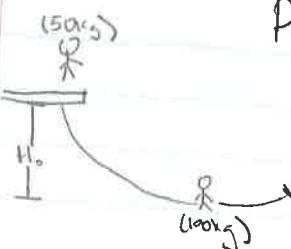


SR think  
it's anal/gal

PS #4

#1



A -  
be detailed about  
your units

Jane's velocity

$$PE = KE$$

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

$$v = \sqrt{2gh}$$

$$v = \sqrt{2(10 \text{ m/s}^2)H_0}$$

$$v = \sqrt{20H_0}$$

conservation of momentum

$$m_J v_J + m_T v_T = V_f (m_J + m_T)$$

$$(150 \text{ kg})(\sqrt{20H_0}) + (100 \text{ g})(0 \text{ m/s}) = V_f (150 \text{ kg})$$

$$\frac{50\sqrt{20H_0}}{150} = V_f$$

$$V_f = \frac{\sqrt{20H_0}}{3}$$

This is a clear combination of energy and conservation of momentum problem like the ballistics pendulum. The velocity before and after the collision can only be found through momentum since energy is lost due to heat.

Final height

$$PE = KE$$

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

$$h_f = \frac{v^2}{2g}$$

$$h_f = \left(\frac{50\sqrt{20H_0}}{150}\right)\left(\frac{1}{9}\right)$$

$$h_f = H_0 \left(\frac{1}{9}\right)$$



a) [Work done to pull trigger] →

[PE of spring/bullet]

[KE of spring/bullet]

[PE of block]

nice workflow!

[KE of block]

[heat]

Mechanical energy is not conserved during the process because heat energy is lost during the collision.

- 1) Force, Energy
- 2) Energy, motion
- 3) Momentum
- 4) Energy

b) This problem requires multiple lenses. As seen above, energy can be used to quantify most transitions. However because heat loss is not easily quantifiable, conservation of momentum can be used to find the final velocity.

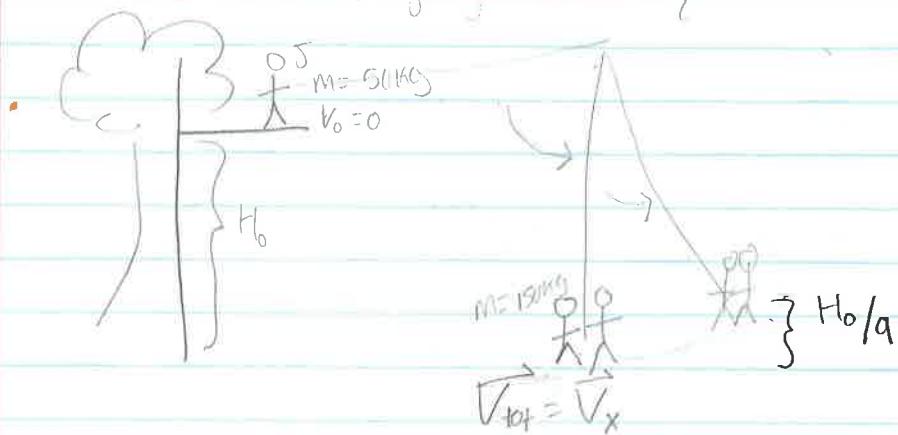
$$V_s = V_{\text{after}} = 4.95019 \text{ m/s}$$

A-

(for notation issues)

Problem Set #4

1. This is an energy problem because Jane's potential energy is converted to kinetic energy. It is also a momentum problem because Jane and Tarzan collide changing the velocity.



$$PE = KE_{\text{before collision}}$$

$$PE = mgh$$

$$= (50 \text{ kg})(10 \text{ m/s}^2)(H_0)$$

$$= 500H_0 \text{ J}$$

$$KE_B = 500H_0 \text{ J}$$

$$KE = \frac{1}{2}mv^2$$

$$500H_0 = \frac{1}{2}(50 \text{ kg})(V_B)^2$$

$$20H_0 = (V_B)^2$$

$$V_B = \sqrt{20H_0}$$

$$P_{\text{Before}} = P_{\text{After}}$$

$$\text{Matter} = \text{Energy}$$

~~$$(50 \text{ kg})(\sqrt{20H_0}) = (150 \text{ kg})(\frac{1}{3}\sqrt{20H_0})$$~~

$$V_{\text{after}} = \frac{1}{3}\sqrt{20H_0}$$

$$KE_A = \frac{1}{2}mv^2$$

$$= \frac{1}{2}(150 \text{ kg})(\frac{1}{3}\sqrt{20H_0})$$

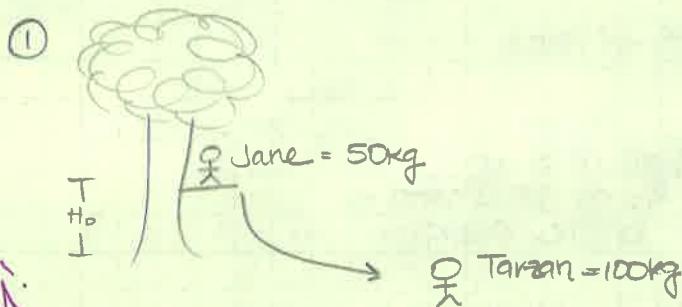
$$KE_A = \frac{1500H_0}{9}$$

$$KE_A = PE_A$$

$$PE_A = mgh$$

$$\frac{1500H_0}{9} = (150 \text{ kg})(10 \text{ m/s}^2)(H_f)$$

$$\frac{H_0}{9} = H_f$$



Great flow of energy!

An energy flow diagram would look as follows:

- ① Jane has potential energy. Tarzan is still, so his KE is  $\emptyset$ .
- ② Jane loses PE and gains KE as she swings down.
- ③ Their KE becomes PE, and they reach a height of  $H_f$ .
- ④ The remaining energy becomes KE as the two swing up.

This must be an energy problem because we are concerned with the transfer of energy from Jane to Tarzan. There is also momentum associated with this problem, because the velocity after the collision is needed to solve the problem.

- ⑤ There is a collision between Jane and Tarzan. Energy is lost as heat.

$$\begin{aligned}
 & * \textcircled{1} \text{ PE} \Rightarrow \textcircled{2} \text{ KE + PE} \Rightarrow \textcircled{3} \text{ KE} \Rightarrow \textcircled{4} \text{ KE + heat} \Rightarrow \textcircled{5} \text{ KE} \Rightarrow \textcircled{6} \text{ PE} \\
 & * \textcircled{1} \text{ mgh} \Rightarrow \textcircled{2} \frac{1}{2}mv^2 + mgh \Rightarrow \textcircled{3} \frac{1}{2}mv^2 \Rightarrow \textcircled{4} \frac{1}{2}mv^2 + \text{heat} \Rightarrow \textcircled{5} \frac{1}{2}mv^2 \Rightarrow \textcircled{6} \text{ mgh} \\
 & * \textcircled{1} (50\text{kg})(10\text{m/s}^2)(H_0) \Rightarrow \textcircled{2} \frac{1}{2}(50\text{kg})v^2 + mgh \Rightarrow \textcircled{3} \frac{1}{2}(50\text{kg})v^2 \Rightarrow \textcircled{4} \frac{1}{2}(150\text{kg})v^2 + \text{heat} \Rightarrow \\
 & \quad \text{continues to change} \\
 & \textcircled{5} \frac{1}{2}(150\text{kg})v^2 \Rightarrow \textcircled{6} (150\text{kg})(10\text{m/s}^2)(H_f)
 \end{aligned}$$

I understand these transfers of energy are occurring, but they do not provide enough info. So, I will leave them out to simplify the equation.

all you need is end result, we don't care about path (#2).

$$(50\text{kg})(10\text{m/s}^2)(H_0) - \frac{1}{2}(50\text{kg})(v^2)$$

$$\frac{m}{52}(2)10H_0 = \frac{1}{2}v^2(2)$$

$$20H_0 = v^2$$

$$v = 2\sqrt{5H_0}$$

Jane's velocity

Jane and Tarzan's final Velocity

$$m_j v_{j,i} + m_t v_{t,i} = m_{j,t} v_{j,t}$$

$$(50\text{kg})(2\sqrt{5H_0}\text{ m/s}) = (150\text{kg})(v_{j,t})$$

$$v_{j,t} = \frac{2\sqrt{5H_0}}{3} \quad \left\{ \frac{1}{3} \text{ of Jane's Velocity} \right.$$

Jane and Tarzan's Velocity

$$(50\text{kg})(10\text{m/s}^2)(H_0)^2 = \frac{1}{2} (150) \left( \frac{2\sqrt{5H_0} \text{ m/s}}{3} \right)^2 + \text{heat}$$

$$500 H_0 \text{ kgm}^2/\text{s}^2 = \frac{500}{3} H_0 \text{ kgm}^2/\text{s}^2 + \text{heat}$$

$$\text{heat} = \frac{1000}{3} H_0 \text{ kgm}^2/\text{s}^2$$

} heat uses up  
 2/3 of transferred  
 kinetic energy

$$KE + \text{heat} \rightarrow PE$$

$$\frac{1}{2}mv_{j+t}^2 + \text{heat} \rightarrow m_j + gh_f$$

$$\frac{1}{2}(150\text{kg}) \left( \frac{2\sqrt{5H_0} \text{ m/s}}{3} \right)^2 \rightarrow (150\text{kg})(10\text{m/s}^2)(h_f)$$

$$\frac{500}{3} H_0 \text{ kgm}^2/\text{s}^2 = \frac{1500\text{kg m/s}^2(h_f)}{150\text{kgm/s}^2}$$

$$h_f = \frac{1}{9} H_0 \text{ meters}$$

$$KE = \frac{P^2}{2m}$$

} Relates KE and  
 momentum

② a. i. Compress the Spring

- There is spring potential energy.
- The force is in the direction of the spring's compression.

2. Fire the gun

$\downarrow$  happens

- The acceleration and velocity increases.

- Spring Potential Energy becomes Kinetic Energy

- The momentum of the ball increases, but momentum is conserved because the spring experiences a change in momentum as well.

3. The ball hits the pendulum.

- Some energy is lost in the collision. It becomes thermal energy.  
But there is some kinetic energy ~~to cause some acceleration~~ remaining

- Because the ball is hitting an object, the acceleration decreases due to the force the block puts on the ball.

- The momentum is conserved. The velocity of the new body decreases since the mass of the body has grown and kinetic energy is lost. ~~To heat~~

4. The pendulum swings upward.

- The remaining kinetic energy becomes potential energy. The amount of kinetic energy will equal potential energy which will determine the height of the block.

b. One conservation equation would not work because energy and momentum is transferred from many processes:  
(1) the spring to (2) the ball to (3) the pendulum.

c. Speed of bullet?

Spring Potential Energy  $\rightarrow$  Kinetic energy

[No energy goes to heat bc frictionless spring]

$$\frac{1}{2} k x^2 = \frac{1}{2} m v^2$$

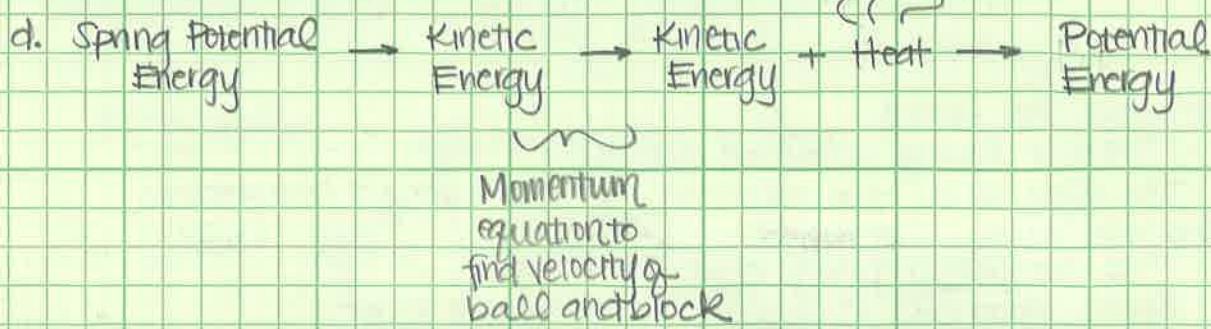


$$k x^2 = m v^2$$

$$\frac{(10^4 \text{ N/m})(.1 \text{ m})^2}{0.002 \text{ kg}} = \frac{(0.002 \text{ kg})(v)^2}{0.002 \text{ kg}}$$

$$v^2 = 50000 \text{ m}^2/\text{s}^2$$

$$v \approx 223.6 \text{ m/s}$$



$$m_0 V_0 + m_{\square} \cancel{V_{\square}} = m_{0+\square} V_{0+\square}$$

$$(0.002\text{kg})(223.1\text{m/s}) + 0 = (0.202\text{kg}) V_{0+\square}$$

$$V_{0+\square} = \frac{(0.002\text{kg})(223.1\text{m/s})}{(0.202\text{kg})}$$

$$V_{0+\square} \approx 2.21 \text{ m/s}$$

*fantastic!*

Finding how much energy goes to heat.

$$\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2 + \text{heat}$$

$$\frac{1}{2} (0.002\text{kg}) (223.1\text{m/s})^2 - \frac{1}{2} (0.202\text{kg}) (2.21\text{m/s})^2 + \text{heat}$$

$$\begin{aligned} \text{heat} &= \frac{1}{2} (0.002\text{kg}) (223.1\text{m/s})^2 - \frac{1}{2} (0.202\text{kg}) (2.21\text{m/s})^2 \\ &= 49.5037 \text{ Joules} \end{aligned}$$

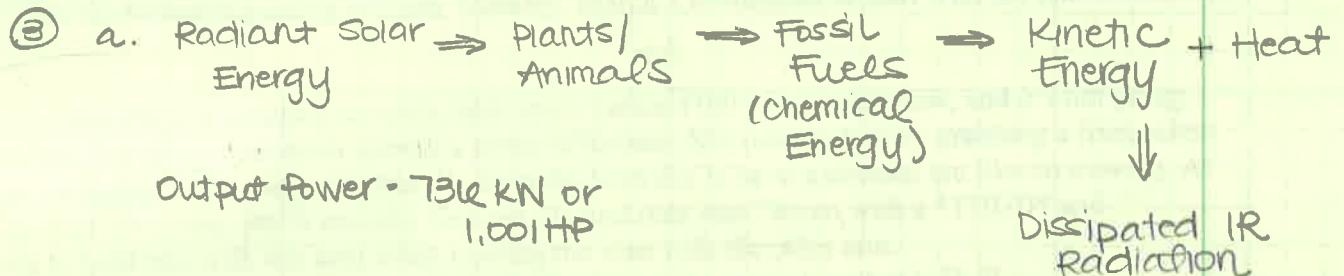
Height of swinging block:

$$\text{KE} + \text{heat} \rightarrow \text{PE} [\text{mgh}]$$

$$\frac{\frac{1}{2} (0.202\text{kg}) (2.21\text{m/s})^2}{(0.202\text{kg}) (10\text{m/s}^2)} \rightarrow (0.202\text{kg}) (10\text{m/s}^2) (h_f)$$

$$h_f = .244 \text{ meters}$$

- e. I do think that the initial velocity of the ball was very large, but it does make sense considering the very large spring constant. I found it fascinating that almost all the energy after the collision became thermal energy. As far as the final height of the block and ball, the answer does not seem too outrageous. .244 meter is 24.4 centimeters, a reasonable amount considering the initial velocity of the ball.



- b. At maximum speed, the Bugatti Veyron can consume about 26.4 gallons in 19 min. A regular gallon of gas has about 114,100 BTU (British Thermal Units  $\rightarrow$  1 BTU = 1,055.06 Joules)

at top  
speed of  
253 mph

$$26.4 \text{ gallons} \quad | \quad 114,100 \text{ BTU} \quad | \quad 1055.06 \text{ Joules} \quad | \quad 1 \text{ min} \\ 19 \text{ minutes} \quad | \quad 1 \text{ gallon} \quad | \quad 1 \text{ BTU} \quad | \quad 60 \text{ sec}$$

$$\approx 2,787,801,494,842 \text{ Joules/sec or Watt} \\ \approx 2,790,000 \text{ Watts}$$

$\nwarrow$  Input Power

great job!  
make sure to cross  
off units like you  
did here. Some  
classes take off pts  
if you don't

- c. A lot of the chemical potential energy becomes thermal energy while the rest becomes kinetic energy.

$$\text{Efficiency} = \frac{\text{Energy Output}}{\text{Energy Input}} \times 100\%$$

$$\cdot \frac{7316,000 \text{ W}}{2,790,000 \text{ W}} \times 100\% = [26.4\%]$$

- d. KE + heat

$$W = J/S$$

$$J = W \cdot S$$

$$KWS \cdot ks$$

$$kWhr = 3.6 \text{ million joules}$$

$$V_{\text{average}} = \frac{\Delta x}{\Delta t}$$

d.

$$P_{\text{propeller}} = (0.002 \text{ kg})(223.6 \text{ m/s}) = P_{\text{car}} \quad KE = \frac{1}{2} (202)(2.213\%)^2 \\ = .4472 \quad = 4.95019 \text{ J} \\ M_{\text{car}} = 2 \text{ kg} + 0.02 \text{ kg} \quad .4472 = .202 (V) \quad KE = P/V \\ = 2.02 \text{ kg} \quad V = 2.21386 \text{ m/s} \quad PE = mgh \\ \underline{\underline{h = 2.45 \text{ m}}} \\ \underline{\underline{PE = 202(10)h}}$$

3. a) radiant solar energy  $\rightarrow$  converted to <sup>chemical</sup> potential energy in plants  $\rightarrow$  gasoline (<sup>chemical</sup> potential energy)

dissipated IR ← heat energy  $\downarrow$  kinetic energy of car

radiation

b) This is an energy problem because we are determining how much energy is needed to power the car (so it is also a dynamics problem because forces are causing acceleration)

max power output of engine 1,001 HP  
736,000 W

$$P = \frac{\Delta E}{t}$$

$$\text{max speed} = 400 \text{ km/hr} \times \frac{1 \text{ hr}}{3600 \text{ min}} \times \frac{1000 \text{ m}}{1 \text{ km}} = 111 \text{ m/s}$$

uses gas at 26 gal/min

$$\text{mass} = 1838 \text{ kg}$$

$$\text{gas} = 13 \times 10^6 \text{ J}$$

~~Show work for cancellation of cancel.~~

$$\frac{26 \text{ gal}}{12 \text{ min}} = \frac{1.3 \times 10^6 \text{ J}}{90 \text{ s}} = 1.468 \times 10^6 \text{ watts}$$

c)  $\frac{736,000 \text{ W}}{1.468 \times 10^6 \text{ W}} \times 100 = 15.7\% \text{ efficient}$

d)  $1.468 \times 10^6 \text{ W} - 736,000 \text{ W} = 394,400 \text{ W lost}$   
 $P_{\text{lost}} = P_{\text{car}}$

$$394,400 \text{ W} \times \frac{1 \text{ light bulb}}{100 \text{ W}} = 3940 \text{ light bulbs}$$

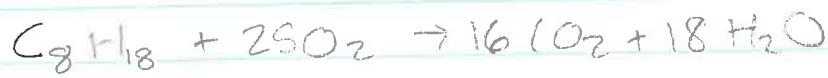
Needs 10 radiators to dissipate heat and not destroy anything

c. .036 gal/s

1 kg gas = 48 MJ

$$\frac{1 \text{ gal}}{10 \text{ kg(CO}_2\text{)}} \times 26 \text{ gal} = 260 \text{ kg CO}_2 \times \frac{1}{720 \text{ s}}$$

= 361 kg CO<sub>2</sub>/s



~1 lb/second

7) USA: \$46,326 per year

$$\$2,250,000 = 23,163 \times$$

98 people in US

Guatemala: \$ 2,740 per year

$$\$2,250,000 = \$1,370 \times$$

1,643 people in Guatemala

DR Congo: \$ 120 per year

$$2,250,000 = 600 \times$$

37,500 people in DR Congo

g) 1% of people in US

.0015% of people in Guatemala

$1.5 \times 10^{-4}\%$  of people in DR Congo

lock

light is not conserved  
is lost as heat during  
perhaps in the