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ENGS121 Mechanics Section C - Homework 1

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Problem 1.

Alex embarked on a road trip to explore a distant city. The outgoing journey of 200 km was filled with excitement as Alex cruised along at a constant speed of 40 km/h. Upon reaching the destination, Alex decided to take a well-deserved 1.0-hour lunch break to recharge for the return journey. After enjoying his meal, Alex hit the road again, this time covering the 200 km return trip at a speed of 50 km/h. The scenic views and the open road made the return journey equally enjoyable.

(a) Find the average speed for the trip.

$$t_{\text{outgoing}} = \frac{200}{40} = 5\text{hours}, t_{\text{return}} = \frac{200}{50} = 4\text{hours}, t_{\text{break}} = 1\text{hour} \implies t = 10\text{hours}$$

$$v_{\text{average}} = \frac{S}{t} = \frac{400}{10} = 40\text{km/h}$$

(b) Find the average velocity for the trip.

$$\vec{v}_{\text{average}} = \frac{\vec{S}}{t} = \frac{0}{10} = 0\text{km/h}$$

(c) If the lunch break extended by an extra 30 minutes due to the engaging conversation, how would this affect the average speed and average velocity of the entire round trip? Provide the new values for both.
The average speed will decrease, because the distance stays the same while the time increases. The average velocity will remain 0, since displacement is still 0.

$$v_{\text{average}} = \frac{S}{t} = \frac{400}{10.5} \approx 38.1\text{km/h}$$

$$\vec{v}_{\text{average}} = \frac{\vec{S}}{t} = \frac{0}{10.5} = 0\text{km/h}$$

Problem 2.

Imagine a long stretch of road where an automobile is cruising at a speed of 50 km/h. Ahead on a parallel track, a train is chugging along at a speed of 30 km/h. The train is 1.50 km long. The car speeds up to overtake the train.

(a) Calculate the time it takes for the car to completely overtake the train (give the answer in seconds). The car goes at a speed of 20km/h with respect to the train.

$$t = \frac{S}{v} = \frac{1.5}{20} = 0.075\text{hours} = 270\text{seconds}$$

(b) How much time does it take for the car to go past (in seconds), and how much distance will the car cover during this period (in km).

$$S = vt = 50 \cdot 0.075 = 3.75km$$

(c) If the car and train are now moving toward each other, find the time it takes for them to meet (in seconds).
Relative speed of car with respect to the train is 80km/h.

$$t = \frac{S}{v} = \frac{1.5}{80} = 0.01875\text{hours} = 1.125\text{minutes}$$

Problem 3.

Alice and Bob are embarking on a great road trip adventure. They start their journey at point x=0 with high spirits and a full tank of gas at t=0. Alice is at the wheel, driving the car as they enjoy the scenic route. At t=5.00 seconds, they pass a charming town, capturing a quick snapshot of the scenery as they zip by at 10.0 m/s, covering a distance of 25.0 m. It's a brief moment, but the memory is forever etched in their minds. As they continue, the landscape changes, and at t=30.0seconds, they reach a bustling city, having traveled 200 m from their starting point. The car is now cruising at 60 m/s, navigating through the urban jungle.

(a) The average velocity between t=5.00s and t=30.0s.

$$v_{\text{average}} = \frac{\Delta x}{t} = \frac{200 - 25}{30 - 5} = 7\text{m/s}$$

(b) The average acceleration between t=5.00s and t=30.0s.

$$a_{\text{average}} = \frac{\Delta v}{t} = \frac{60 - 10}{30 - 5} = 2\text{m/s}^2$$

(c) If the car maintains the same acceleration, at what time will it reach x=500 m.

$$S = v_0 t + \frac{at^2}{2} \implies 300 = 60t + \frac{2t^2}{2}$$

$$\implies t^2 + 60t - 300 = 0 \implies t = \frac{-60 + \sqrt{60^2 + 4 \cdot 1 \cdot 300}}{2 \cdot 1} \approx 4.64\text{seconds}$$

Problem 4.

Imagine a futuristic hovercraft cruising at a speed of 7 m/s. The pilot decides to initiate a deceleration process by adjusting some control settings, causing the hovercraft to slow down at a constant rate of 0.5 m/s^2 without applying any additional propulsion.

(a) Determine the distance the hovercraft coasts before coming to a complete stop.

$$a = \frac{\Delta v}{t} \implies t = \frac{\Delta v}{a} = \frac{7-0}{0.5} = 14\text{seconds}$$

$$S = v_0 t - \frac{at^2}{2} = 7 \cdot 14 - \frac{0.5 \cdot 14^2}{2} = 49\text{meters}$$

(b) Find the time it takes for the hovercraft to come to a stop.

$$t = 14\text{seconds, found at (a)}$$

(c) Calculate the distances the hovercraft travels during the second and fourth seconds of the deceleration. To find the time the hovercraft traveled during the second second, we can calculate distance traveled in 2 seconds and subtract distance traveled in 1 second from the starting point of dceleration.

$$S_2 = \left(7 \cdot 2 - \frac{0.5 \cdot 2^2}{2}\right) - \left(7 \cdot 1 - \frac{0.5 \cdot 1^2}{2}\right) = 13 - \frac{27}{4} = 6.25\text{meters}$$

$$S_4 = \left(7 \cdot 4 - \frac{0.5 \cdot 4^2}{2}\right) - \left(7 \cdot 3 - \frac{0.5 \cdot 3^2}{2}\right) = 24 - \frac{75}{4} = 5.25\text{meters}$$

Problem 5.

Jack and Emma, are playing together in the backyard. Jack jumps up one-and-a-half times higher than Emma. When Emma starts bouncing, she has an initial speed of 14.0 m/s.

(a) Find out the maximum height Emma reaches during her jumps.

$$g = \frac{\Delta v}{t} \implies t = \frac{\Delta v}{g}$$

$$H = v_0 t - \frac{gt^2}{2} = \frac{v_0^2}{g} - \frac{g\left(\frac{v_0}{g}\right)^2}{2} = \frac{v_0^2}{g} - \frac{v_0^2}{2g} = \frac{v_0^2}{2g} = \frac{14^2}{2 \cdot 9.8} = 10\text{meters}$$

(b) Determine the initial speed with which Jack starts his bouncing session.

$$H = 15\text{meters} \implies v_0 = \sqrt{2gH} \approx 17.1$$

(c) Calculate the total time Jack spends in the air during the game.
Since the time going up and the time going down are equal, we can find one of them and multiply by 2. Consider the change in velocity at the time of jumping and at the highest point, where velocity is 0.

$$t = 2\frac{\Delta v}{g} = 2\frac{17.1 - 0}{9.8} \approx 3.49\text{seconds}$$