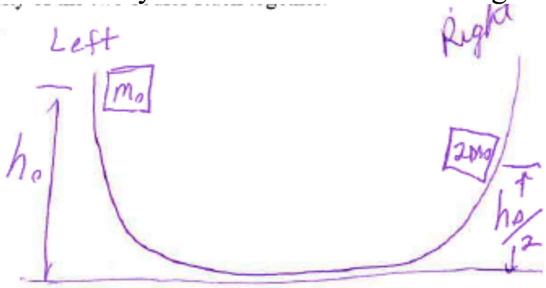
You will be graded on your *COMMUNICATION* of physics understanding

#1 You and your friends are excited to take part in the X-treme skate board challenge: Two skate boarders drop off opposite (rounded) sides of a (dry) swimming pool and stick to each other at the bottom of the pool! On the left side, a skater drops from H_o, while another skater with *twice the mass* drops from *half the height* from the right side. They collide in the middle.

a) After the collision, (joined together) which way are they going, or are they at rest? Of course, you know to provide a thorough explanation.

b) The left side skater is 50 kg and drops from 6 m, while the right side skater is 100 kg and drops from 3 m. Calculate the approximate final velocity of the two bodies stuck together.



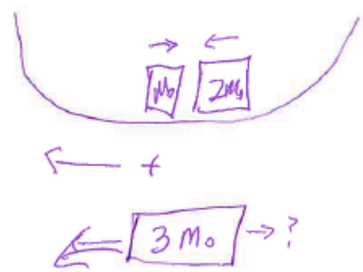
Energy Lens $E_g \Rightarrow E_k$

$E_p = E_k$

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

$v = \sqrt{2gh}$

$\boxed{V_L = \sqrt{2gh_o}}$ $\quad V_R = \frac{1}{\sqrt{2}} V_L$



$\vec{p}$ lens $\vec{p}$ is conserved,

$F_{outside} \approx 0$

$\vec{p}_L = m_L \vec{v}_L \qquad \vec{p}_R = m_R \vec{v}_R$

$P_L = m_o V_L \qquad P_R = 2m_o \frac{1}{\sqrt{2}} V_L = \frac{2}{\sqrt{2}} m_o V_L = \sqrt{2}\, m_o V_L$

$P_R = \sqrt{2}\, P_L \approx 1.4 P_L$

$\Sigma \vec{P}_i = \Sigma \vec{p}_f \qquad m_f V_f = P_R - P_L$

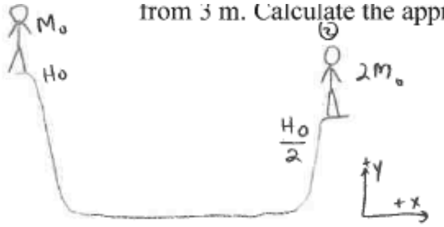
$-P_L + P_R = m_f V_f \qquad = \sqrt{2}\, P_L - P_L = (\sqrt{2} - 1) P_L$

$3 m_o V_f = (0.41)\, m_o (2gh_o)^{\frac{1}{2}} \qquad h_o = 6\,m$

$V_f = \frac{1}{3}(0.41)(2 \cdot 10\,m/s^2 \cdot 6\,m)^{\frac{1}{2}}$

$= 0.133\,(11)\,\frac{m}{s} \approx \underline{1.4\,m/s}$

from 3 m. Calculate the approximate final velocity of the two bodies stuck together.



Ⓐ

energy lens because it changes forms

momentum lens because it is conserved because of the minimal outside forces

(inelastic)
- KE not conserved

While KE isn't conserved, the PE of each must equal KE at the bottom

$mgh_0 = \frac{1}{2}mv^2$ $\qquad$ $2mg\frac{h_0}{2} = 2\frac{1}{2}mv^2$

$m_0 V_1 + (-V_2 m2) = 3m\, V_f$

$\sqrt{2gh_0} = V_1$ $\qquad$ $-\sqrt{gh_0} = V_2$

$m_0\sqrt{2gh_0} - 2m_0\sqrt{gh} = 3m_0 V_f$

$\frac{\sqrt{2gh_0}}{3\,kg} - \frac{2\sqrt{gh}}{3\,kg} = V_f$

$\Sigma \vec{p}_i = \Sigma \vec{p}_f$

the momentum of the second skateboarder is larger and negative, so the final velocity is negative. They are going left after colliding

A+

Ⓑ

$(50kg)\sqrt{2\cdot 10m/s^2 \cdot 6m} - (100kg)\sqrt{10m/s^2\cdot 6m} = 150kg\, V_f$

$\approx 50kg\cdot\sqrt{120\,m^2/s^2} - 100\,kg\sqrt{60\,m^2/s^2} = 150\,kg\, V_f$

$\approx \frac{50\cdot 11\,kg\,m/s}{50\cdot 3\,kg} - \frac{100\cdot 8\,kg\,m/s}{100\cdot 1.5\,kg} = \frac{150\,kg\,V_f}{150\,kg}$

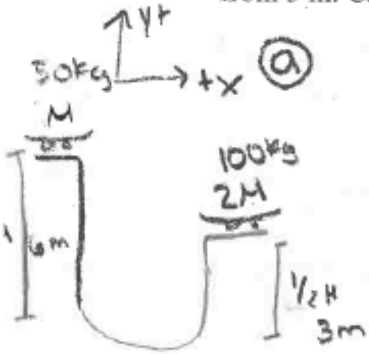
This is great work! I love the estimating

$\approx 3\,m/s - 5\,m/s = V_f$

$\boxed{V_f = -2\,m/s}$

closer to 4 m/s

from 3 m. Calculate the approximate final velocity of the two bodies stuck together.



ⓐ Energy Lens

PE = KE

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

$gH = \frac{1}{2}v^2$ $\qquad$ $\frac{1}{2}Hg = \frac{1}{2}v^2$

$2gH = v^2$ $\qquad$ $Hg = v^2$

$v = \sqrt{2gH}$ $\qquad$ $v = \sqrt{gH}$

momentum lens → because?

A ⊤

$m_1v_1 = m_2v_2$

547.7

$M\sqrt{2gH} - 2M\sqrt{gH} = 3Mv$

$v = \dfrac{M\sqrt{2gH} - 2M\sqrt{gH}}{3M}$

$2M\sqrt{gH} > M\sqrt{2gH}$
therefore numerator is negative
negative divided by a positive
is negative $\boxed{\text{⊖ answer moving to the left}}$

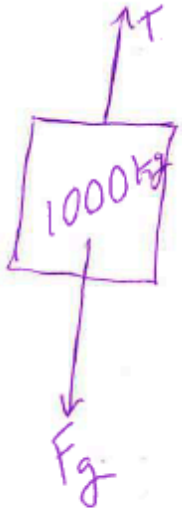
ⓑ $v_f = \dfrac{M\sqrt{2gH} - 2M\sqrt{gH}}{3M}$

$v_f = \dfrac{50\text{kg}\sqrt{2(10\text{m/s}^2)(6\text{m})} - 100\text{kg}\sqrt{(10\text{m/s}^2)(6\text{m})}}{150\text{kg}}$

$\boxed{v_f = 1.51 \text{ m/s to the left}}$

nice work...
good units!
well organized.

#2 Your friend is standing in a 1000 kg elevator (combined mass). At a height of 20 m, she's moving downward at 8 m/s. She continues at this speed for 1 second and then smoothly comes to rest at some height over the next 2 s. Please make the graphs describing her motion and the tension in the elevator cable during this experience. Label the axis to make the values explicitly clear. A lot of students made sign errors. I think you should decide which way is positive and check it for all calculations. Also, state your lens(es).



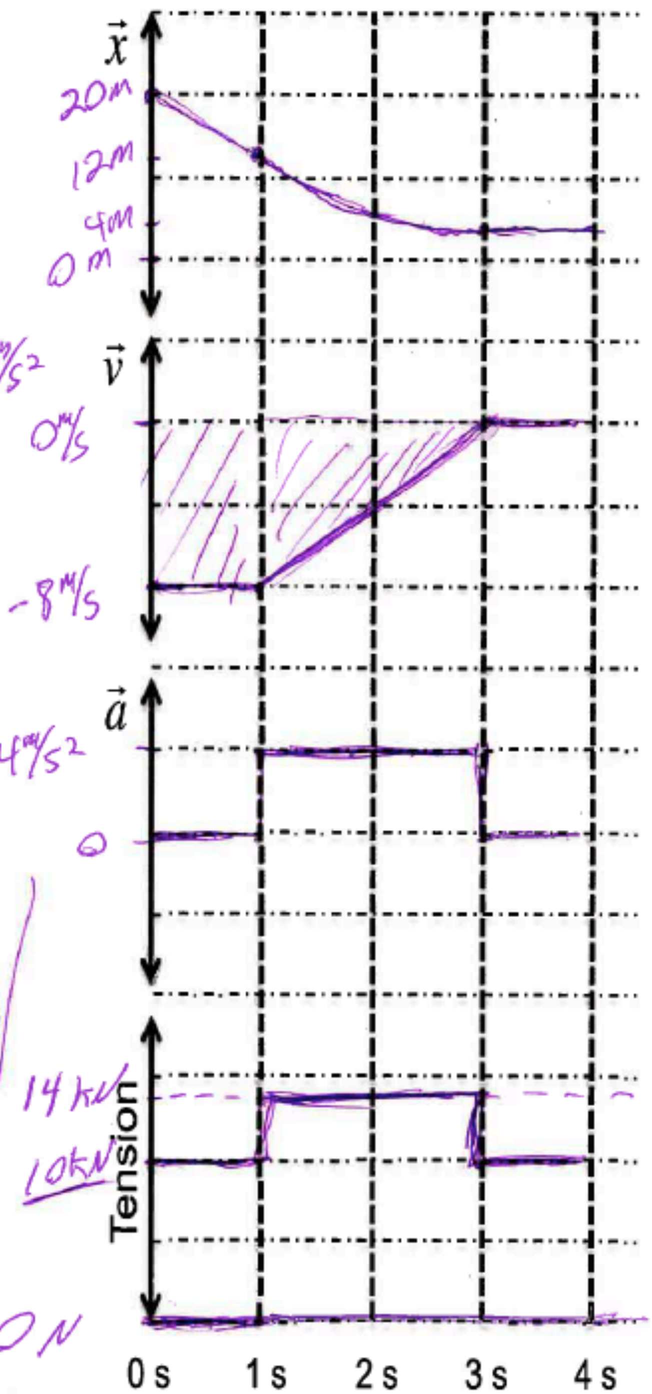
Kinematics

V as f(time)

+↑ ↓ V_i a↑ +↑

$a = \frac{\Delta V}{\Delta t} = \frac{8 m/s}{2 s} = 4 m/s^2$

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



Dynamics lens. F cause $\vec{a}$

$\sum \vec{F} = m\vec{a}$

$T + \vec{F}_g = m\vec{a}$ $T = F_g + ma$

$a = 0$

$T = F_g = mg = 1000 kg \cdot 10 m/s^2$
$= 10 kN$

T Fg

$\sum F = MG = 0$

$a = 4 m/s^2$

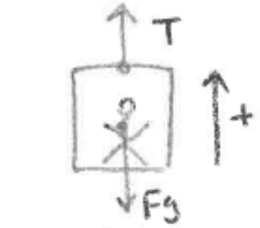
T F

$\sum F = ma$

$T = 10 kN + 1000 kg (4 m/s^2)$
$10 kN + 4 kN = 14 kN$

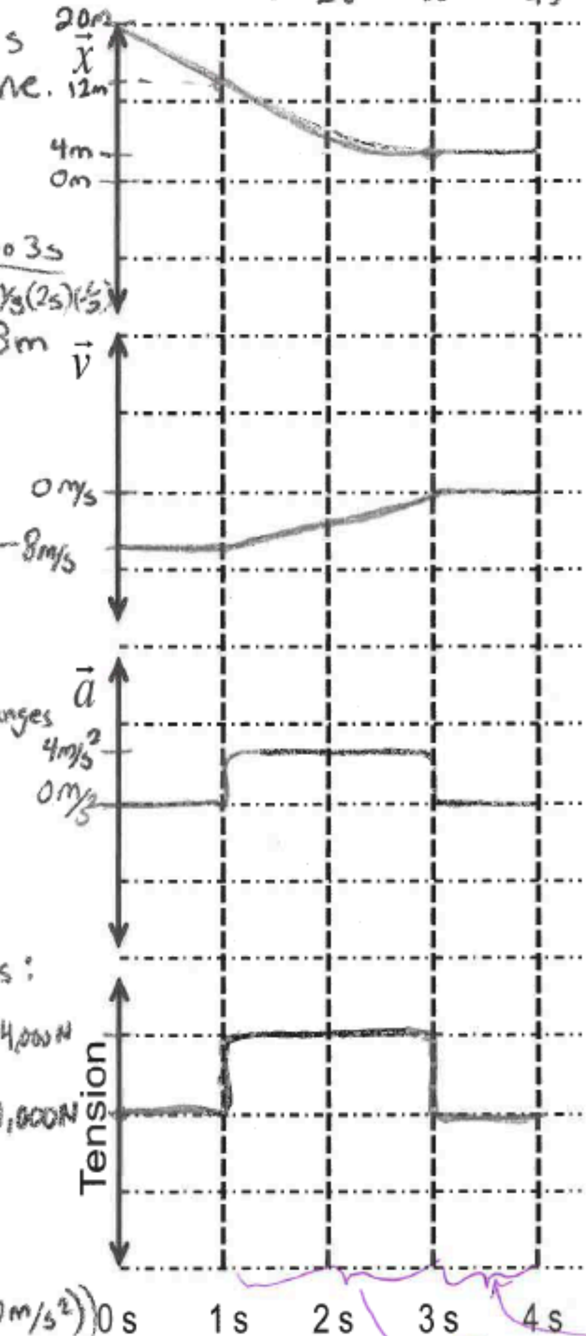
2 s. Please make the graphs describing her motion and the tension in the ... Label the axis to make the values explicitly clear.

Lens: Kinematics: x and $\vec{v}$ given as explicit fn of time.



$x = \partial v dt$

$t = 0$ to $1s$	$t = 1$ to $3s$
$x = 8 m/s (1s)$	$x = 8 m/s (2s)(\frac{1}{2})$
$x = 8 m$	$x = 8m$



V = 8 m/s at t = 0 s to t = 1s
Comes to rest, velocity goes to 0 over 2s.

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

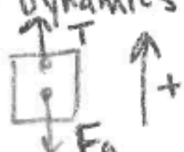
$\Delta V = 0 m/s - (-8 m/s)$
$= +8 m/s$
$\Delta t = 2s$

$= \frac{8 m/s}{2s} = 4 m/s^2$

$\vec{a}$ is $\frac{\Delta V}{\Delta t}$. V changes 8 m in 2s

$\vec{a}$ is constant
$\vec{a}$ is zero 0s to 1s and 3s to 4s

Lens: Dynamics: $\vec{a}$ caused by forces: tension and F_g



$\Sigma \vec{F} = m\vec{a}$

When $\vec{a} = 0 m/s^2$ $\quad \Sigma \vec{F} = 0 = T + F_g$

$T = F_g$

$T = mg$

$= -(1000 kg(-10 m/s^2))$

$T = 10,000 N$

$\Sigma F = ma = 0$

When $\vec{a} = 4 m/s^2$ $\quad 1000 kg (4 m/s^2) = T + (1000 kg)(-10 m/s^2)$

$T = 14,000 N$

$\Sigma F = ma$

#3 I have a 2 kg block, bouncing between two springs as shown below. Each spring is about 1 m long and there is a 2 m low friction track in between. The spring on the left has a spring constant twice as large as that on the right: $k_L = 2k_R$.

a) I compress the spring on the left and use it to launch the mass across the low friction floor into the spring on the right. How far does the right spring compress? That is: $\Delta x_R = \underline{??}\, \Delta x_L$. Show work.

b) Above the image below, please make a potential energy diagram, showing the potential energy of the block as a function of displacement. I'm just looking for the shape. You can't put scales on the axis because I don't give you the required constants.

For (c) and (d) below, what if the floor is *not* frictionless? What if there is a 2 m section of floor that has a coefficient of friction of 0.3 with the block?

c) Find the acceleration of the block on this surface as it slides to the right after leaving the spring.

d) How would this friction change the calculation you did for (a) above? How would you go about finding the compression in the second spring now? Please explain and set up the equation(s) necessary. There is not enough information to calculate the value.

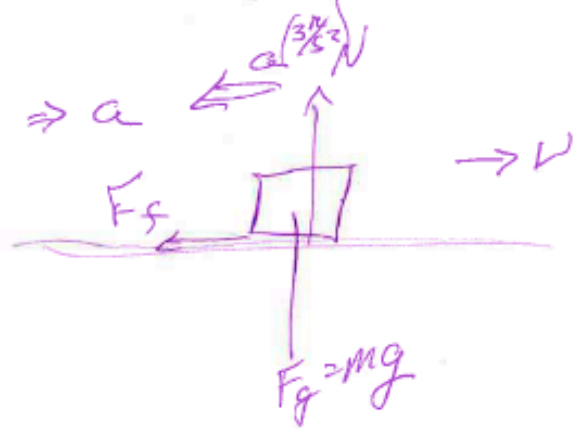
$E_{SL} \Rightarrow E_k = E_{SR}$

$\frac{1}{2}k x_L^2 = \frac{1}{2}\frac{k}{2} x_R^2$ $\quad x_R^2 = 2x_L^2$

$x_R = \sqrt{2}\, x_L \approx 1.4\, x_L$

c) Dynamics $F_f \Rightarrow a$

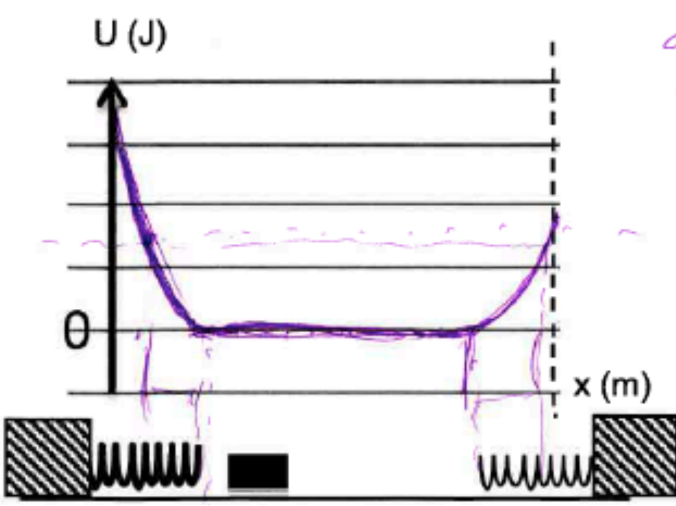
$\sum \vec{F} = m\vec{a}$



$F_f = \mu N = ma$

$a = \frac{\mu N}{m} = \frac{\mu mg}{m}$

$= \mu g = 3\,m/s^2$



d) Energy $E_{SL} \Rightarrow E_{SR} + Heat$

$Heat = W_f = F_f \Delta x$

$= \mu mg \Delta x$

$= .3(20N)\cdot 2m$

$= 12 J$

a) lens: energy b/c if the floor is frictionless, no energy is lost to thermal energy, so the potential in spring transfers completely to kinetic after the spring expands & returns to spring potential energy as it hits the right spring. and in this closed system the total energy is conserved

$E_{sp_L} \to E_K \to E_{sp_R} \to E_K \ldots$ (cont. as it goes back & forth)

$E_{sp} = \frac{1}{2}k\Delta x^2$ & $E_K = \frac{1}{2}mv^2$ & $E_{sp} = E_K$

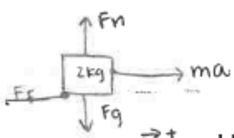
The left & right spring produce the same amount of E_K (b/c conservation of energy) so $E_{sp_L} = E_{sp_R}$ & $k_L = 2k_R$. in order to cancel out the doubled k value (to make the potential energy be the same) you need to make $\Delta x^2 = 2$, so:

$\hookrightarrow \frac{1}{2}(2k_R)\Delta x_R^2 = \frac{1}{2}k_L \square \Delta x_L^2$

$\Delta x_R = \sqrt{2}\,\Delta x_L$

** If the floor wasn't frictionless (w/ $\mu = .3$) then the potential energy would not all transform to kinetic energy ($E_{sp} \neq E_K$), instead the friction would cause the block to lose kinetic energy as it bounces back & forth

c) lens: dynamics b/c forces cause acceleration & the force of friction goes "against" relative velocity of block



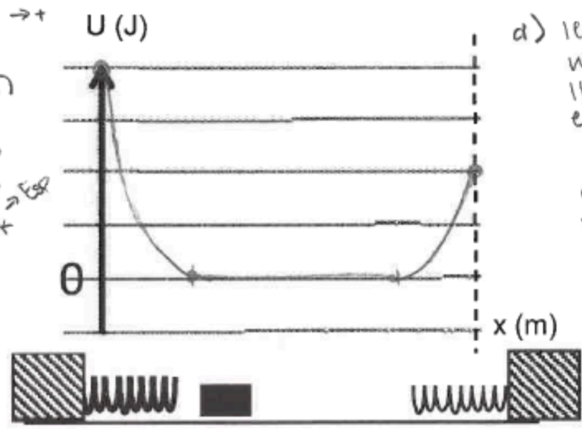
* Fg = Fn b/c no up/downwards acceleration

$F_f = \mu F_n$ & $F_n = F_g = mg$ & $\mu = .3$ & $\Sigma F = ma$ &

$F_f = ma \to \mu mg = ma \to a = \mu g$

$a = (.3)(10\,m/s^2) = 3\,m/s^2$

b)



energy lens $E_{sp} \to E_K \to E_{sp}$

d) lens: energy b/c potential energy wouldn't all go to kinetic energy, instead, it would be kinetic & thermal energy

$E_{sp} \to E_K + E_{th} \to E_{sp} \ldots$

as the block bounces back & forth, thermal energy would increase & spring energy would decrease (so Δx would also decrease)

$E_{sp} = \frac{1}{2}k\Delta x^2$ & $E_K = \frac{1}{2}mv^2$ & $E_{th} = W$ by friction

$\downarrow$

$W = F_f\, x$

$W = \mu F_n x$

$E_{sp} = E_K + E_{th}$

$\frac{1}{2}k_L\Delta x_L^2 = \frac{1}{2}mv^2 + \underbrace{\mu F_n x}_{12J}$

$= \frac{1}{2}k_R\Delta x_R^2$

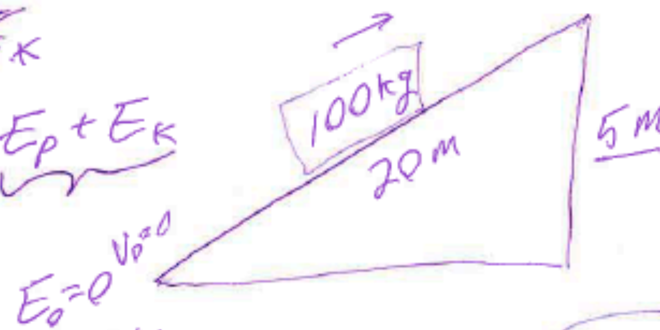
=

#4 Your 100 kg friend, said he ran up a flight of stairs in 4 seconds… starting from rest and still going strong at the end! You measure the stairs and note that the flight is 20 m long and rises 5 meters.
Estimate your friend's power output. State any assumptions you make in the process. There need to be considerations for both kinetic and potential energy for full credit. You should state the assumptions (simplification) you make for the motion.

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

$\cancel{E_p = E_K}$

$W \Rightarrow E_p + E_K$



$\Delta E = E_p + E_K$

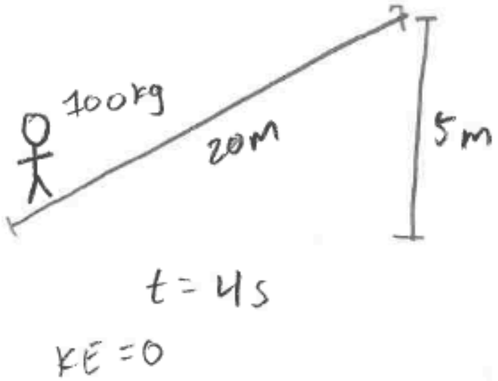
$= mgh + \frac{1}{2}mv^2$

kinematics $V_{av} = \frac{\Delta x}{\Delta t} = \frac{20m}{4s} = 5\,m/s$

$= 100kg \cdot 10\,m/s^2 \cdot 5m + \frac{1}{2}(100kg)(5\,m/s)^2$

$= 5000\,kg\frac{m^2}{s^2} + 1250\,kg\frac{m^2}{s^2} = 6250J$

$P = \frac{\Delta E}{\Delta t} = \frac{6250J}{4s} \approx 1.6\,kW \approx 2\,Hp$



We find power using the energy lens as it is the change of energy over time. we analyze both potential and kinetic energy.

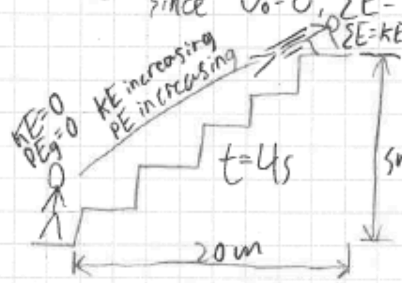
Potential energy can be found with PE = mgh. the initial potential energy is 0 because the height is 0. The final Potential energy PE = 100kg · 10m/s2 · 5m = 5000J, so a 5000J change in PE. This change occurs over 4 seconds, So power = dE/dt = 5000J/4s = 1250W.

Because the person starts from rest, there is a change in KE from the bottom to top of the stairs. The initial KE is 0. we use kinematics to find the velocity, which we will then use to find the final kinetic energy. $V = \Delta X / \Delta t$ = 20m total / 4 seconds = 5m/s velocity at the top. We then find $KE = 1/2 mv^2 = 1/2(100kg)(5m/s)^2 = 1250J$. The total Change in KE = 1250J. This also occurs over 4 seconds, so power = 1250J/4s = 312.5W.

The total power is the sum of 1250W + 312.5W, so a total of 1562.5W.

---- OR ----

(4) Energy lens: KE ⇒ KE + PE
Since $V_0 = 0$, $\Sigma E = KE + PE_g$



All energy is conserved, the ATP in her body is converged through work to KE and PE_g

$W = F\Delta X = \Delta E \quad \Delta E = (KE_f + PE_f) - (KE_i + PE_i) \rightarrow 0$

$\Delta E = \frac{1}{2}mv^2 + mgh$

In order to find V we use kinematics lens, position as a function of time. $V = \frac{\Delta x}{\Delta t} = \frac{20m}{4s} = \underline{5 m/s}$

$$W = \Delta E = \frac{1}{2}mv^2 + mgh$$
$$= \frac{1}{2}(100\,kg)(5m/s)^2 + (100kg)(10m/s^2)(5m)$$
$$= 1250J + 5000J$$
$$= 6250J$$

$$Power = \frac{W}{\Delta t} \Rightarrow W = 6250J$$
$$= \frac{6250J}{4s} = \boxed{1562.5W} \approx \underline{1.6\ kw}$$