= 2 \cdot \frac{9V_B^2}{V_B^2} = 18$$

$$\boxed{\therefore E_{KA} = 18 E_{KB}}$$

5.) If I double the height from which I drop a rock, by what factor will this change the final velocity of the rock immediately before impact? If $\Delta H_B = \Delta H_A$, $V_{fB} = \underline{?}\ V_{fA}$.

A

$a = 10\ m/s^2$

$PE = KE$

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

$v^2 = 2gh$

$v = \sqrt{2gh}$

$V_{fA} = \sqrt{2(10\ m/s^2)(1\ m)} = \sqrt{20\ m^2/s^2} = \sqrt{20}\ m/s$

$V_{fB} = \sqrt{2(10\ m/s^2)(2\ m)} = \sqrt{2} \cdot V_{fA}$

I would use an energy lens for this because it involves a transformation of energy; the rock's PE at the top transforms to KE when it is dropped. If I double the height from which I drop the rock, the final velocity will increase by a factor of $\sqrt{2}$ or about 1.414. Given that energy must be conserved, $PE = KE \rightarrow mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh}$. $V_{fB} = \sqrt{2}\,V_{fA}$.

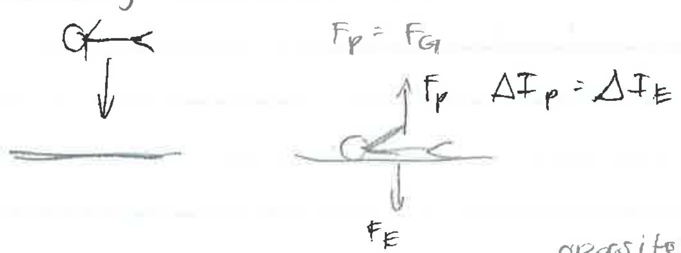
6. Walk off cliff. 3 seconds later → hit the ground.

a) momentum lens

great

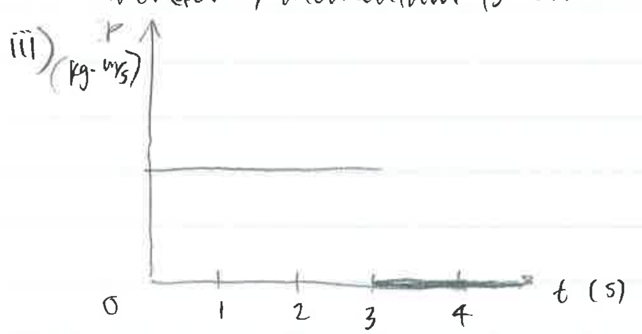
i) How does my momentum change during the 3 s & there after? You experience a sudden change – a decrease – in momentum while the Earth experiences an equal change – an increase – in momentum.

ii) Why should this be the case? This is the case because the force between Pete and the Earth acts equally on each of them. Therefore the impulse Pete experiences is equal and opposite to the impulse Earth experiences.



Therefore, momentum is conserved in the Pete-Earth system.

iii)



iv) Is momentum conserved?

Yes, momentum is conserved for the Pete - Earth system. The amount of momementum Pete loses is equal to the amount the Earth gains; both experience the same impulse. So, $\Delta P_P = \Delta P_E \rightarrow -M_P V_P = M_E V_E$. This relationship implies that Pete experienced the bigger change in velocity since he has a considerable smaller mass compared to Earth.

v) If momentum in a closed system is conserved, describe the full system we're talking about here.

The system we're talking about here is that of Pete and the Earth, both of which interacted with each other during the collision when Pete hit the ground. Both members of this system experience equal and opposite changes in momentum, meaning that momentum is conserved between the two and therefore the system as a whole.

b) Energy

i) The energy started out as KE when Pete was walking towards the edge of the cliff. Then, at the edge, before Pete falls, he has PE = mgh, relative to the height of the cliff, when he falls, that PE is converted to KE gradually as he advances towards the ground. Upon impact, that KE changes to E_{th} or heat from the collision of Pete and the ground, as well as KE of the Earth, whose velocity changes by an unnoticeable amount.

ii) At the very beginning, before Pete falls, the energy is in the form of potential energy of Pete, relative to how high he is from the ground; PE = mgh. At the end, the energy was turned into heat E_{th} and KE of the Earth, while Pete's KE dropped to zero.

iii) Energy was conserved; just because Pete doesn't have

KE by the end of the collision doesn't mean energy wasn't conserved in the system. Pete's energy, as stated earlier, was simply transferred to the Earth as KE and to the surroundings as heat.

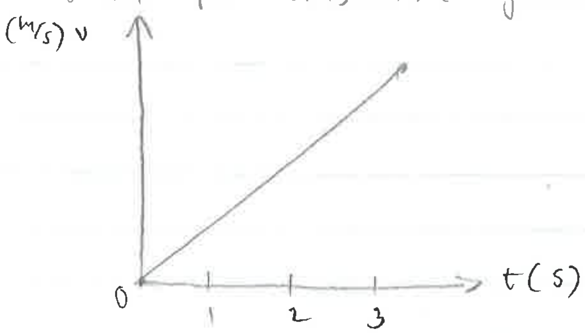
c) Forces

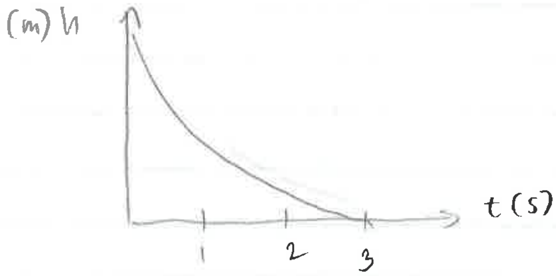
i) During Pete's fall, the only force acting on him was the force of gravity. Upon impact, there is a single force between him and the ground, which depends on the speed he hits the ground.

ii) The two bodies are Pete and the ground, or Earth. Momentum is transferred from Pete to the Earth; Pete loses the same amount of momentum that the Earth gains in return.

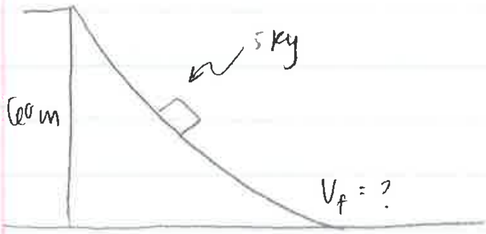
d) Kinematics

i) During the 3 seconds that Pete falls, Pete accelerates due to gravity at $10\,m/s^2$. His velocity increases until Pete hits the ground. The graph of his velocity with respect to time is a straight line because his acceleration is constant, meaning the slope of his velocity doesn't change. The graph of his height





7.



a) From a momentum lens, the only change in momentum is as the box slides down the ramp, the force between them, gravity, acts equally between them, pushing the ramp backwards and the box forwards. If the ramp was on wheels, we would see that it's pushed backwards as the box slides down. From an energy lens, we see that the box's potential energy from when it was at the top of the cliff is turned into kinetic energy as it accelerates down the track. From a dynamic lens, we see that the downwards force of gravity causes the box to accelerate down the track. From a kinematics lens, we see that the box travels a certain y- and x-distance over a period of time; its motion can be described as a function of time.

b) To find the final speed of the box at the end, I'd use an energy lens since the PE of the box is strictly only turned to KE — the surface is frictionless and doesn't allow for heat transfer. Given that, we know energy is conserved, so: $PE = KE \rightarrow mgh = \frac{1}{2}mv^2 \rightarrow V = \sqrt{2gh}$

c) $PE_{box} = KE_{box}$

$mgh = \frac{1}{2}mV_f^2$

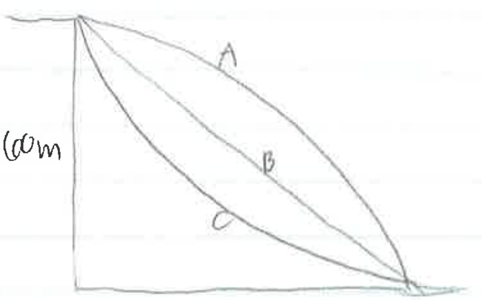
$2gh = V_f^2$

$V_f = \sqrt{2gh}$

$V_f = \sqrt{2(10\ m/s^2)(600\ m)}$

$V_f = \sqrt{1200\ m^2/s^2}$

$\boxed{V_f = 20\sqrt{3}\ m/s}$



d) I would use an energy lens for this again because for each track, energy is conserved; each track starts at the same height, so each must have the same $PE = mg\underline{h}$. All that PE is eventually turned to $KE = \frac{1}{2}mv^2$, and since each track would yield the same KE at the end, they would also each yield the same final velocity.

e) I would use an energy lens for this again; halfway down the track, each track would still yield the same speed since energy is conserved. Half way down the track, each box would have covered the same height and, since $mgh = \frac{1}{2}mv^2$, reached the same velocity.

f) Again, I'd use an energy lens since energy is being transformed from PE to KE and being conserved for each track. However, the downwards curvature on track C allows it to convert PE to KE much faster than the other tracks and, since $KE = \frac{1}{2}mv^2$, allows the box to gain velocity much faster and reach the end first. On track C, the box would be able to convert all its PE to KE before the other 2.

10) a) In the photograph, I perceive speed through a kinematic lens because I can see the golf clubs motion over explicit periods of time — each frame.

b) I would use a kinematics lens to see that the club travels the fastest in the beginning since it covers more distance at each frame. Since velocity is displacement over time, the club has a higher velocity at the beginning than the end.

c) Using a kinematics lens and viewing the clubs motion as a function of time, I see that the club speeds up as it hits the ball, slowing down as the club is brought over the golfer's shoulder, traveling gradually shorter distances for each frame.

d) Using a momentum lens, since there was a collision between the club and the ball where momentum is conserved, I can compare the speeds of the two

using the fact that $\Delta P_{club} = \Delta P_{ball} \Rightarrow m_{club} v_{club} = m_{ball} v_{ball}$.
Since the club has a larger mass than the ball, it experiences less change in velocity compared to the ball, showing that the golf ball has the higher speed.

e) Using a momentum lens again, at the collision we know that the ball moves at a much higher velocity than the club. So the club is most likely still near the golfer's foot as the ball exits the screen.

f) I would use a kinematics lens to estimate velocity since it's a function of time:

100 flashes/s
1 flash/0.01 s

$t=0 \quad dx = 0m$
$t=1 \quad dx = 0.2m$
$t=2 \quad dx = 0.5m$

@ t=1 $$V_{avg} = \frac{\Delta x}{\Delta t} = \frac{0.2\,m - 0m}{0.01\,s - 0s} = 20\,m/s$$

@ t=2 $$V_{avg} = \frac{\Delta x}{\Delta t} = \frac{0.5m - 0.2m}{0.02s - 0.01s} = 30\,m/s$$

g) Using a kinematics lens and imagining the ball's motion over the period of time that it becomes airbourne, I roughly estimate the ball accelerating to a velocity of around 70-80 m/s, which is around 150-180 mph.

h) Using a momentum lens, I see that momentum is conserved in this inelastic collision, therefore the club and ball should each individually have different velocities before and after the collision. The club transfers momentum to the ball, and therefore loses velocity while the ball gains velocity.

i) Using a momentum lens again, the club doesn't undergo a very noticeable change in velocity compared to the ball since the ball's mass is considerably smaller than the club.
$m_{club} V_{i\,club} + m_{ball} V_{i\,ball} = m_{club} V_{f\,club} + m_{ball} V_{f\,ball}$.