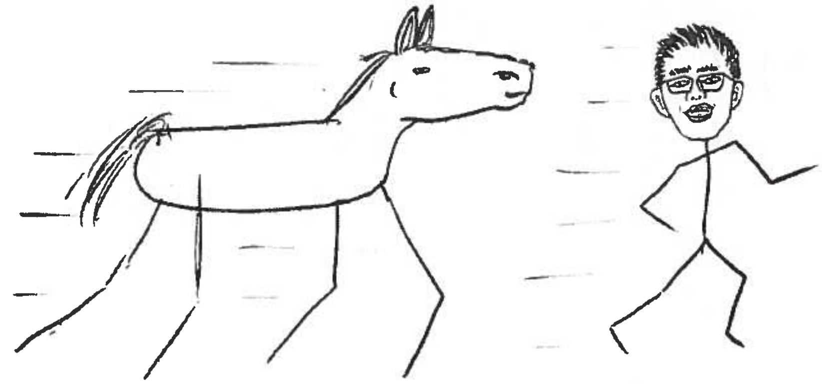
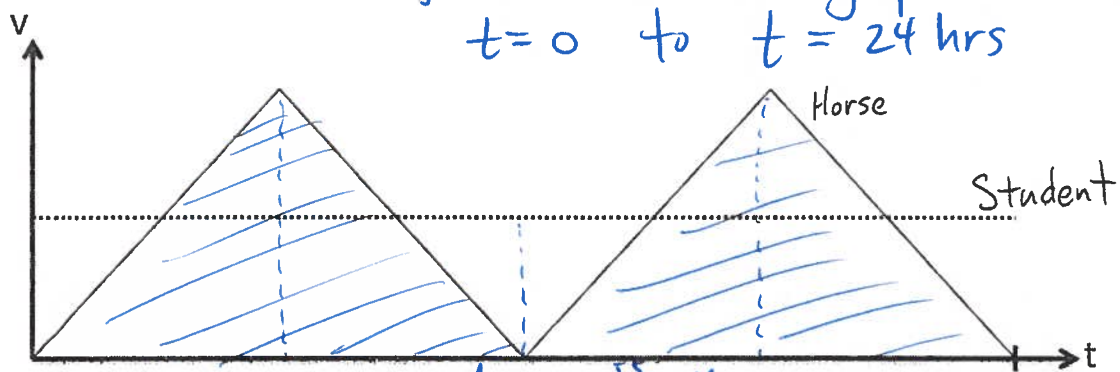


Question 1: A Science One student races a horse for 24 hours. The Science One student runs at a constant velocity, while the horse speeds up and slows down as shown in the graph.

$x_f - x_i$ = area under graph of $v(t)$ from $t = 0$ to $t = 24$ hrs

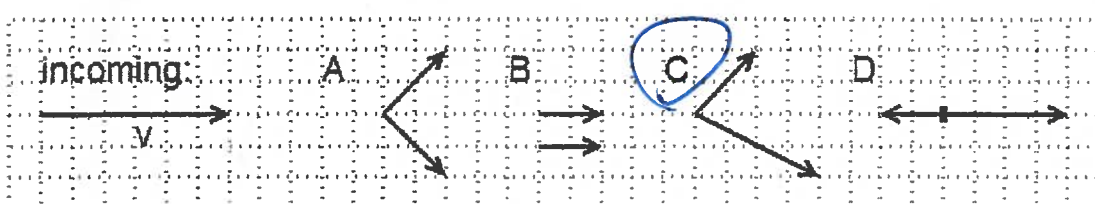


Areas ~~are~~ is the same as area under dotted line

Who travels the farther in 24 hours?

A) The student B) The horse C) The distances are approximately equal
D) The answer cannot be determined from the information provided

Question 2: A billiard ball moving to the right at speed v strikes a stationary billiard ball of the same mass. Which pair of vectors represents possible velocities for the two balls after the collision, if the arrow at the left represents the initial velocity of the first ball?



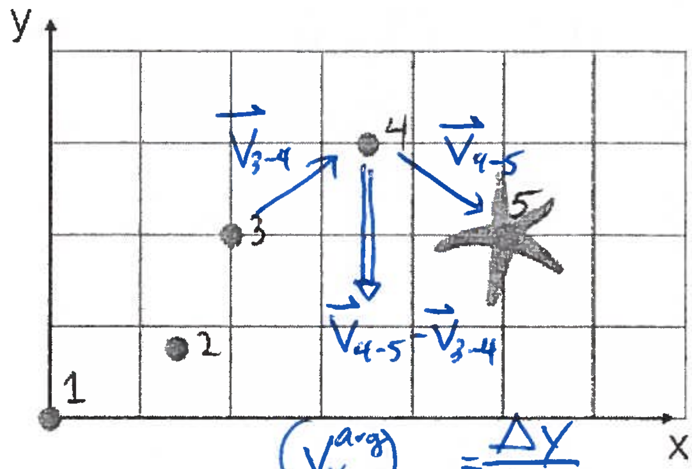
E) Any of the above

Momentum conservation:

$$m\vec{V}_{initial} = m\vec{V}_1^{f} + m V_2^{f}$$

$$\Rightarrow \vec{V}_{initial} = \vec{V}_1^{f} + \vec{V}_2^{f}$$

Question 3: A sea star meanders along a large flat rock during your intertidal study. Every 30 minutes, you plot the position of the sea star on a grid where 1 box represents 1 square metre. The data are shown on the right.



The average y velocity of the sea star between points 3 and 4 is closest to

$$(V_y^{avg})_{3\to 4} = \frac{\Delta y}{\Delta t} = 1m/0.5hrs = 2m/hr$$

A) 1 m/hr B) 2 m/hr C) 3 m/hr D) 4 m/hr E) 5 m/hr

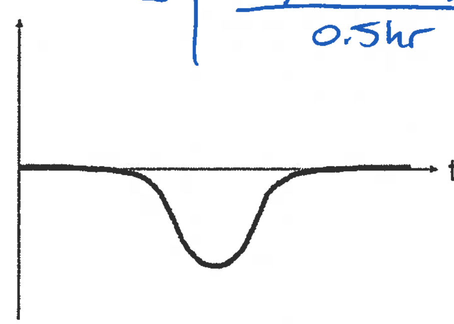
Question 4: Assuming that the sea star in the previous question travels on a path that smoothly connects the points above (without wiggles), the best estimate of the magnitude of the sea star's acceleration at point 4 would be:

A) 0 m/hr^2 B) 0.1 m/hr^2 C) 1 m/hr^2 D) 10 m/hr^2 E) 100 m/hr^2

Extra: draw the direction of the acceleration on the diagram (**1 point**)

$$\vec{Accel} \approx \frac{\vec{V}_{4-5} - \vec{V}_{3-4}}{\Delta t} \rightarrow \text{in -ve } y \text{ direction}$$

$$\text{magnitude } \frac{(V_y)^{4-5} - (V_y^{3-4})}{\Delta t} = \left| \frac{-2m/hr + 2m/hr}{0.5hr} \right| \approx 8m/hr^2$$



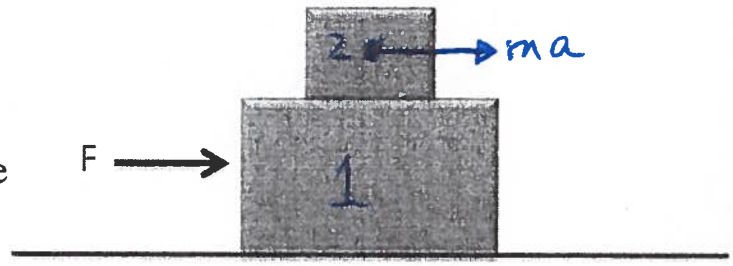
Question 5: A giant grapefruit rolls up a slope as shown, with more than enough initial speed to reach the top. In the graph on the right, which quantity is plotted as a function of time?

A) x B) v_x C) a_y D) y E) v_y F) a_x

$a_x = 0$ on flat parts

-ve on slope since grapefruit slows down.

Question 6: A force causes two blocks to slide together across a surface. If the blocks are accelerating together to the right, in which direction is the force on the top block *from the lower block*?



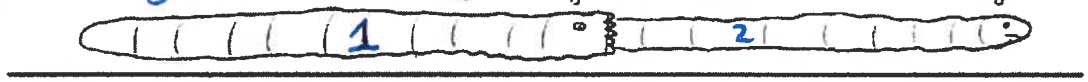
A) ↑ B) → C) ↗ D) ↘ E) ↖

$F_{1 on 2} = F_{Normal} + F_{friction} = \uparrow + \rightarrow = \nearrow$
(push)

or $F_{1 on 2} = F_{NET} - F_{grav} = \rightarrow - \downarrow = \nearrow$

mm... worm

I hate when this happens



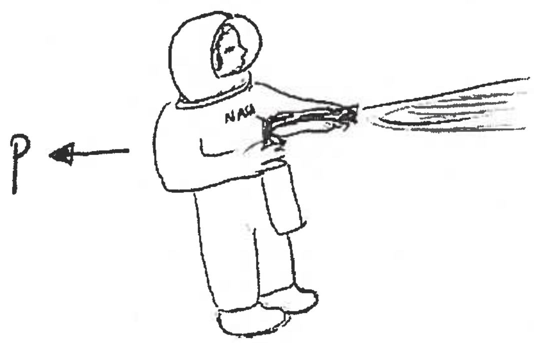
Question 7: A larger (more massive) worm is swallowing a smaller worm on a frictionless surface. The acceleration of the smaller worm due to the swallowing force is

$|\vec{F}_{1 on 2}| = |\vec{F}_{2 on 1}| \Rightarrow m_2 a_2 = m_1 a_1$

A) Larger in magnitude than the acceleration of the larger worm.
B) Smaller in magnitude than the acceleration of the larger worm.
C) The same magnitude as the acceleration of the larger worm.
D) Any of the above are possible, depending on the initial velocities.

$a_2 = \frac{m_1}{m_2} a_1 > a_1$

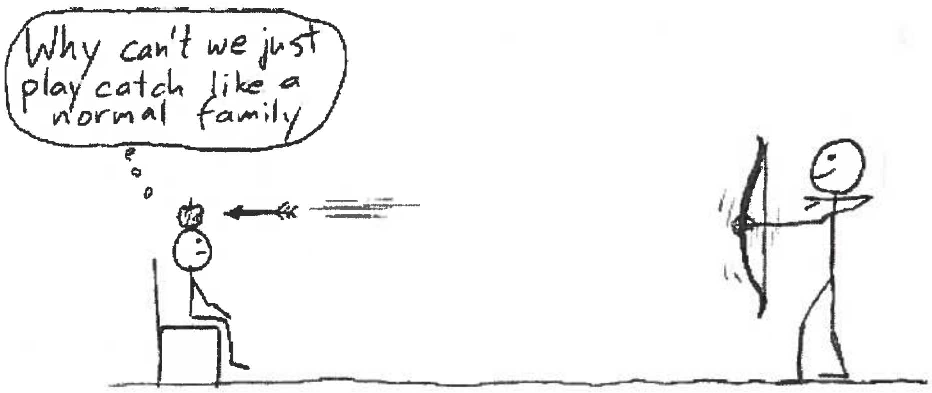
since $m_1 > m_2$



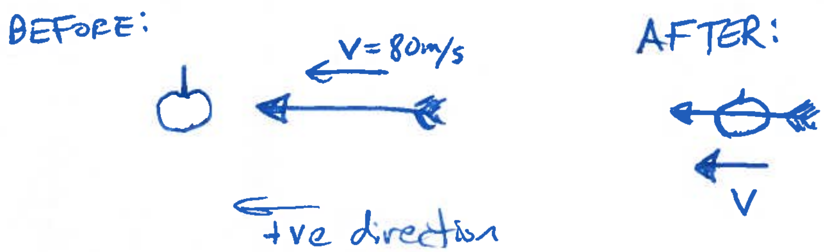
Question 8: Sandra Bullock is trapped in a disintegrating spaceship. (Yes, she really is. It's not just a movie this time.) She uses a fire extinguisher to launch herself to safety. If her momentum increases as $p = 20\ t^2$ (where all quantities are in SI units), how much force acts on her after 4 seconds?

A) 160N B) 320 N C) 80N D) 426N
E) Can't be determined without knowing her mass

$F = \frac{dp}{dt} = 40t$
$= 40 \cdot 4\ N$
$= 160N$



Question 9: William Tell shoots an apple off the (frictionless) head of his son. The apple weighs 200g and is originally 1m off the ground, and the arrow weighs 50g and strikes the apple at 80 m/s. If the arrow sticks in the apple,
a) what is the horizontal velocity of the arrow plus apple immediately after the collision?
b) estimate the horizontal velocity of the arrow+apple 0.01s after the collision if the drag force has magnitude (0.01 N s^2/m^2) v^2. (**6 points**)



By momentum conservation:

$$P_{BEFORE} = P_{AFTER}$$

$$\Rightarrow M_{arrow} \cdot V_{arrow}^{before} = (M_{arrow} + M_{apple}) V_{after}$$

$$\Rightarrow 50g \cdot 80\,m/s = (50g + 200g) \cdot V_{after}$$

$$\Rightarrow \boxed{V_{after} = 16\,m/s}$$

At time $\delta t = 0.01s$ after the collision, we have

$$V(\delta t) = V(0) + \delta t \cdot a$$

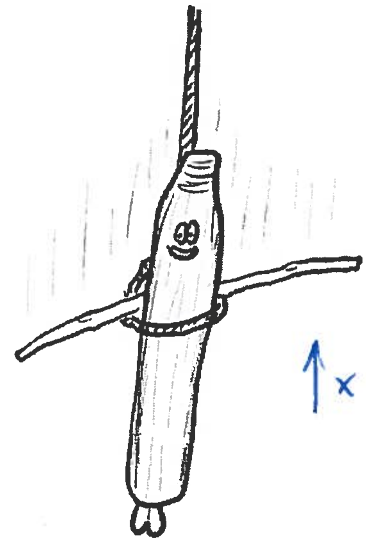
$$= V(0) + \delta t \cdot \frac{F}{m}$$

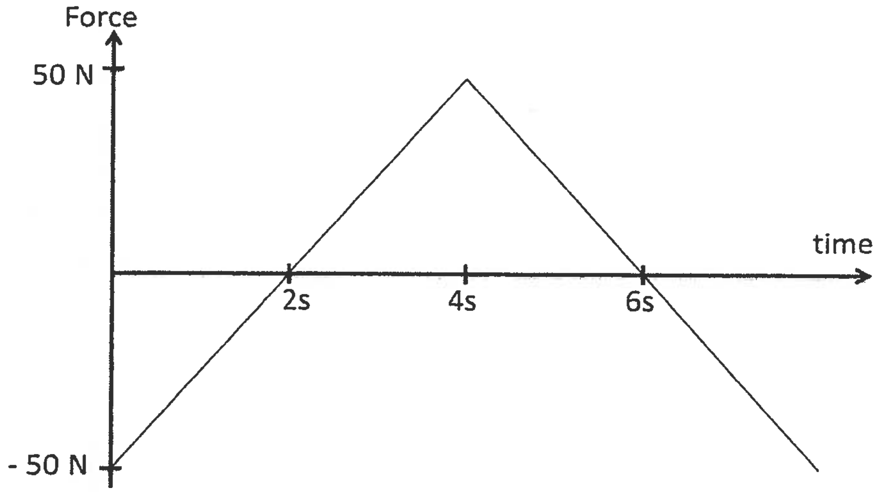
$$= V(0) - \delta t \cdot \frac{Cv^2}{m}$$

$$= 16\,m/s - (0.01s) \cdot \frac{0.01Ns^2/m^2}{0.25kg} (16\,m/s)^2$$

$$= 16\,m/s - 0.10\,m/s \;\boxed{= 15.90\,m/s}$$

Question 10: Mr. Zucchini (mass 5kg) goes bungee jumping from the UBC clock tower. If the net upward force from the bungee cord plus gravity is shown in the graph below, how far does Mr. Zucchini fall before bouncing back up? **(6 points)**





The anthropomorphized vegetable stops its downward descent when the net area under the acceleration vs time graph from 0 to t_{STOP} is zero, since

$$v_f = v_i + \left(\text{area under acceleration vs time graph from } t_i \text{ to } t_f\right)$$

To get acceleration vs time, we divide the F_{NET} vs time above by mass, so we see that the velocity will again be zero at $t = 4s$.

From $t=0$ to $t=4s$, we have

straight line w. slope 25N/s and intercept -50N.

$$F_{NET} = -50N + (25N/s)\cdot t$$

By Newton's 2nd Law

$$\Rightarrow ma = -50N + (25N/s)\cdot t$$

$$\Rightarrow a(t) = -10m/s^2 + 5m/s^3 \cdot t$$

see over

Since $a = \frac{dv}{dt}$, we must have

$$v(t) = -(10 m/s^2)\cdot t + (2.5 m/s^3)\cdot t^2 + C$$

But $C = 0$ since $v(0) = 0$. Thus

$$\frac{dx}{dt} = -(10 m/s)\cdot t + (2.5 m/s^3)\cdot t^2$$

so $x(t) = -(5 m/s)t^2 + (0.833 m/s^3)t^3 + C$

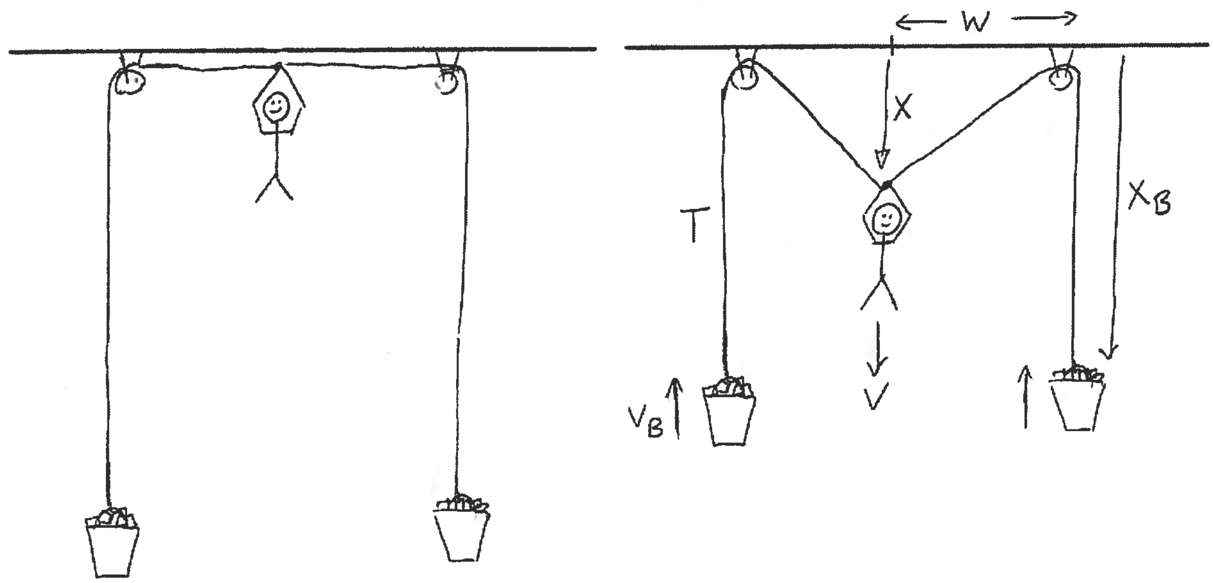
Again $C = 0$ if we define $x = 0$ to be the top of the clock tower.

The distance Mr. Zucchini falls is then

$$|x(4s)| = |-5 m/s (4s)^2 + (0.833 m/s)(4s)^3|$$

$$= |-80 m + 53.3 m|$$

$$\boxed{= 26.7 m}$$



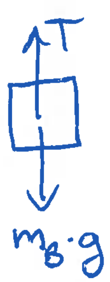
Question 11: Mark decides to (theoretically) accept the Ice Bucket Challenge. He sets up two buckets of ice connected to himself via ropes and pulleys. As he falls, the buckets rise up to the pulleys and then spill the ice water on him (see next page). Mark would like to figure out how long it will take before the water spills on him. Determine a set of equations that could be solved to determine the positions x(t) and $x_B(t)$, the speeds v(t) and $v_B(t)$, and the rope tension T(t) as functions of time. Your equations may also include the constants M (the mass of Mark), m_B (the bucket mass), L (the rope length), w (the horizontal distance shown in the picture), and g. Do not try to solve your equations. **(4 points)**

We have first that

$$\boxed{\frac{dx}{dt} = v} \quad \text{and} \quad \boxed{\frac{dx_B}{dt} = -v_B}$$

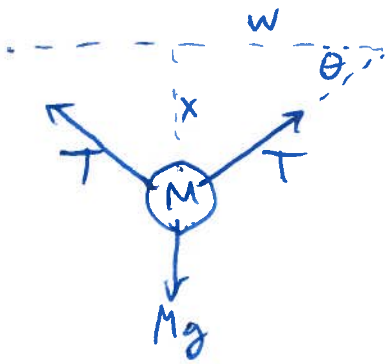
by the definition of velocity.

Newton's 2nd Law applied to the bucket gives



$$\boxed{m_B \frac{dv_B}{dt} = T - m_B \cdot g}$$

Newton's 2nd Law applied to ~~the~~ Mark gives



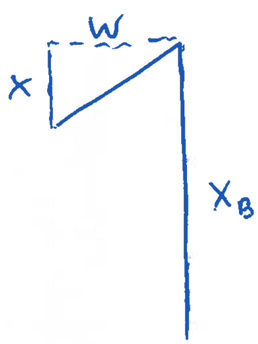
$$M \frac{dv}{dt} = Mg - 2T \cdot \sin\theta$$

Here, $\sin\theta = \frac{x}{\sqrt{w^2+x^2}}$ so:

$$\boxed{\frac{dv}{dt} = g - \frac{2}{M} \cdot T \cdot \frac{x}{\sqrt{w^2+x^2}}}$$

Finally we have a relation between x and x_B; since the total rope length is fixed. This gives

$$\boxed{\sqrt{x^2+w^2} + x_B = L}$$



We now have a system of 5 differential equations for 5 unknown functions, which can in principle be solved.