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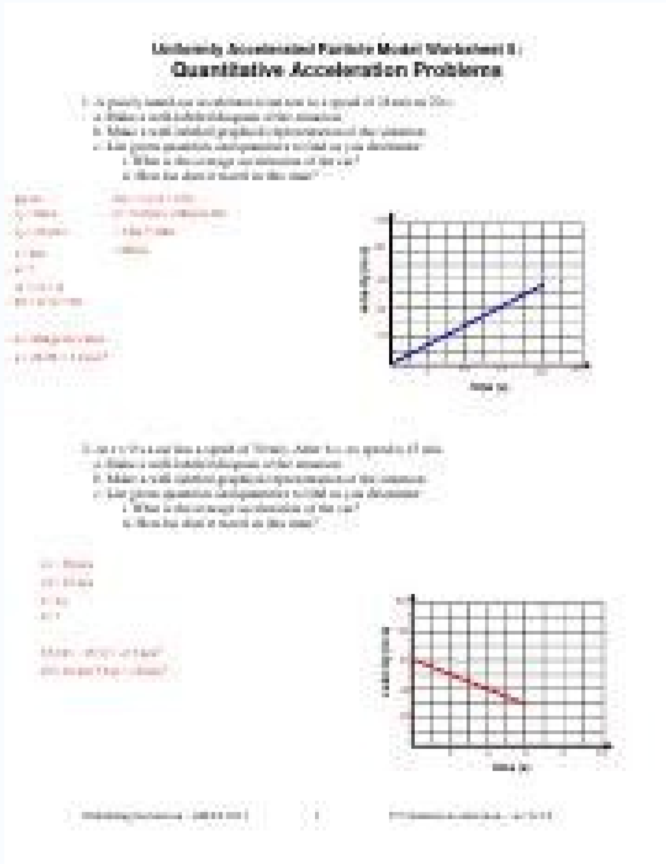
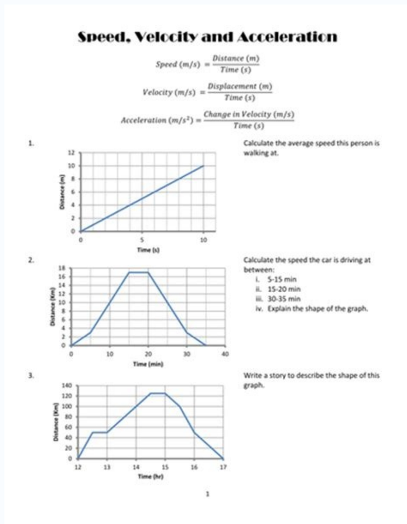
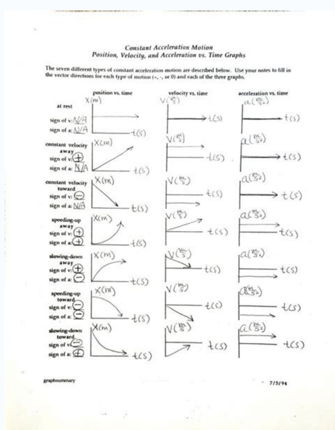
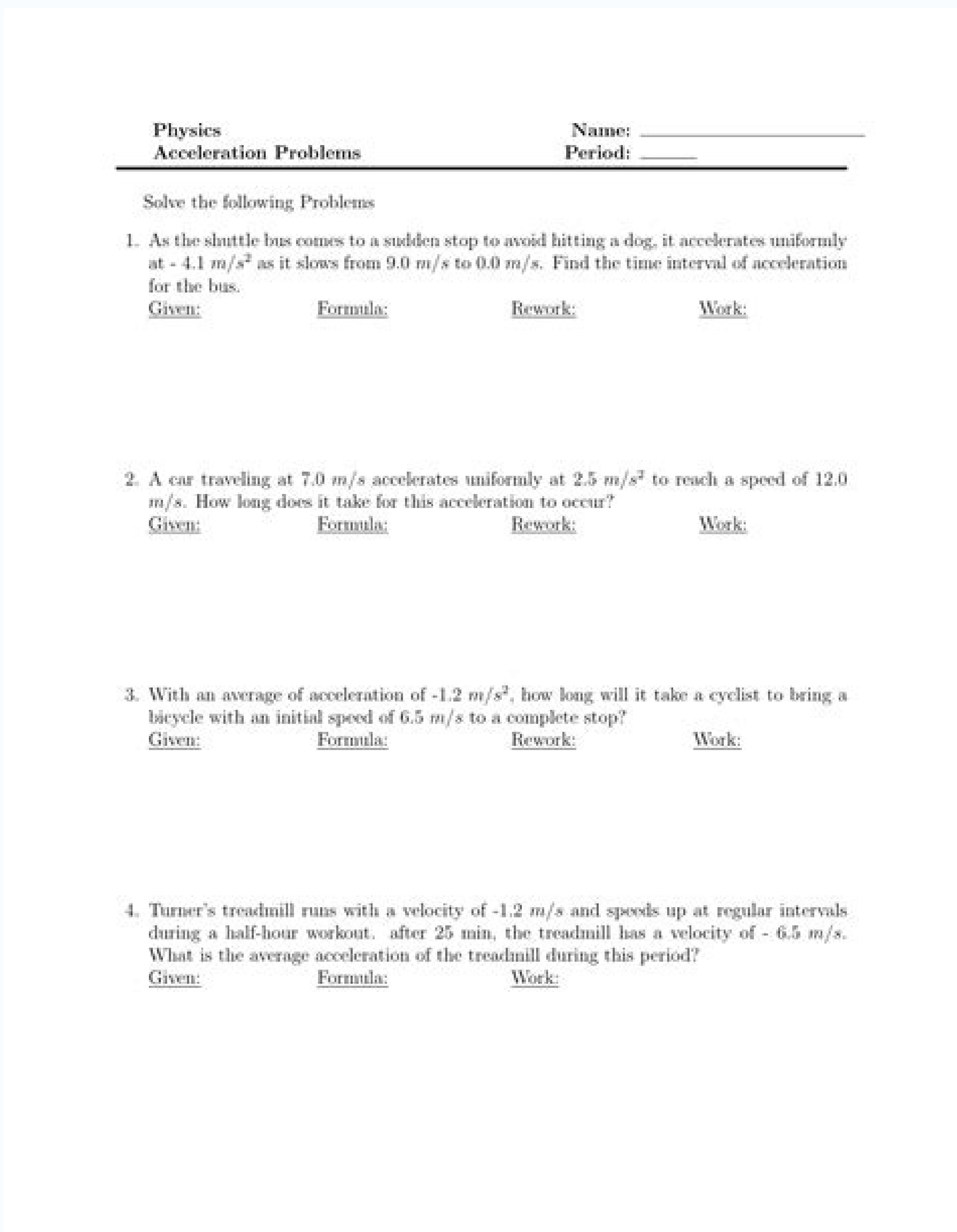








Physics | Name: ____________________
Acceleration Problems | Period: ______

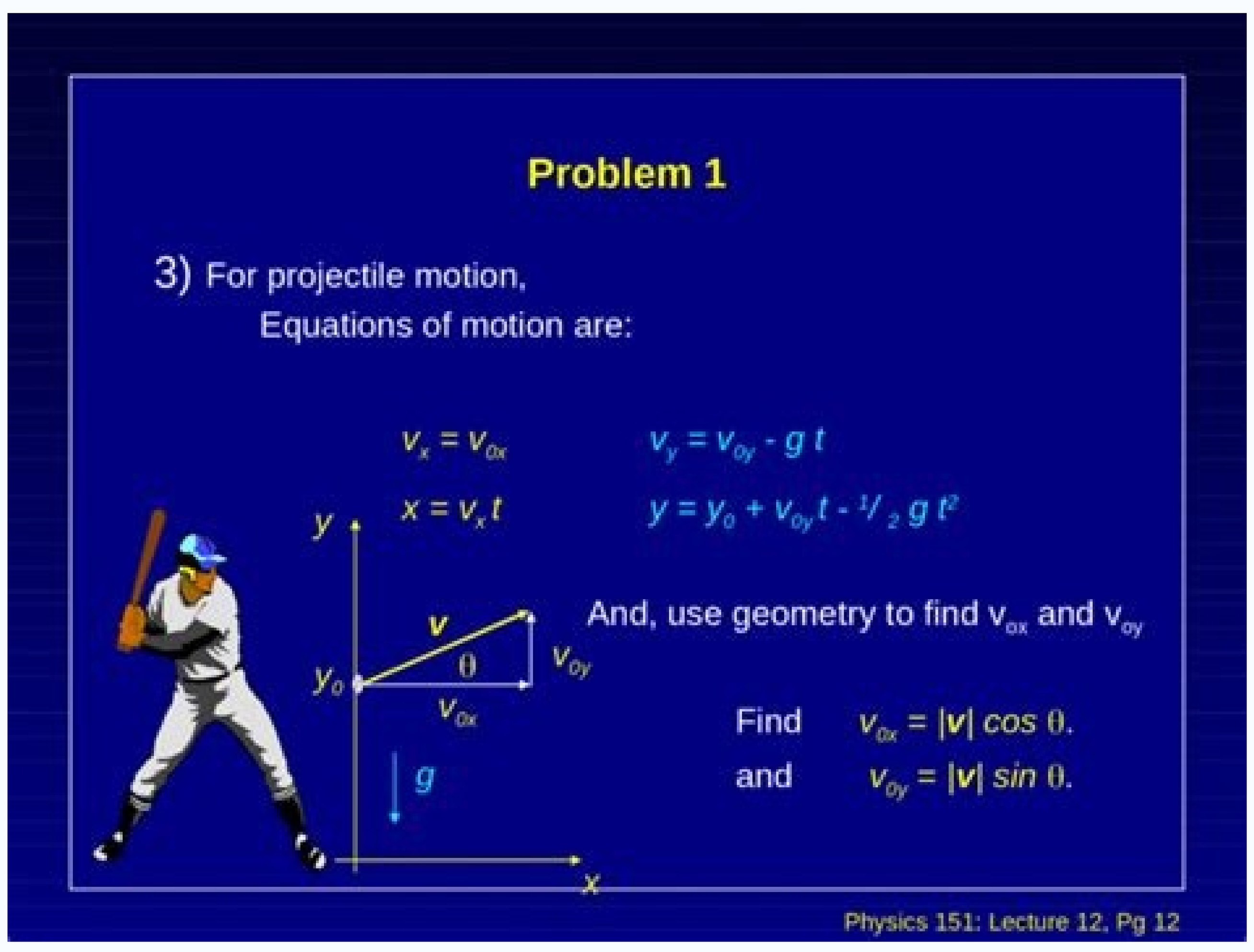
Solve the following Problems

1. As the shuttle bus comes to a sudden stop to avoid hitting a dog, it accelerates uniformly at - 4.1 m/s^2 as it slows from 9.0 m/s to 0.0 m/s. Find the time interval of acceleration for the bus.
Given: Formula: Rework: Work:

2. A car traveling at 7.0 m/s accelerates uniformly at 2.5 m/s^2 to reach a speed of 12.0 m/s. How long does it take for this acceleration to occur?
Given: Formula: Rework: Work:

3. With an average of acceleration of -1.2 m/s^2, how long will it take a cyclist to bring a bicycle with an initial speed of 6.5 m/s to a complete stop?
Given: Formula: Rework: Work:

4. Turner's treadmill runs with a velocity of -1.2 m/s and speeds up at regular intervals during a half-hour workout. after 25 min, the treadmill has a velocity of - 6.5 m/s. What is the average acceleration of the treadmill during this period?
Given: Formula: Work:



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All these kinematic problems on speed, velocity, and acceleration are easily solved by choosing an appropriate kinematic equation. Applying definition of average acceleration, we get \begin{align*}\bar{a}&=\frac{v_f-v_i}{\Delta t}\\&=\frac{30-10}{2}\\&=10\,{\rm m/s^2}\end{align*} Problem (18): A motorcycle starts its trip along a straight line with a velocity of $10\,{\rm m/s}$ and ends with $20\,{\rm m/s}$ in the opposite direction in a time interval of $2\,{\rm s}$. If the object at $t_1=5\,{\rm s}$ is at position $x_1=+6\,{\rm m}$ and at $t_2=20\,{\rm s}$ is at $x_2=36\,{\rm m}$ then find its equation of position as a function of time. $2\,{\rm s}$ after starting, it decelerates its motion and comes to a complete stop at the moment of $t=4\,{\rm s}$. It travels for t_1 seconds with an average velocity $50\,{\rm m/s}$ and t_2 seconds with constant velocity $25\,{\rm m/s}$. Applying the position kinematic equation below to find the required time \begin{align*}\Delta y&=-\frac 12\,gt^{2}+v_0\,t\\-25&=-\frac 12\, (10)\,t^{2}+20\,t\end{align*} Rearranging and converting it into the standard form of quadratic equation $ax^{2}+b\,x+c=0$ as $t^{2}-4t-5=0$, solutions are obtained as\begin{align*}x_{1,2}&=\frac{-b\pm \sqrt{b^{2}-4\,a\,c}}{2a}\\&=\frac{-(-4)\pm\sqrt{(-4)^{2}-4(1)(-5)}}{2(1)}\\&=-1 \ \text{and}\ 5 \end{align*}Therefore, the time needed the ball hit the ground is $5\,{\rm s}$. Recall that the projectiles are a particular type of free-fall motion with a launch angle of $\theta=90$ with its own formulas. Solution: once the position equations of two objects are given, equating those equations and solving for t, you can find the time when they reach each other. Recall that the highest point is where $v_f=0$ so we have\begin{align*}v_f^{2}-v_0^{2}&=-2g\Delta y\\0-(30)^{2}&=-2(10)(\Delta y)\\&=45\,{\rm m}\end{align*} Of this height $25\,{\rm m}$ is for well's height so the stone is $20\,{\rm m}$ outside of the well. (b) Here, we have $\Delta y=0$ and v_0 must be determined as below\begin{align*}v_i^{2}-v_0^{2}&=-2g\Delta y\\v_i^{2}-(30)^{2}&=-2(10)(25)\\\Rightarrow v_i&=+20\,{\rm m/s}\end{align*} where v_i is the velocity just before leaving the well which can serve as initial velocity for the second part to find the total time which the stone is out of the well\begin{align*}\Delta y&=-\frac 12 gt^{2}+v_0 t\\0&=-\frac 12 (-10)t^{2}+20\, (2)\end{align*} Solving for t, one can obtain the required time is $t=4\,{\rm s}$. What is the ratio of the velocity of the ball A to the ball B at the instant of hitting the ground? Applying the quadratic formula, $t_{1,2}=\frac{-b\pm\sqrt{b^{2}-4\,a\,c}}{2a}$ for the standard equation $at^{2}+b\,t+c=0$, we obtain two roots as $t_1=2\,{\rm s}$ and $t_2=6\,{\rm s}$. \begin{align*}v&=v_0+at\\0&=3+a\,(4)\\\Rightarrow a&= -\frac 34\,{\rm m/s^2}\end{align*} Now write down the position kinematic equation $x=\frac 12\,at^{2}+v_0t+x_0$ to find the position as a function of time as \begin{align*}x&=\frac 12\,at^{2}+v_0t+x_0\\&=\frac 12\,(-\frac 34)t^{2}+3t+4\\&=-\frac 38\,t^{2}+3t+4\end{align*} Now at time $t=8\,{\rm s}$ its position is \begin{align*}x&=-\frac 38\,t^{2}+3t+4\\&=-\frac 38\,(8)^{2}+3(8)+4\\&=4\,{\rm m}\end{align*} Speed, Velocity, and Acceleration Problems for Free-Fall Motion: Problem (44): A stone is thrown vertically upward from a building of $15\,{\rm m}$ high with an initial velocity of $10\,{\rm m/s}$. One is descending into the well which is a constant acceleration motion and the other is ascending the sound of impact which is uniform motion. For the first part use the kinematic equation $\Delta y=-\frac 12 gt^{2}+v_0 t$ to find the falling time as \begin{align*}\Delta y&=-\frac 12 gt^{2}+v_0 t\\-34&=-\frac 12 (10)t^{2}+ (-7)t\\\Rightarrow 0&=5t^{2}+7t-34\end{align*}Since initial velocity is a vector and its direction is initially downward so a negative is included in front of it. Solution: By comparing those with the velocity kinematic equation $v=v_0+a\,t$, one can identify acceleration and initial velocity as $4\,{\rm m/s}$,$2\,{\rm m/s^{2}}$,respectively. Average acceleration defined as difference in velocities divided by the time interval between those points \begin{align*}\bar{a}&=\frac{v_2-v_1}{t_2-t_1}\\&=\frac{20-0}{4}\\&=5\,{\rm m/s^2}\end{align*} In above, we converted the km/h to the SI unit of velocity (m/s) as \[1\,\frac{km}{h}=\frac {1000\,m}{3600\,s}=\frac{10}{36}\,m/s\] so we get $72\,km/h=72\times \frac{10}{36}=20\,m/s$. Problem (17): A race car accelerate from an initial velocity of $v_i=10\,{\rm m/s}$ to a final velocity $v_f = 30\,{\rm m/s}$ in a time interval $2\,{\rm s}$. How far does the car travel? Solution: Known: $v_0=0$, $t_1=2\,{\rm s}$, $x_1=1\,{\rm m}$,$t_2=4\,{\rm s}$, $x_2=13\,{\rm m}$, $t_0=0$ and $x_0=?$ Substitute the known values into the kinematic equation $x=\frac 12 a\,t^{2}+v_0t+x_0$ which gives two equations with two unknowns \begin{align*}x&=\frac 12 a\,t^{2}+v_0t+x_0\\1&=\frac 12 a\,(2)^{2}+x_0\\13&=\frac 12 a\,(4)^{2}+x_0\end{align*} Multiply the first equation by -1 and sum with thee second equation gives $a=2\, {\rm m/s^{2}}$ and $x_0=-3\,{\rm m}$. The time needed for reaching that point is obtained as\begin{align*}\Delta y&=-\frac 12\,g\,t^{2}+v_0\,t\\25&=-\frac 12\,(10)\,t^{2}+30\,(t)\end{align*} Solving for t (using quadratic formula), we get $t_1=1\,{\rm s}$ and $t_2=5\,{\rm s}$ one for up way and the second for down way. Problem (56): From the top of a $20-{\rm m}$ tower, a small ball is thrown vertically upward. What is the total distance traveled by this moving object? Solution: This motion problem has two parts. Therefore, we have \begin{align*} \bar{v}&=\frac{x_1+x_2}{t_1+t_2}\\ \\&=\frac{60+60}{5+3}\\ \\&=15\,{\rm m/s}\end{align*} Problem (6): A plane flies the distance between two cities in 1 hour and 30 minutes with a velocity of $900\,{\rm km/h}$. A person drops a stone vertically into it with an initial velocity of $7\,{\rm m/s}$. Solution: Let the dropping point be the origin and positive direction up. Problem (2): How long will it take if you travel $400\,{\rm km}$ with an average speed of $100\,{\rm m/s}$? Find the displacement equation of this motion as a function of time. Find the ratio of $\frac {\Delta x_2}{\Delta x_1}$. Solution: This is left up to you as a practice problem. Problem (53): An object is thrown vertically in the air from a $100\,{\rm m}$ height with an initial velocity of v_0. How far has the car traveled between applying the brake and come to rest? Applying the time-independent free fall kinematic equation, we have \begin{align*}v_f^{2}-v_i^{2}&=2\,(-g)\Delta y\\v_f^{2}-(10)^{2}&=2\,(-10)(-15)\\\Rightarrow v_f&=\pm 20\,{\rm m/s}\end{align*} Since velocity is a vector quantity and just before striking to the ground its direction is vertically downward so the negative value must be chosen i.e. $v_f=-20\,{\rm m/s}$. Practice Problem (45): A bullet is released without initial velocity from a height of h and in the last second of falling, it drops a distance of $35\,{\rm m}$. Solution: Between the origin (surface level) and the highest point ($v=0$) apply the time-independent kinematic equation below to find the greatest height H where the ball reaches.\begin{align*}v^{2}-v_0^{2}&=-2\,g\,\Delta y\\0-(30)^{2}&=-2(10)H\\\Rightarrow H&=45\,{\rm m}\end{align*} The point $20\,{\rm m}$ below H has height of $h=45-20=25\,{\rm m}$. After some time its motion becomes uniform and finally comes to rest with an acceleration of $1\,{\rm m/s^2}$. Time Graphs Velocity vs. The total displacement vector is $\Delta x=\Delta x_1+\Delta x_2=750\,\hat{i}+250\,\hat{j}$ with magnitude of \begin{align*}|\Delta x|&=\sqrt{(750)^{2}+(250)^{2}}\\ \\&=790.5\,{\rm m}\end{align*} In addition, the total elapsed time is $t=12\times 60$ seconds.Therefore, the magnitude of the average velocity is $v=\frac{790.5}{12\times 60}=1.09\,{\rm m/s}$ Problem (5): An object moves along a straight line. In this problem, the velocity at the end of the path is given so we have \begin{align*}\Delta x&=-\frac 12\,at^{2}+v_f\,t\\80&=-\frac 12\,a\,(8)^{2}+(15)(8)\\\Rightarrow a&=-\frac{40}{32}\\&=-\frac 54\end{align*}   Problem (37): Starting from rest and at the same time, two objects with accelerations of $2\,{\rm m/s^2}$ and $8\,{\rm m/s^2}$ travel from A in a straight line to B. Thus, substitute the known values $v_0=3\,{\rm m/s}$ and $v=0$ at time $t=4\,{\rm s}$ into the velocity kinematic equation $v=v_0+at$ to find the acceleration of the object. If the total displacement over the whole time interval is $60\,{\rm m}$, What is the displacement in the first t-seconds? Solution: In the free-fall problems, the important note is choosing the origin. Find average velocity and average speed of the particle. The tower's height is $20-{\rm m}$ and total time which the ball is in the air is $4\,{\rm s}$. Solution: According to the time-independent kinematic equation $v^{2}-v_0^{2}=-2\,g\,\Delta y$, the velocity at the end of the path is dependent on the height from which the object drops. Find t_2 and determine the greatest height reached by the rock (neglect air resistance and let $g=10\,{\rm m/s^2}$). The above quadratic equation has two solutions as $t_1=2\,{\rm s}$ and $t_2=-3.4\,{\rm s}$. Solution: In this velocity problem, the whole path Δx is divided into two parts Δx_1 and Δx_2 with different average velocities and times elapsed, so the total average velocity across the whole path is obtained as \begin{align*}\bar{v}&=\frac{\Delta x}{\Delta t}\\\\&=\frac{\Delta x_1+\Delta x_2}{\Delta t_1+\Delta t_2}\\\\&=\frac{\bar{v}_1\,t_1+\bar{v}_2\,t_2}{t_1+t_2}\\\\10&=\frac{2\times 20+12\times t}{20+t}\\\Rightarrow t&=80\,{\rm s}\end{align*} Note: whenever a moving object, covers distances $x_1,x_2,x_3,\cdots$ in $t_1,t_2,t_3,\cdots$ with constant or average velocities $v_1,v_2,v_3,\cdots$ along a straight-line without changing its direction, then its total average velocity across the whole path is obtained by one of the following formulas Distances and times are known:\[\bar{v}=\frac{x_1+x_2+x_3+\cdots}{t_1+t_2+t_3+\cdots}\] Velocities and times are known: \[\bar{v}=\frac{v_1\,t_1+v_2\,t_2+v_3\,t_3+\cdots}{t_1+t_2+t_3+\cdots}\] Distances and velocities are known:\[\bar{v}=\frac{x_1+x_2+x_3+\cdots}{\frac{x_1}{v_1}+\frac{x_2}{v_2}+\frac{x_3}{v_3}+\cdots}\] Problem (11): A car travels one-fourth of its path with a constant velocity of $10\,{\rm m/s}$, and the remaining with a constant velocity of v_2. Problem (14): An object moves with constant acceleration along a straight line. Problem (46): A bullet is fired with an initial velocity of $15\,{\rm m/s}$ from the top of a tower of $20\,{\rm m}$ high. It travels with an average velocity $2\,{\rm m/s}$ for $20\,{\rm s}$ and $12\,{\rm m/s}$ for t seconds. Solution: Average velocity is displacement divided by time elapsed i.e. $\bar{v}\equiv \frac{\Delta x_{tot}}{\Delta t_{tot}}$. If the total average velocity across the whole path is $30\,{\rm m/s}$, then find the ratio $\frac{t_2}{t_1}$? Practice Problem (32): An object starts moving from rest with an acceleration of a. Thus, average speed is $=\frac{12}{4-2}=6\,{\rm m/s}$ and average velocity is $\bar{v}=\frac{-12}{4-2}=-6\,{\rm m/s}$. Use the velocity kinematic equation $v=v_0-g\,t$ to find the time required as \begin{align*}v&=v_0-g\,t\\-5&=+20-10\times t\\\Rightarrow t&=2.5\,{\rm s}\end{align*} Problem (63): A rock is dropped from a tower with the height $60\,{\rm m}$. Solution: Let the slower car be $v_B=54\,{\rm km/h}$ with a total time t for covering the total path D. Find the object's velocity at the end of the given time interval? Solution: Known: $\Delta x= 50\,{\rm m}$, $v_i=5\,{\rm m/s}$, $\Delta t=4\,{\rm s}$, $v_f=?$ With the above known values, we only use the following displacement kinematic equation to first find the acceleration \begin{align*} \Delta x&=\frac 12\,at^{2}+v_i\,t\\50&=\frac 12 (a)(4)^{2}+(5)(4)\\\Rightarrow a&=\frac{30}{8}=\frac{15}{4}\end{align*} Now apply the below kinematic formula to find the final velocity \begin{align*}v_f&=v_i+a\,t\\&=5+\frac{15}{4}\times 4=20\,{\rm m/s}\end{align*} Alternative solution: Since in this problem we have two unknowns that is acceleration and final velocity and the motion is constant acceleration, so one can use the below total displacement formula \begin{align*}\Delta x&=\frac{v_i+v_f}{2}\times \Delta t\\50&=\frac{5+v_f}{2}\times (4)\\\Rightarrow v_f&=20\,{\rm m/s}\end{align*} Problem (22): A car starts its motion from rest with a constant acceleration of $4\,{\rm m/s^2}$. Problem (7): A particle is moving along a straight-line path. What is its total displacement after $2\,{\rm s}$? Since the velocity of the car is decreasing, so its acceleration must be negative $a=-4\,{\rm m/s^2}$. Solution: Let the dropping point be the origin so in the kinematic equations the vertical displacement must be negative i.e. $\Delta y=-\frac h2$. It reaches the height of $40\,{\rm m}$ from the surface at times $t_1=2\,{\rm s}$ and t_2. The highest point is $5\,{\rm m}$ above the kicking point. Projectiles are also another type of motion in two dimensions with constant acceleration. Usually, the throwing (releasing or dropping) point is the best choice. Solution: This is a sample test for projectile questions on the AP Physics 1 exam. The distance traveled is also obtained using time-independent kinematic equation $v^{2}-v_i^{2}=2\,a\,\Delta x$ as \begin{align*}v^{2}-v_i^{2}&=2\,a\,\Delta x\\0-(20)^{2}&=2(-4)\Delta x\\\Rightarrow \Delta x&=50\,{\rm m}\end{align*} Problem (41): A plane starts moving along a straight-line path from rest and after $45\,{\rm s}$ takes off with a velocity $80\,{\rm m/s}$. If the arriving time difference between them is $3\,{\rm s}$, then how far is the total distance between A and B? It reaches the highest point of its path with an elevation of $20\,{\rm m}$ from the surface. What is the rock's velocity at the instant of hitting the ground? Solution: Apply the time-independent kinematic equation as \begin{align*}v^{2}-v_0^{2}&=-2\,g\,\Delta y\\v^{2}-(20)^{2}&=-2(10)(-60)\\v^{2}&=1600\\\Rightarrow v&=40\,{\rm m/s}\end{align*}Therefore, the rock's velocity when it hit the ground is $v=-40\,{\rm m/s}$. Solution: at the moment of braking, the earlier constant velocity serves as initial velocity (which must be converted into SI units m/s). What is its average acceleration during the time interval $1\leq t\leq 5$? Problem (57): A rock is thrown vertically upward into the air. But keep in mind that since distance is in SI units so the time traveled must also be in SI units which is m/s. In this motion problem, use the following kinematic equation to find the unknown initial velocity \begin{gather*}\Delta x=\frac 12\,at^{2}+v_0 t\\ 45=\frac 12 (2)(5)^{2}+v_0 (5)\\ \Rightarrow \boxed{v_0=4\,{\rm m/s}} \end{gather*} Problem (21): An object, without change in direction, travels a distance of $50\,{\rm m}$ with an initial speed $5\,{\rm m/s}$ in $4\,{\rm s}$. \begin{align*} \Delta y&=-\frac 12 \,t^{2}+v_0\,t\\-100&=-\frac 12\,(10)(5)^{2}+v_0\,t\\\Rightarrow v_0&=-5\,{\rm m/s}\end{align*} the minus sign indicates initial velocity is downward with the magnitude (speed) of $5\,{\rm m/s}$. Now apply average acceleration definition in the time intervals $[t_0,t_1]$ and $[t_0,t_2]$ and equate them.\begin{align*}\text{average acceleration}\ \bar{a}&=\frac{\Delta v}{\Delta t}\\\\\frac{v_1 - v_0}{t_1-t_0}&=\frac{v_2-v_0}{t_2-t_0}\\\\ \frac{10-v_0}{3-0}&=\frac{20-v_0}{8-0}\\\\ \Rightarrow v_0 &=4\,{\rm m/s}\end{align*} In the above, v_1 and v_2 are the velocities at moments t_1 and t_2, respectively. Problem (15): For $10\,{\rm s}$, the velocity of a car which travels with a constant acceleration, changes from $10\,{\rm m/s}$ to $30\,{\rm m/s}$. In the above, the minus sign of the displacement indicates its direction which is toward the $-x$ axis. Problem (62): A stone is launched directly upward from the surface level with an initial velocity of $20\,{\rm m/s}$. These two objects how many times meet each other in the time interval $t=0$ through $t=5\,{\rm s}$? Solution: Average speed defines as the ratio of the path length (distance) to the total elapsed time, \[\text{Average speed} = \frac{\text{path length}}{\text{elapsed time}}\] On the other hand, average velocity is the displacement $\Delta x=x_2-x_1$ divided by the elapsed time Δt. Problem (3): A person walks $100\,{\rm m}$ in 5 minutes, then $200\,{\rm m}$ in 7 minutes and finally $50\,{\rm m}$ in 4 minutes. At the instant $t=1\,{\rm s}$, it is at the position $x=+4\,{\rm m}$ and has a velocity of $4\,{\rm m/s}$. Problem (25): A car moves at a speed of $72\,{\rm km/h}$ along a straight path. Thus, use the below equation to find the speed at the desired level \begin{align*}v_2^{2}-v_1^{2}&=2(-g)\Delta y\\v_2^{2}-0&=-2g(-\frac h2)\\\Rightarrow v_2&=\sqrt{gh}\end{align*} Practice Problem (49): An small bullet is released without initial velocity from a tower and travels the last $80\,{\rm m}$ of its motion in $2\,{\rm s}$. Another plane covers that distance with $600\,{\rm km/h}$. Keep in mind that these motion problems in one dimension are of the uniform or constant acceleration type. Solution: Let the initial speed at time $t=0$ be v_0. (The above roots can be obtained readily by taking square root from both sides as $t=\pm\,2(t-3)$ and solving for t). Determine the height of h? Solution: This is left up to you as a practice problem. Downward or upward indicate the direction of velocity. Now use again the above equation to find the velocity at the hitting point v_2 as \begin{align*}v_2^{2}-v_0^{2}&=-2\,g\Delta y\\v^{2}-0&=-2(10)(-60)\\\Rightarrow v&=\sqrt{1200}\\&=\sqrt{400\times 3}=20\sqrt{3}\end{align*} The asked ratio is $\frac{v_1}{v_2}=\frac{3}{2\sqrt{3}}$. Find its kinematic equation of position as a function of time. Solution: Average acceleration is defined as the difference in velocities divided by the time interval that change is occurred. With these known values, one can find the initial velocity as \begin{align*}\Delta y&=-\frac 12 gt^{2}+v_0\,t\\-25&=-\frac 12 (10)(4)^{2}+v_0\,(4)\\\Rightarrow v_0&=15\,{\rm m/s}\end{align*} When the ball returns to its initial point, its total displacement is zero i.e. $\Delta y=0$ so we can use the following kinematic equation to find the total time to return to the starting point \begin{align*}\Delta y&=-\frac 12 gt^{2}+v_0\,t\\0&=-\frac 12\,(10)t^{2}+(15)\,t\end{align*} Rearranging and solving for t, we get $t=3\,{\rm s}$. The accepted time is t_2. Using kinematic formula $v_f=v_i+at$ one can find the car's acceleration as \begin{align*} v_f&=v_i+at\\0&=20+(a)(5)\\\Rightarrow a&=-4\,{\rm m/s^2}\end{align*} Now apply the kinetic formula below to find the total displacement between braking and resting points \begin{align*}v_f^{2}-v_i^{2}&=2a\Delta x\\0-(20)^{2}&=2(-4)\Delta x\\\Rightarrow \Delta x&=50\,{\rm m}\end{align*} Alternative Solution: Between the above points we can apply the well-known kinematic equation below to find total displacement \begin{align*}\Delta x&=\frac{v_i+v_f}{2}\,t\\&=\frac{0+20}{2}\times 5\\&=50\,{\rm m}\end{align*} Problem (26): A motorcycle starts its trip along a straight path from position $x_0=5\,{\rm m}$ with a speed of $8\,{\rm m/s}$ at a constant rate. Solution: In all kinematic problems, you must first identify two points with known kinematic variables (i.e. x,v,a) and then apply equations between those points. Applying quadratic formula yield a negative discriminant $(b^{2}-4\, a\,c)

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