2013 District Physics Benchmark Review solutions

1. It takes 3 seconds using a power of 35 W to lift a resting 7 Kg bowling ball from the ground and place it on a shelf. Ignoring friction, what is the height to which the bowling ball was lifted?

$t = 3\,s$

$P = 35\,W$

$m = 7\,kg$

$g = 9.8\,m/s^2$

$h = ?\,m$

$P = \frac{W}{t}$ $\quad W = Fd$ OR $GPE = mgh$

$35 = \frac{W}{3} \rightarrow W = (35)(3)$

$F = mg \rightarrow F = (7)(9.8)$

$W = Fd \rightarrow (35)(3) = (7)(9.8)d$

$$d = \frac{(35)(3)}{(7)(9.8)} \quad \frac{N\,m}{(kg\,m/s^2)} = 1.531\,m$$

$$\boxed{h = 1.531\,m}$$

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2. The brakes of a bus lock when it skids to a stop at a stoplight. If the bus was going 3 times as fast how many times farther does the work-energy theorem predict the bus will skid?

____________________ times as far.

mass = m

$g = 9.8\ m/s^2$

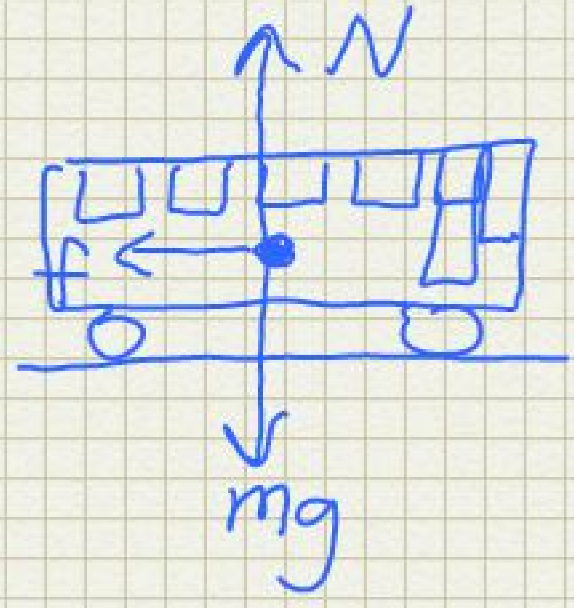
initial velocity 1 = v_i

initial velocity 2 = $3v_i$

final velocity = 0

skid distance 1 = d_1

skid distance 2 = d_2 = ?



F_{net} = force of friction, f

Net work = work done by friction, $W_f = fd$.

$W = Fd$, $W_{net} = \Delta KE$, $KE = \frac{1}{2}mv^2$.

$fd_1 = 0 - \frac{1}{2}mv_1^2 = -\frac{1}{2}mv_1^2 \therefore d_1 = \left(\frac{1}{f}\right)\left(-\frac{1}{2}mv_1^2\right)$

Skid 2, same brakes, same tires, same road, same friction = f.

$W_{net} = fd_2 = \Delta KE = 0 - \frac{1}{2}m(3v_1)^2 = -\frac{1}{2}mv_1^2(3^2)$

$fd_2 = 9\left(-\frac{1}{2}mv_1^2\right)$

$\therefore d_2 = 9\left(\frac{1}{f}\right)\left(-\frac{1}{2}mv_1^2\right) = 9d_1$.

$\boxed{d_2 = 9d_1}$

3. A man running on a straight path at 3.00 meters per second accelerates uniformly to a speed of 5.23 meters per second in 9.65 seconds. The total distance traveled by the man during this time is

$v_i = 3.00\ m/s$

$v_f = 5.23\ m/s$

$t = 9.65\ s$

$d = ?\ m$

$$a = \frac{v_f - v_i}{t}, \quad d = v_i \cdot t + \frac{1}{2} a t^2$$

$$a = \frac{(5.23 - 3.00)}{9.65} = 0.2311\ m/s^2$$

$$d = (3.00)(9.65) + \frac{1}{2}(0.2311)(9.65)^2$$

$$\boxed{d = 39.7\ m}$$

4. A juggler tosses a flaming torch straight up with a force of 30.0 Newtons. The torch reaches a maximum height of 5.0 meters in 3 seconds and returns back to his hand. What is the magnitude of the acceleration of the torch while moving upward? Use the conventional up/right = positive, down/left = negative frame of reference.

$t = 3\,s$

$g = 9.8\,m/s^2$ down.

Free Body Diagram of torch in free fall:

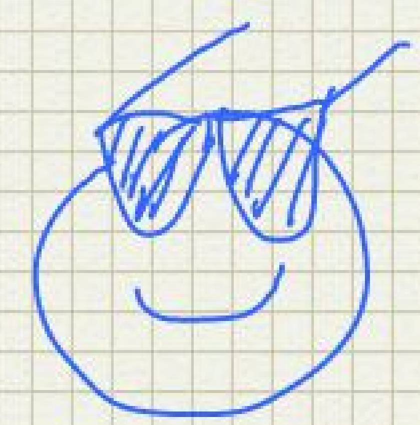
F_{net} in free fall = weight, mg.

$F_{net} = ma$

$mg = ma$

$\frac{mg}{m} = \frac{ma}{m}$

$g = a$



$\boxed{a = 9.8\,m/s^2 \text{ down, or } -9.8\,m/s^2}$

5. What is the net force acting on the box in the diagram to the right?

What diagram on the right?
This question doesn't make any sense!

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6. A 150 kg motorcycle falls off a bridge and drops straight down into the water. The motorcycle is moving at 12.5 m/s when it hits the water. If the motorcycle comes to rest 7.00 m beneath the surface, determine the average force exerted by the water.

$m = 150\ kg$

$v_i = 12.5\ m/s$

$v_f = 0\ m/s$

$d = 7.00\ m$ down

$g = 9.8\ m/s$ down

$W_{net} = \Delta KE$,

$W = Fd$,

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

$W_{net} = 0 - \frac{1}{2}mv_i^2 = \left(-\frac{1}{2}\right)(150)(12.5)^2$

$W_{net} = (-11,718.75)$ joules

$W_{net} = F_{net}\,d$ $\quad F_{net} = \frac{W_{net}}{d} = \frac{11718.75}{7} = 1674\ N$ up.

$F_{net} = F_{water} - weight$
(up) (down)

$\rightarrow F_{water} = F_{net} + weight$

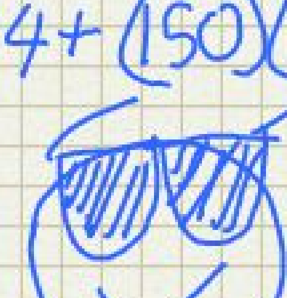
$F_{water} = 1674 + (150)(9.8) = 3144$ newtons up.

OR $\quad a = \frac{v_f^2 - v_0^2}{2d} = \frac{0-(12.5)^2}{2(-7)} = 11.161\ m/s^2$ up.

$\Sigma F = ma \qquad \Sigma F = (150)a = 1674\ N$

$\Sigma F = F_{water} - mg = 1674, \quad F_{water} = 1674 + (150)(9.8)$

$F_{water} = 3144$ newtons up.



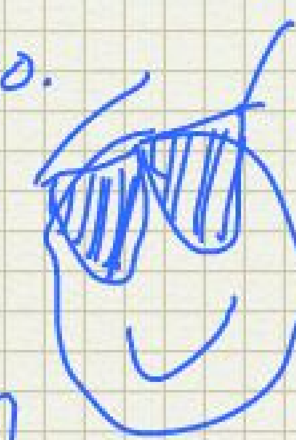
Object is moving with constant velocity, v.

$a = \frac{v - v}{t} = \frac{0}{t} = 0$, acceleration is zero.

$F_{net} = ma = m(0) = 0$, net force is zero.

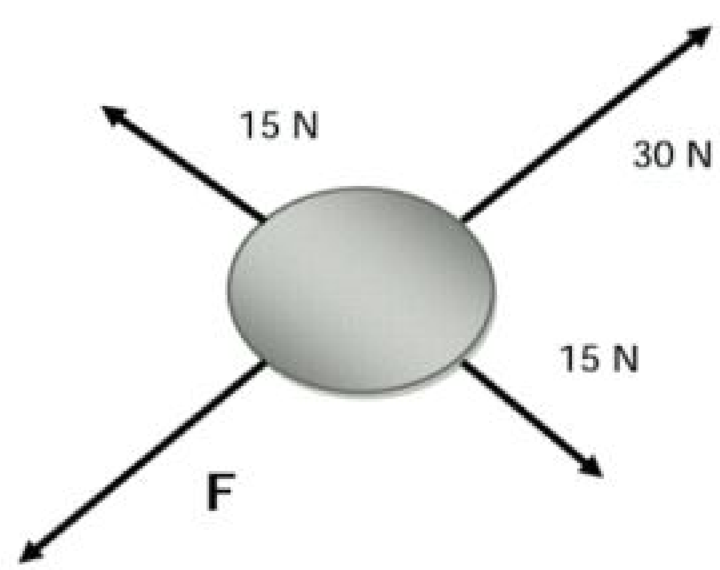
$\Sigma F_y = 15 - 15 = 0$. $\Sigma F_x = 30 - F = 0$.

$F = -30$.



The magnitude of force $F = 30$ newtons.

7. Four forces are acting on an object as shown in the diagram below. If the object is moving with a constant velocity, the magnitude of force ***F*** must be –



8. A 136.0 kg wagon is rolling down a hill. Halfway down the hill the wagon has a velocity of 12.00 m/s and a height of 4.000 meters. What is the mechanical energy of the wagon? (Ignore friction)

$m = 136.0\,kg$

$h = 4.000\,m$

$v = 12.00\,m/s$

MechE = ? joules

$g = 9.8\,m/s^2$

$GPE = mgh$

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

MechE = GPE + KE

$GPE = (136)(9.8)(4)$

$KE = \frac{1}{2}(136)(12.00)^2$

MechE = 15,123 joules.

9. A parent exerts a 35.0 N push on a child on a swing for 0.50 meters. How much work did the parent do on the child?

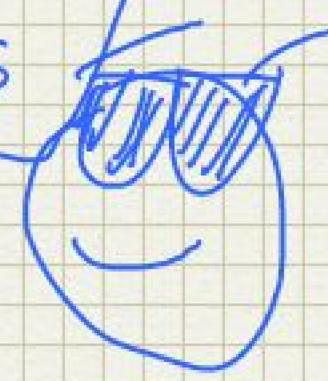
$F_{app} = 35.0\ N$

$d = 0.50\ m$

$W = Fd$

$W = (35.0)(0.50)$

$W = 17.5\ Nm = 17.5\ joules$



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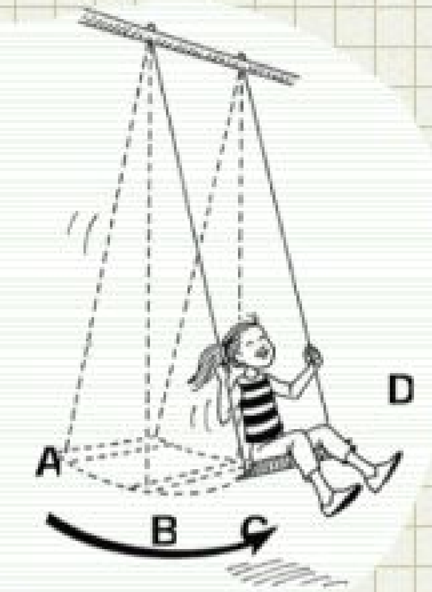
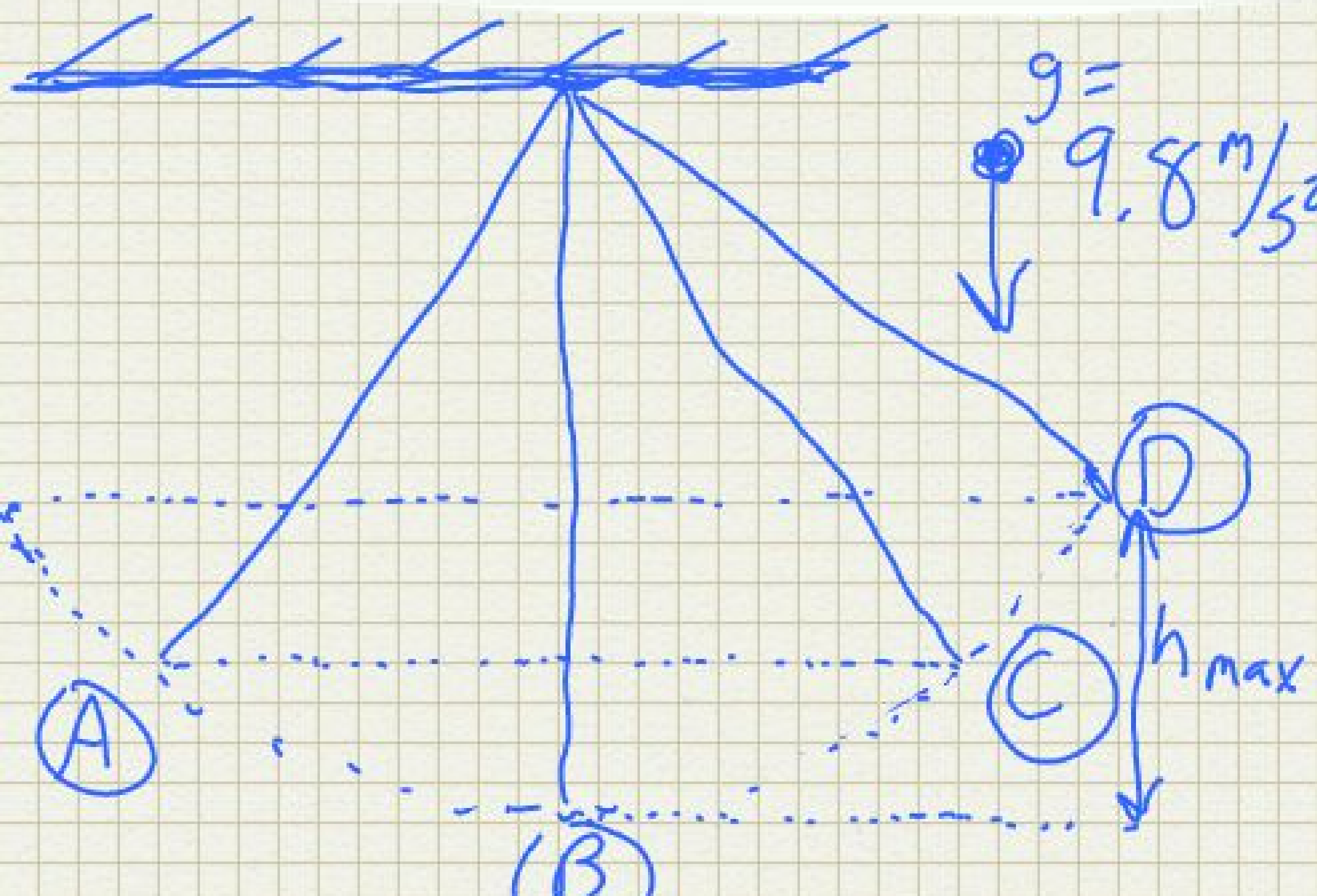
(Another problem) At what point in the child's swing would the child have :

a: the greatest potential energy
b: the greatest kinetic energy
c: equal potential and kinetic energy





$GPE = mgh$

$KE = \frac{1}{2} m v^2$

$Mech E = GPE + KE$

Max height at (D), so max GPE at (D).

Lowest height at (B), so max KE at (B).

At (A) and (C), height $= \frac{1}{2} h_{max}$, $GPE = \frac{1}{2} GPE_{max}$.

$Mech\ E = GPE + KE = constant$, $GPE_{max} = KE_{max}$

$\frac{1}{2} GPE_{max} + \frac{1}{2} KE_{max} = constant$.

So at (A) and (C), GPE = KE.

10. The swing is 1.50 meters higher at the highest point of its swing (point D) than it is at the lowest point of its swing (point B). If you ignore friction, what is the velocity of the 27.0 Kg child at point B?

$h_{max} = 1.50\,m$

$m = 27.0\,kg$

$g = 9.8\,m/s^2$

$v_{max} = ?$

$GPE_{max} = KE_{max}$

$GPE = mgh, \; KE = \frac{1}{2}mv^2$

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

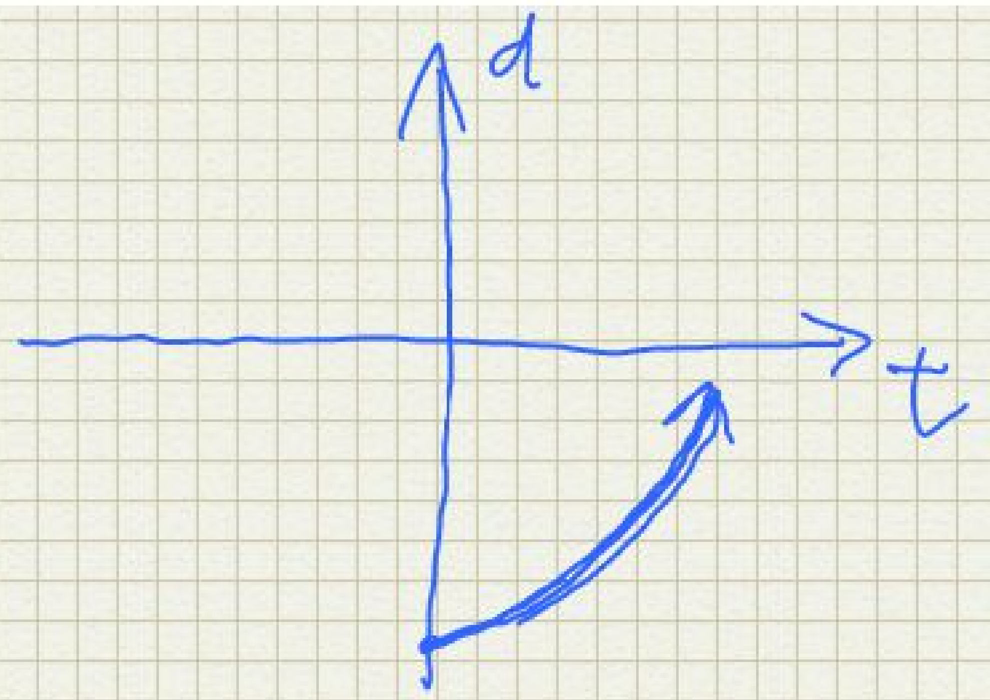
$(27)(9.8)(1.50) = (\frac{1}{2})(27)(v_{max})^2$

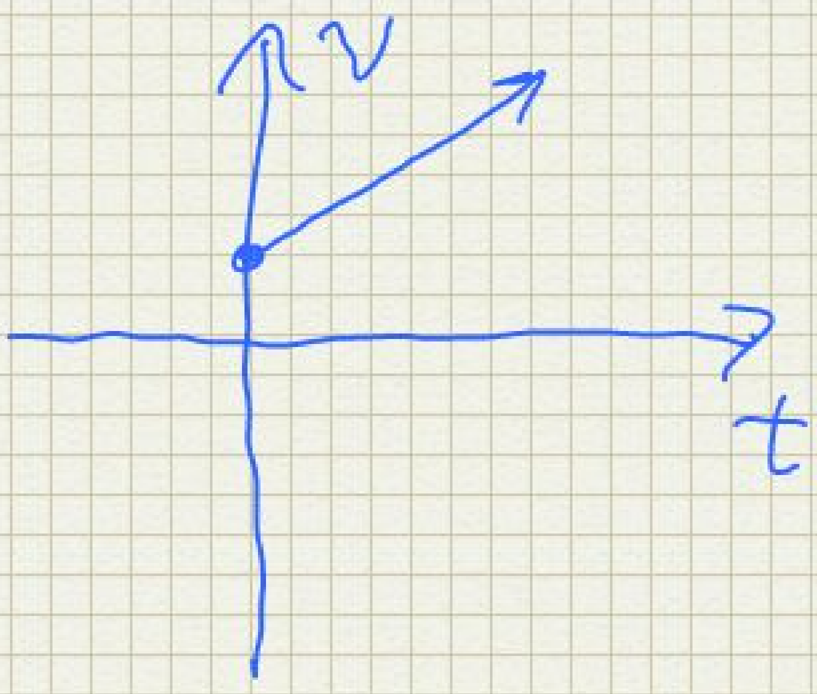
$\frac{(2)(27)(9.8)(1.50)}{27} = v_{max}^2$

$$\boxed{v_{max} = \sqrt{(2)(9.8)(1.50)} = 5.42\ m/s}$$

11. Draw the distance vs. time graphs for the following scenarios.

a. A bicyclist riding towards a reference point at an increasing speed.
b. A boat moving towards a reference point as a decreasing speed.
c. A jogger running away from a reference point at an increasing speed.
d. An airplane moving away from a reference point at a decreasing speed.
e. A balloon moving toward a reference point at a constant speed.
f. A dog running away from a reference point at a constant speed.





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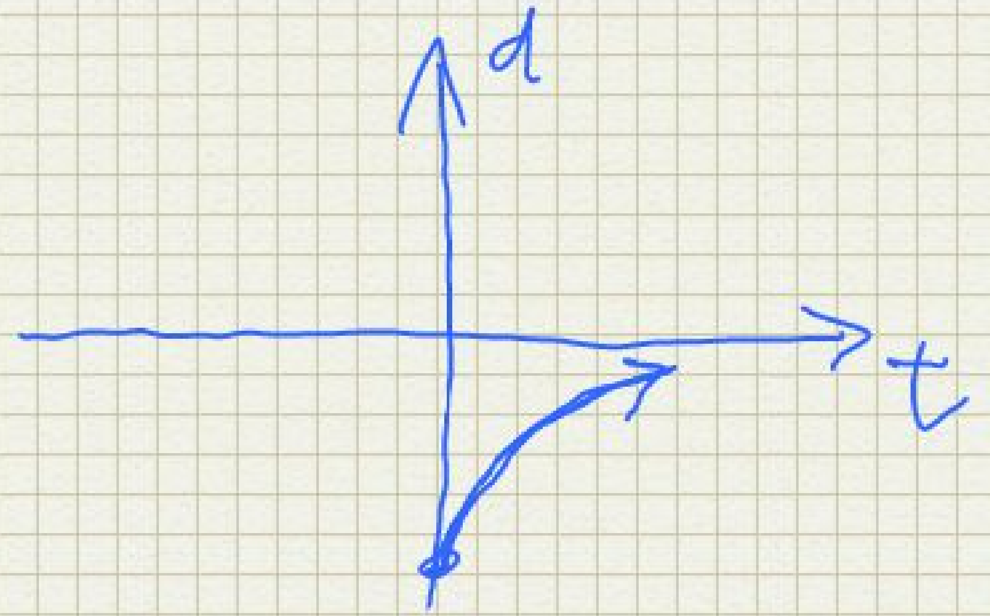

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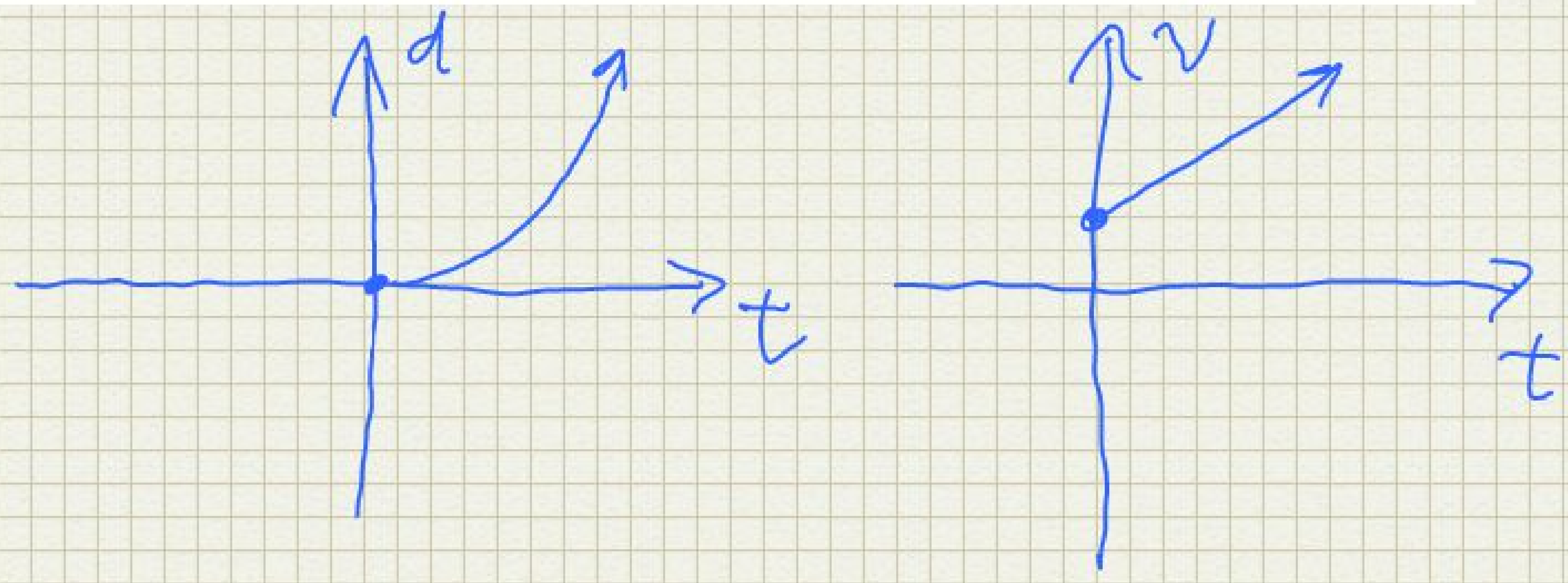

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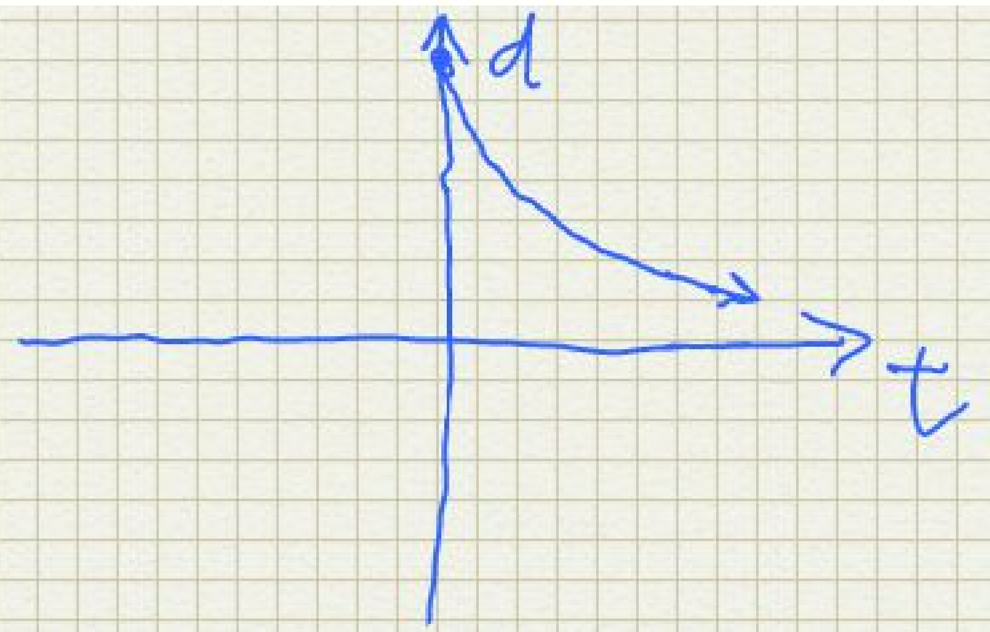

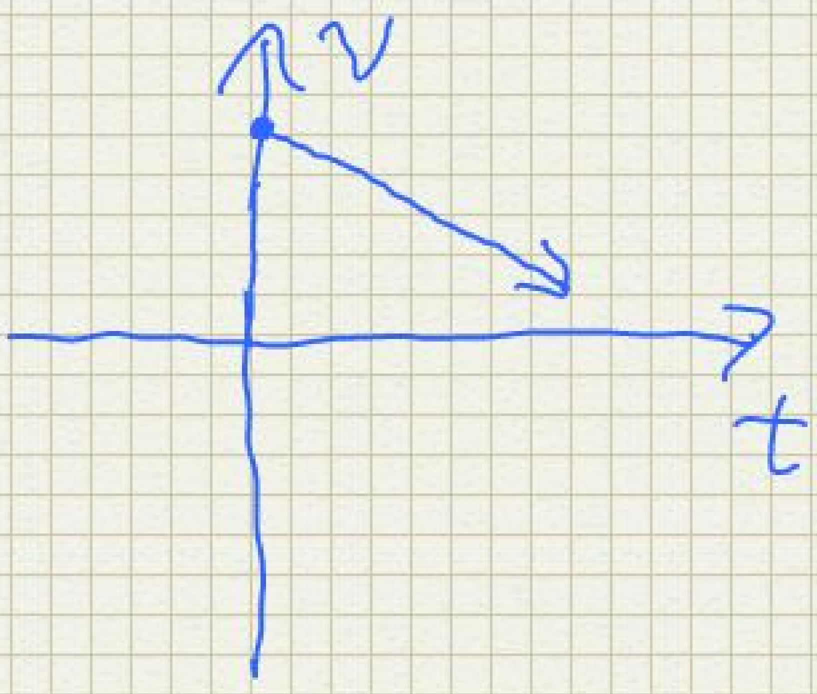

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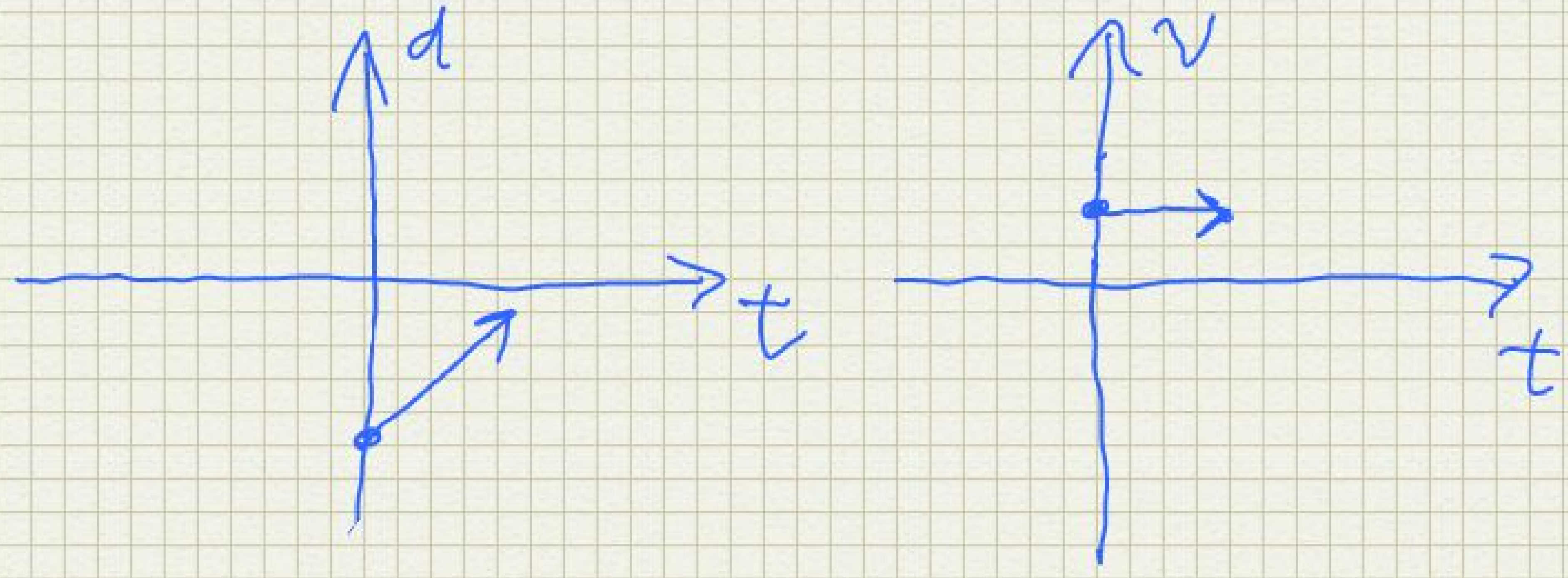

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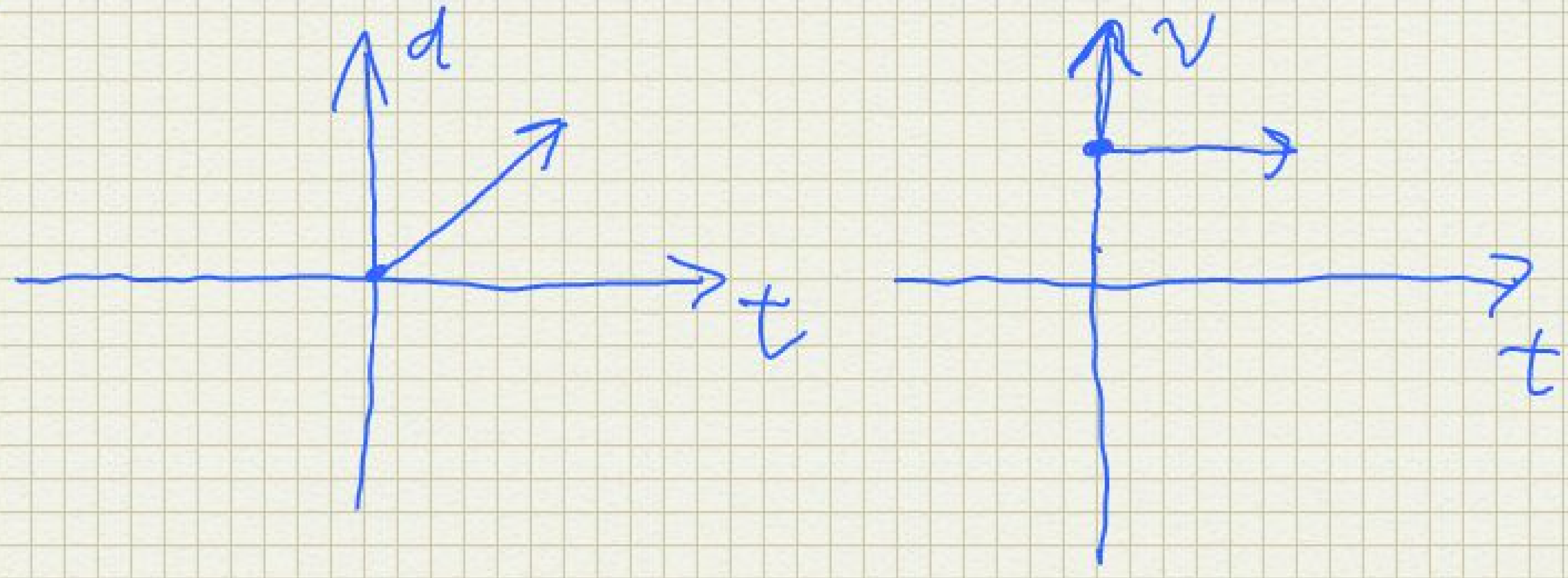


12. How would you determine the velocity of the object using its distance vs. time graph?

The slope of a distance vs. time graph equals the velocity of the object.

$$v_{avg} = \frac{\Delta d}{\Delta t}$$

13. How do velocity vs. time graphs compare to distance vs. time graphs?

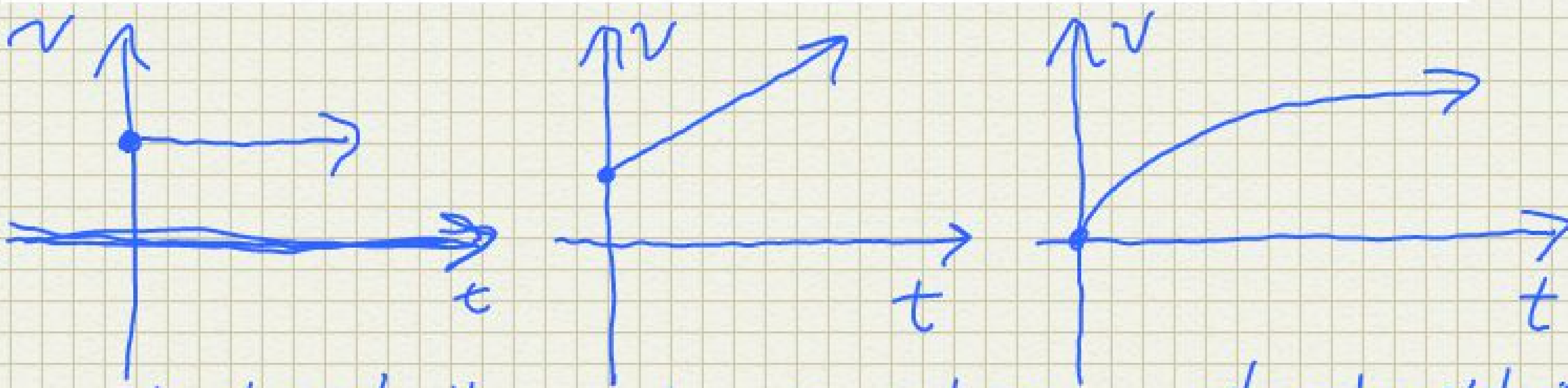
A distance vs. time graph charts the position of an object at each moment in time. The slope equals the velocity.

$\Delta d = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$, $v_{avg} = \frac{\Delta d}{\Delta t}$.

A velocity vs. time graph charts the velocity of an object at each moment in time. The slope equals the acceleration.

$$a = \frac{v_f - v_i}{\Delta t}$$

14. How do velocity vs. time graphs of zero, constant, and changing acceleration compare?



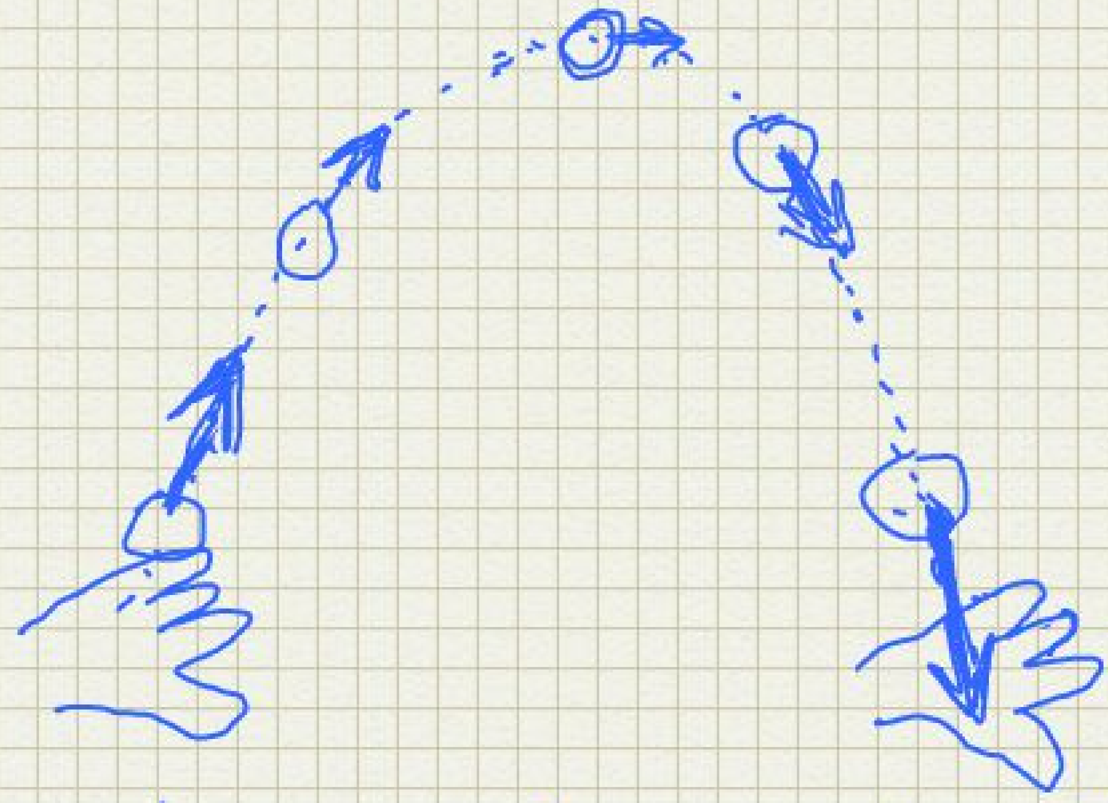
constant velocity, slope is zero, acceleration zero.

changing velocity, slope is constant, acceleration is constant.

changing velocity, slope is changing, acceleration is changing.

15. A child sits in the back of a car that is traveling forward. He throws a ball straight up in the air and watches it come straight back down into his hand. As he does this, the car passes another child sitting in a car at a stop. What would the path of the ball look like to the child sitting in the car at rest?

As seen from moving car frame of reference, the ball goes straight up and straight down.

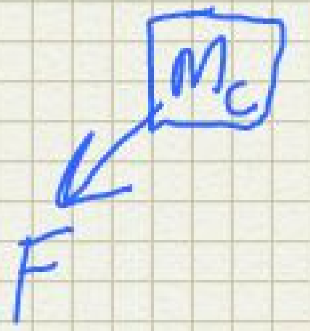


As seen from stopped car frame of reference, the ball moves in a parabola.

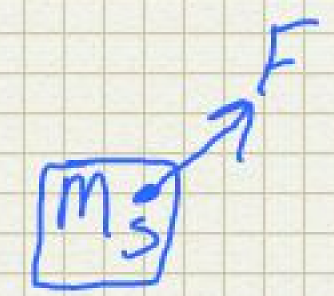
16. A swimmer jumps out of a canoe that has half the mass of the swimmer. The swimmer applies a force on the canoe down and to the side. The force the boat exerts back on the swimmer is equal and opposite to the force the swimmer applies to the boat. What is the relative acceleration of the swimmer and the canoe?

$$m_c = \frac{1}{2} m_s$$

Action:



Reaction:



$$\Sigma F_c = m_c a_c \qquad \Sigma F_s = m_s a_s$$

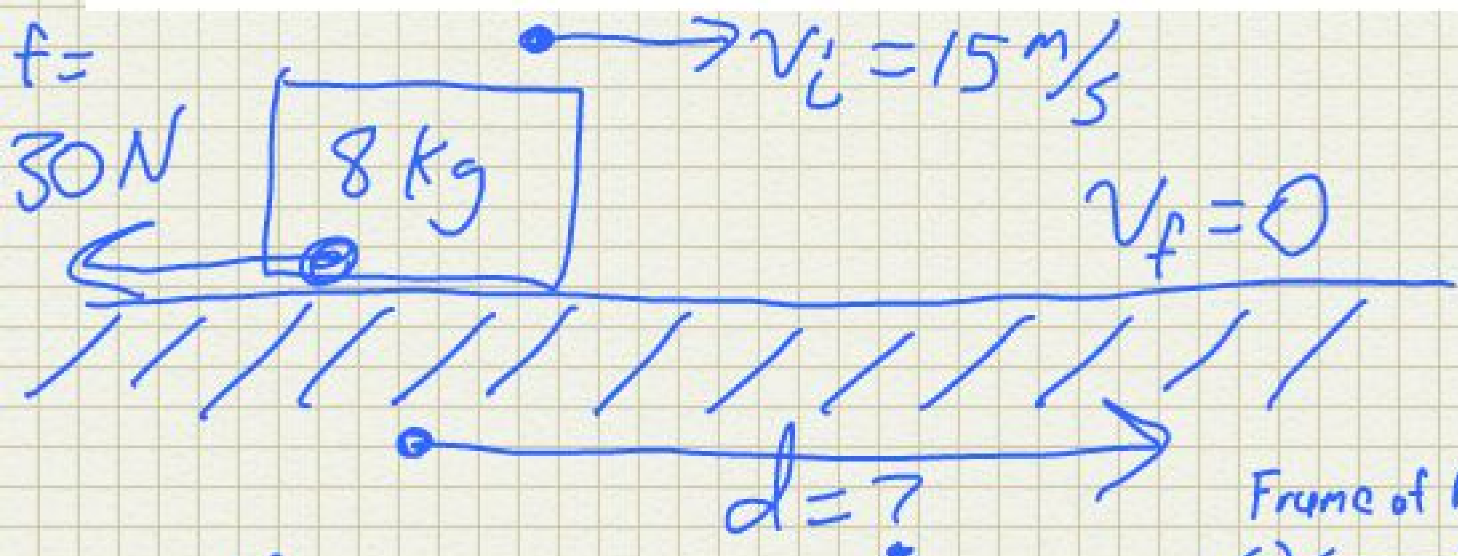
$$\Sigma F_c = F \qquad \Sigma F_s = F$$

$$a_c = \frac{F}{m_c} = \frac{F}{\left(\frac{1}{2} m_s\right)} = \frac{2F}{m_s} \qquad a_s = \frac{F}{m_s}$$

$$\frac{a_c}{a_s} = \frac{\left(\frac{2F}{m_s}\right)}{\left(\frac{F}{m_s}\right)} = \left(\frac{2F}{m_s}\right)\left(\frac{m_s}{F}\right) = 2$$

The acceleration of the canoe is twice the acceleration of the swimmer.

17. An 8 Kg mass slides across a rough surface and is brought to rest from an initial speed of 15 m/s by 30.0 N of friction. What distance did the mass slide?

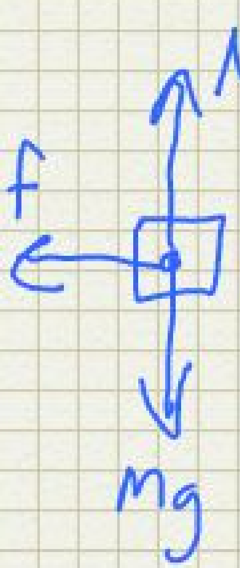


$W_{net} = \Delta KE$

$W = Fd$

$KE = \frac{1}{2} m v^2$

Frame of Reference
(-) ←→ +



Normal force and weight cancel, so net work is the work done by friction, $W_{net} = fd$.

$$\Delta KE = \left(\frac{1}{2}\right)(8)(0)^2 - \left(\frac{1}{2}\right)(8)(15)^2 = -900 \text{ joules}$$

$$900 = fd = (30)d \qquad d = \frac{900 \text{ Nm}}{30 \text{ N}} = 30 \text{ m}$$

d = 30 meters

(Direction of friction is opposite the displacement, so friction did <u>negative</u> work.)

<u>OR</u> $\Sigma F = ma$, $\Sigma F = f$, $a = \frac{f}{m}$. $a = \frac{v_f^2 - v_i^2}{2d}$, $d = \frac{v_f^2 - v_i^2}{2a}$

$$d = \frac{-(15)^2}{(2)(-30/8)} = 30 \text{ m}$$

18. A student tosses a 2 kg ball into the air 4 meters above his hand. Ignoring air friction, what will be the magnitude of the velocity of the ball when it returns to his hand?

$m_b = 2\ kg$

$h = 4\ m$

$g = 9.8\ m/s^2$

$GPE_{max} = KE_{max}$

$GPE = mgh, \quad KE = \frac{1}{2}mv^2$

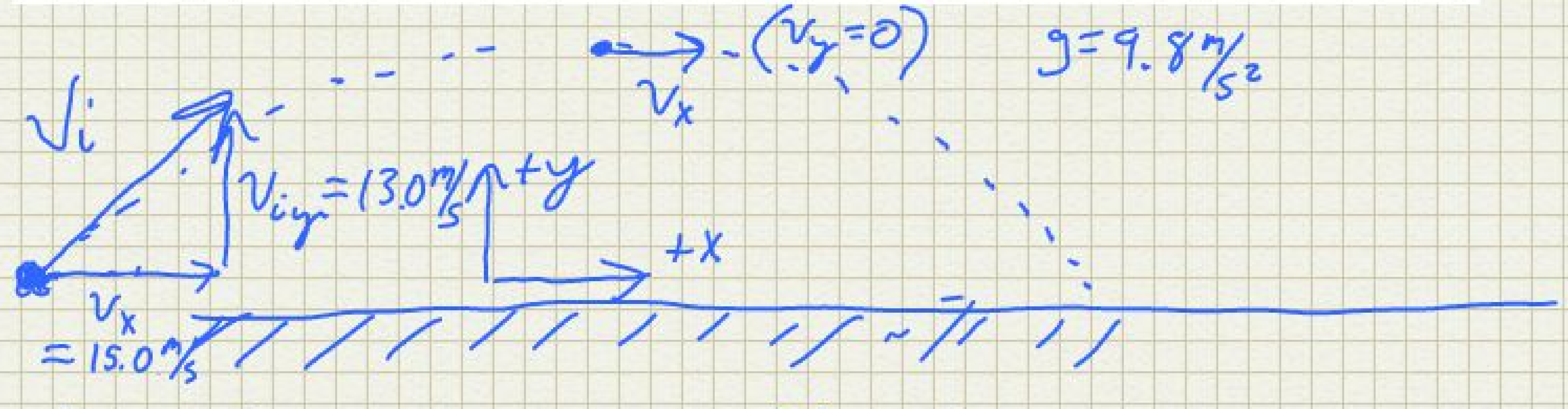
$mgh = \frac{1}{2}mv^2$

$(2)(9.8)(4) = \frac{1}{2}(2)v^2$

$\sqrt{(2)(9.8)(4)} = v = 8.85\ m/s$

Check: $\sqrt{\left(\frac{m}{s^2}\right)m} = m/s$

19. A boulder is launched from the ground by a catapult with a vertical velocity of 13.0 m/s and a horizontal velocity of 15.0 m/s. It misses the enemy castle and hits the ground. How long did it take the boulder to hit enemy ground? (ignore air friction)



$$\Delta t_{up} = \frac{1}{2}\Delta t_{total} \qquad a = \frac{v_f - v_i}{\Delta t}, \quad g = \frac{0 - 13\ m/s}{\Delta t_{up}}$$

$$\Delta t_{up} = \frac{-13\ m/s}{-9.8\ m/s^2} = 1.327 \text{ seconds}$$

$$\boxed{\Delta t_{total} = 2(\Delta t_{up}) = 2.65\ s}$$

units check: $\left(\frac{m}{s}\right)\left(\frac{s^2}{m}\right) = \text{seconds}$

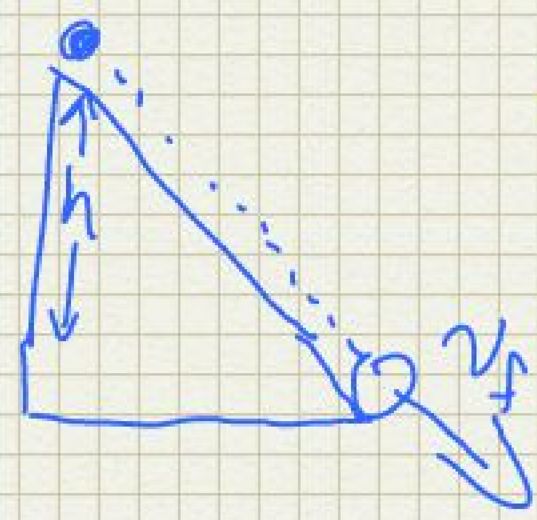
20. A 30 kg child and sled slides down a 9.0 meter high hill. It is going a speed 12 m/s at the bottom of the hill. How much mechanical energy was transformed into thermal energy?

$m = 30\,kg$

$h = 9.0\,m$

$g = 9.8\,m/s^2$

$v_f = 12\,m/s$



$GPE = mgh$

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

$Mech\,E = GPE + KE$

$Mech\,E_i - Mech\,E_f =$ Energy lost to Heat

$Mech\,E_f = 0 + \frac{1}{2}mv_f^2$

$Mech\,E_i = mgh + 0$

$E_{Heat} = mgh - \frac{1}{2}mv^2 = (30)(9.8)(9.0) - \frac{1}{2}(30)(12)^2$

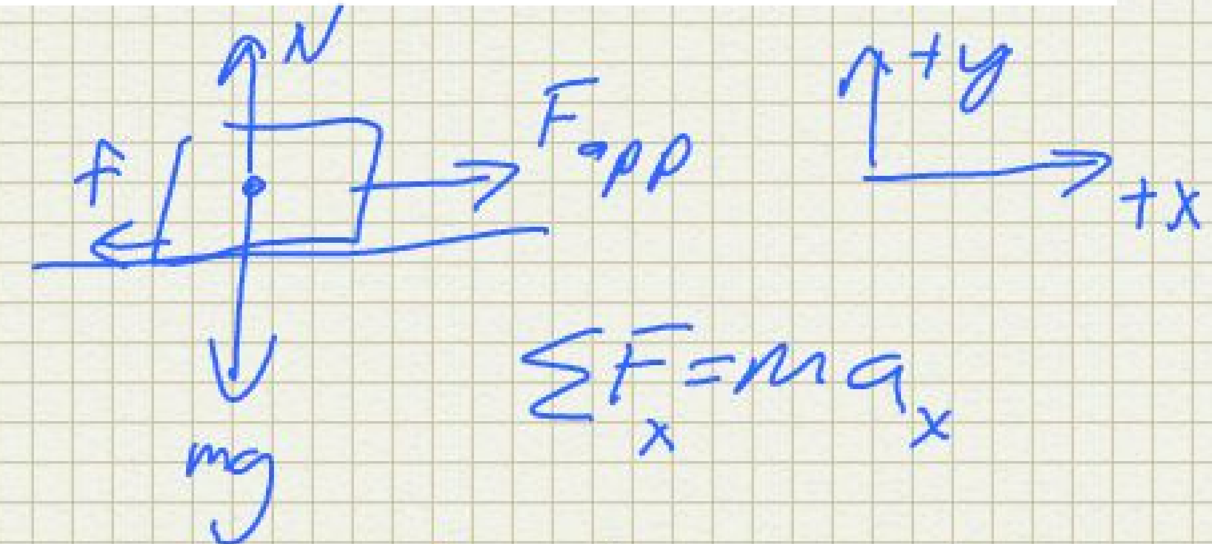
$E_{Heat} = 486$ joules

21. A 0.25 Kg hockey puck is hit with a force of 7.00 N. The force of friction acting on the puck when it is hit is 0.30 N. What is the magnitude of the acceleration of the hockey puck?

$m = 0.25\ kg$

$F_{app} = 7.00\ N$

$f = 0.30\ N$



$\sum F_x = m a_x$

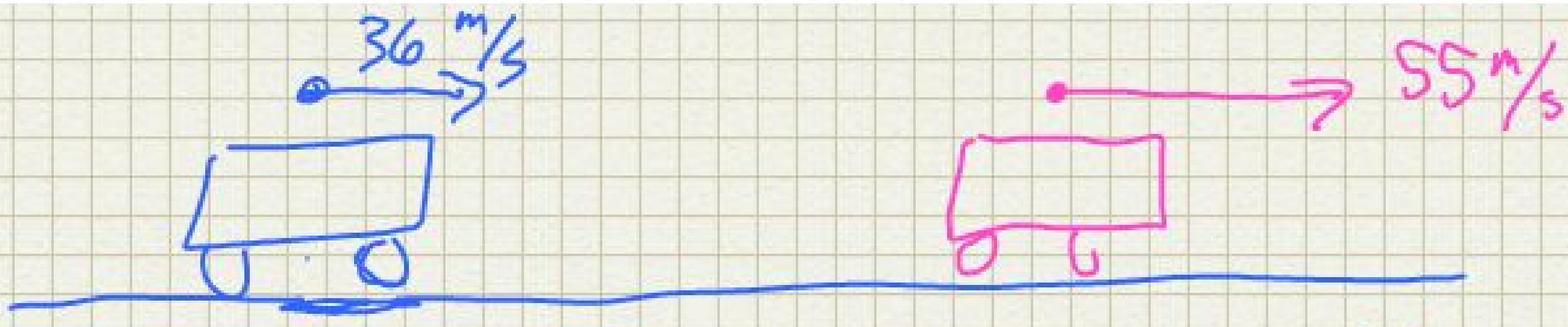
$\sum F_x = +F_{app} - f$

$a_x = \left(\frac{1}{m}\right)\left(F_{app} - f\right) = \frac{1}{(0.25)}\left(7.00 - 0.30\right)$

$a_x = 26.8\ m/s^2$

units check: $\frac{N}{kg} = \left(\frac{kg\ m}{s^2}\right)\left(\frac{1}{kg}\right) = \frac{m}{s^2}$

22. A pink race car passes a blue race car on the track. The blue race car is traveling at a velocity of 36 m/s the pink race race car is traveling at a velocity of 55 m/s. How fast does the pink race car appear to be traveling to the driver of the blue race car?



$V_B = 36\ m/s$ relative to ground

$V_P = 55\ m/s$ relative to ground

$$V_{P \text{ to ground}} = V_{P \text{ to } B} + V_{B \text{ to ground}}$$

so

$$V_{P \text{ to } B} = V_{P \text{ to ground}} - V_{B \text{ to ground}}$$

$$\boxed{V_{P \text{ to ground}} = 55 - 36 = 19\ m/s}$$

23. Describe the changes in kinetic and potential energy of an object attached to a spring as the spring is compressed and released.

If the object is launched vertically into the air how does the kinetic and potential energy of the object change as it travels upward?

Work is done on a spring as it is compressed. That work is stored as elastic potential energy. When the spring is released, the spring stats to move, and the elastic potential energy changes over time to kinetic energy. If the spring is put on a table and launched upward, the spring slows down as it rises as the kinetic energy becomes gravitational potential energy.

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24. The 1200 Kg open cage of a tower drop amusement park ride is shown in the picture to the right. The cage has a potential energy of 705,600 J when it is at the top of the drop. Ignoring friction, at what height during the cage drop would the cage have a velocity of 13 m/s?

$M = 1200 \text{ kg}$ $GPE = mgh$

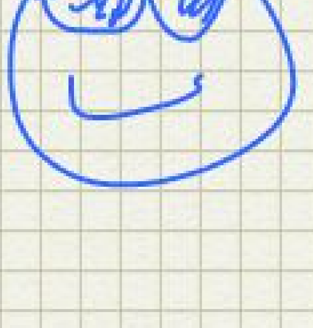
$GPE_i = 705600 \text{ J}$ $KE = \frac{1}{2}mv^2$

$v_f = 13 \text{ m/s}$ $GPE_i + KE_i = GPE_f + KE_f$

$v_i = 0 \text{ m/s}$ $705600 + 0 = mgh_f + \frac{1}{2}mv_f^2$

$h_f = ?\text{ m}$ $h_f = \left(705600 - \left(\frac{1}{2}\right)(1200)(13)^2\right)\frac{1}{(1200)(9.8)}$

$h_f = 51.38$ meters below the top.



25. Three men push a broken down car for 50 meters. They exert a combined force of 200 Newtons on the car for 120 seconds. What is the power they deliver to the car?

$d = 50\ m$

$F_{app} = 200\ N$

$\Delta t = 120\ s$

$W = Fd$

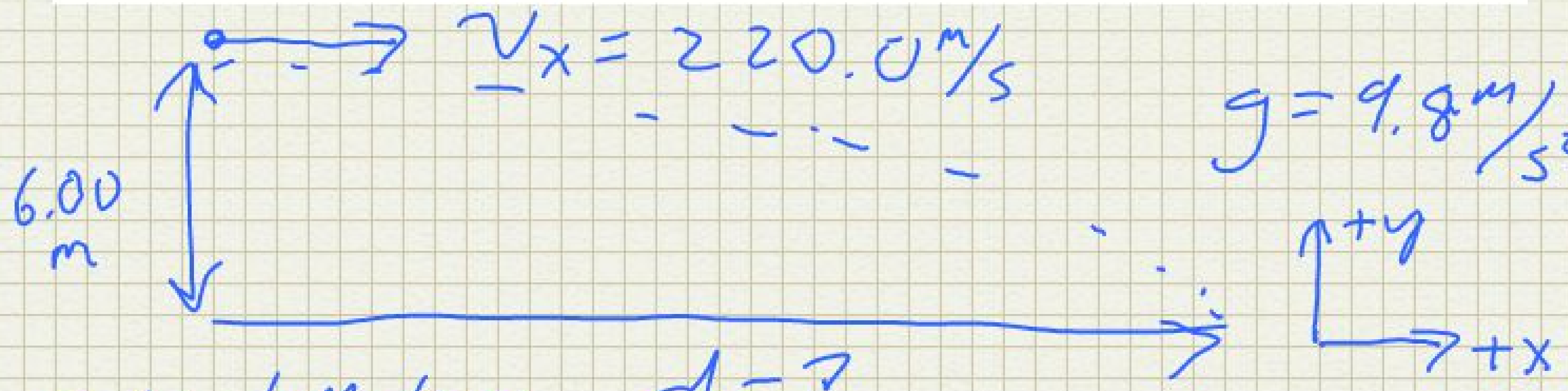
$P = \frac{W}{\Delta t}$

$$P = \frac{(200)(50)}{120} = 83.3 \text{ watts}$$

units check:

$$\frac{Nm}{s} = \frac{\text{joules}}{s} = \text{watts}$$

26. A hunter shoots a bullet horizontally from a tree stand at a height of 6.00 meters. The bullet has an initial horizontal velocity 220.0 m/s. The bullet did not hit its intended target and struck the ground. How far did the bullet travel in the horizontal direction?



Vertical Motion:

$\Delta y = \frac{1}{2} g \Delta t^2$

$\Delta t = \sqrt{\frac{2\Delta y}{g}}$

$\Delta t = 1.107\,s$

Horizontal Motion:

$v_x = \frac{d}{\Delta t}$

$d = (v_x)(\Delta t) = (220)(1.107) = 243\,m$

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Four Frisbees were launched into the air and flew until hitting the ground after 5 seconds. The data table below shows the initial horizontal velocity, initial vertical velocity, and time of flight of the Frisbees.

Motion of a Frisbee			
Frisbee	Initial Vertical velocity (m/s)	Initial Horizontal velocity (m/s)	Time of Flight (s)
Red	2.0	1.5	5.0
Blue	2.4	2.5	5.0
Green	1.5	3.0	5.0
Yellow	3.0	1.5	5.0

27. Which Frisbee traveled the greatest horizontal distance? (neglect friction)

Horizontal distance depends only on horizontal velocity and fight time,

$$V_x = \frac{d}{\Delta t} \rightarrow d = V_x \Delta t$$

Red: $(1.5\ m/s)(5\ s) = 7.5\ m$

Blue: $(2.5\ m/s)(5\ s) = 12.5\ m$

Green: $(3.0\ m/s)(5\ s) = 15\ m$

Yellow: $(1.5\ m/s)(5\ s) = 7.5\ m$

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The velocity of four airplanes is recorded at two different times in their flight. The data recorded is shown in the data table below.

Flight of Three Airplanes			
Airplane	Initial Velocity (km/hr)	Final Velocity (km/hr)	Change in Time (s)
W	600	870	2
X	500	850	4
Y	840	560	2
Z	860	490	4

28. Which airplane has the greatest magnitude of acceleration?

$$a = \frac{v_f - v_i}{\Delta t}$$

$$\frac{(870-600)}{2} = 135 \frac{(km/h)}{s}$$

$$\frac{(850-500)}{4} = 87.5 \frac{(km/h)}{s}$$

$$\frac{(560-840)}{2} = -140 \frac{(km/h)}{s}$$

$$\frac{(490-860)}{4} = -92.5 \frac{(km/h)}{s}$$

29. How much force is required to accelerate of 135 kg motorcycle at a rate of 4.0 m/s^2?

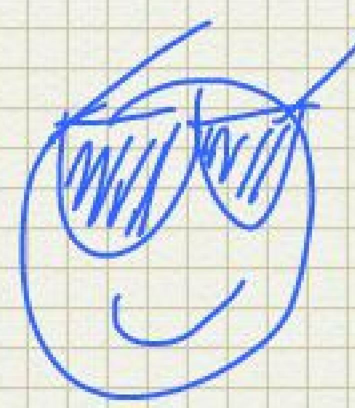
$a = 4.0\ m/s^2$

$F_{net} = ma$

$m = 135\ kg$

$F_{net} = (135)(4.0)$

$F_{net} = 540$ newtons



unit check:

newtons $= (kg)\left(\frac{m}{s^2}\right)$

30. An Olympic runner ran the 400 meter dash in 43.5 seconds. What was the runner's average speed?

$d = 400\ m$

$\Delta t = 43.5\ s$

$v_{avg} = ?\ m/s$

$$v_{avg} = \frac{d}{\Delta t}$$

$$v_{avg} = \frac{400}{43.5} = 9.20\ m/s$$

31. A spaceship traveling at 680 m/s accelerates for 10 seconds at a rate of 50 m/s^2. How far did the spaceship travel during the 10 seconds it accelerated?

$v_i = 680\ m/s$

$\Delta t = 10\ s$

$a = 50\ m/s^2$

$d = ?\ m$

$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta d = (680)(10) + \frac{1}{2}(50)(10)^2$

$\Delta d = 9300\ m$

OR $\Delta d = 9.300$ kilometers

units check

$m = \left(\frac{m}{s}\right)(s) + \left(\frac{m}{s^2}\right)(s^2)$

32. How many minutes will it take a student to walk home if they live 2000 meters from school and walk at a speed of 1.8 m/s?

$d = 2000\,m$

$V_{avg} = 1.8\,m/s$

$\Delta t = ?$

$$V_{avg} = \frac{d}{\Delta t} \qquad \Delta t(V_{avg}) = \left(\frac{d}{\Delta t}\right)\Delta t$$

$$\frac{(\Delta t)(V_{avg})}{V_{avg}} = \frac{d}{V_{avg}}$$

$$\Delta t = \frac{d}{V_{avg}} = \frac{2000\,m}{1.8\,m/s} = 1111.11\,(m)\left(\frac{s}{m}\right)$$

$$= 1111.11 \text{ seconds}$$

$$(1111.11\,s)\left(\frac{1\ min}{60\ s}\right) = 18.5185 \text{ minutes}$$

$$(0.5185\,min)\left(\frac{60\,s}{1\,min}\right) = 31.11\,s$$

$$\boxed{\Delta t = 18\ min,\ 31.11 \text{ seconds}}$$

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33. Draw and label the forces acting on a book as a student pushes it across a table.

Draw and label the forces acting on the book if the book slides off the table.