Assignment P–11–2
(Motion in One Dimension)

1. The position of a pine-wood derby car was observed at various times; the results are summarized in the table below. Find the average velocity of the car for (a) the first second, (b) the last 3 s, and (c) the entire period of observation.

x (m)	0	2.3	9.2	20.7	36.8	57.5
t (s)	0	1.0	2.0	3.0	4.0	5.0

2. The position versus time for a certain particle moving along the x axis is shown in Fig 1. Find the average velocity in the time intervals (a) 0 to 2 s, (b) 0 to 4 s, (c) 2 s to 4 s, (d) 4 s to 7 s, (e) 0 to 8 s.

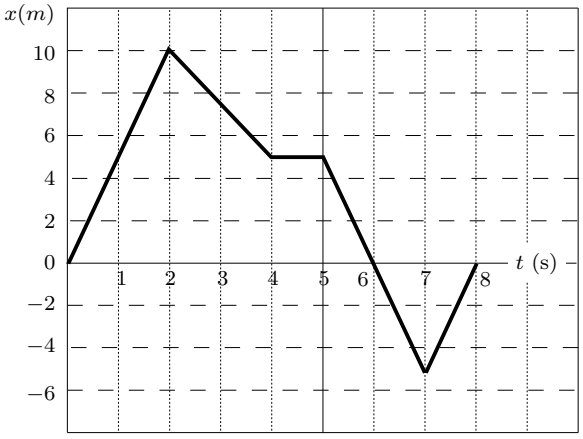


Figure 1: Problem 2

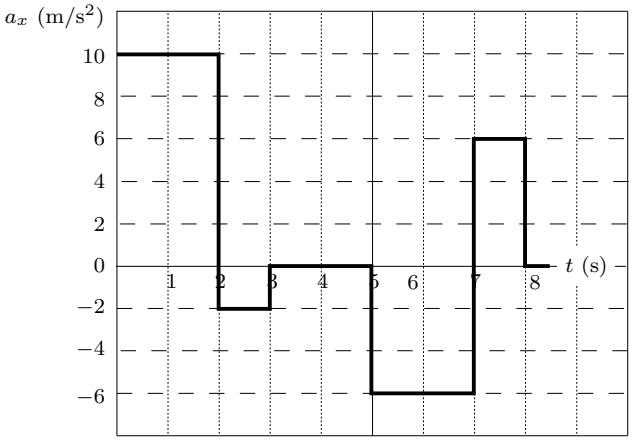


Figure 2: Problem 3

3. A particle starts from rest and accelerates as shown in Fig 2. Determine: (a) the particle's speed at $t = 10$ s and at $t = 20$ s, and (b) the distance traveled in the first 20 s.

4. From a town, cars start at regular intervals of 30 s and run towards another town with constant speed of 60 km/h. At some point of time, all of the cars simultaneously have to reduce their speed to 40 km/h due to bad weather conditions. What will become the time intervals between their arrival at the second town during the bad weather?

5. Sonu walks to school every morning, and it takes him 20 minutes. Once on his way to school he realized that he had forgotten his homework notebook at home. He knew that if he continue walking to school at the same speed, he would be there 8 minutes before the bell, so he went back home for the notebook and arrived at the school 10 minutes late. If he had walked all the way with his usual speed, what fraction of the way to school had he covered at the moment he turned back?

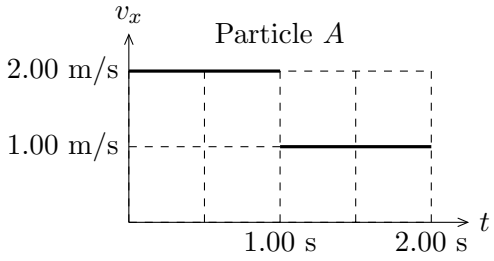
6. A particle moves along the x axis according to the equation $x = 2.00 + 3.00t - t^2$, where x is in meters and t is in seconds. At $t = 3.00$ s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

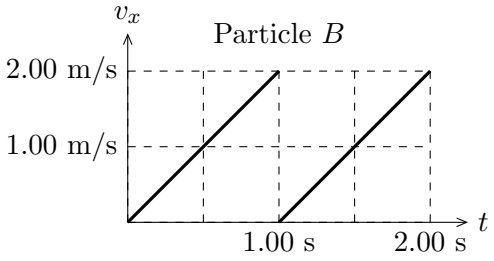
7. A truck on a straight road starts from rest, accelerating at 2.00 m/s^2 until it reaches a speed of 20.0 m/s. Then the truck travels for 20.0 s at constant speed until the brakes are applied, stopping the truck in a uniform manner in an additional 5.00 s. (a) How long is the truck in motion? (b) What is the average velocity of the truck for the motion described?

8. A test rocket is fired vertically upward from a well. A catapult gives it an initial velocity of 80.0 m/s at ground level. Subsequently, its engines fire and it accelerates upward at 4.00 m/s^2 until it reaches an altitude of 1000 m. At that point its engines fail, and the rocket goes into free fall, with an acceleration of 9.80 m/s^2 in the downward direction. (a) How long is the rocket in motion above the ground? (b) What is its maximum altitude? (c) What is its velocity just before it collides with the Earth?

9. An inquisitive physics student and mountain climber climbs a 50.0–m cliff that overhangs a calm pool of water. He throws two stones vertically downward, 1.00 s apart, and observes that they cause a single splash. The first stone has an initial speed of 2.00 m/s. (a) How long after release of the first stone do the two stones hit the water? (b) What was the initial velocity of the second stone? (c) What is the velocity of each stone at the instant the two hit the water?

10. Two particles A and B starts from the same point and move in the positive x direction. Their velocity-time graphs are shown in the figure below. What is the maximum separation between them during the time interval shown?





11. A commuter train travels between two stations. Because the stations are only 1.00 km apart, the train never reaches its maximum possible cruising speed. The engineer minimizes the time t between the two stations by accelerating at a rate $a_1 = 0.100$ m/s^2 for a time t_1 and then by braking with acceleration $a_2 = -0.500$ m/s^2 for a time t_2. Find the minimum time of travel t and the time t_1.

12. Two cars start off to race with velocities v_1 and v_2 and travel in a straight line with uniform accelerations a_1 and a_2. If the race ends in a dead heat(both cars reach finish line simultaneously), prove that the length of the course is

$$\frac{2(v_1 - v_2)(v_1 a_2 - v_2 a_1)}{(a_1 - a_2)^2}$$

13. A body dropped from rest travels a distance h_1 during the first 5 s, h_2 during the next 5 s, and h_3 during the next 5 s. Determine $h_1 : h_2 : h_3$.

14. In a 100–m race, Maggie and Judy cross the finish line in a dead heat, both taking 10.2 s. Accelerating uniformly, Maggie took 2.00 s and Judy 3.00 s to attain maximum speed, which they maintained for the rest of the race. (a) What was the acceleration of each sprinter? (b) What were their respective maximum speeds? (c) Which sprinter was ahead at the 6.00–s mark, and by how much?

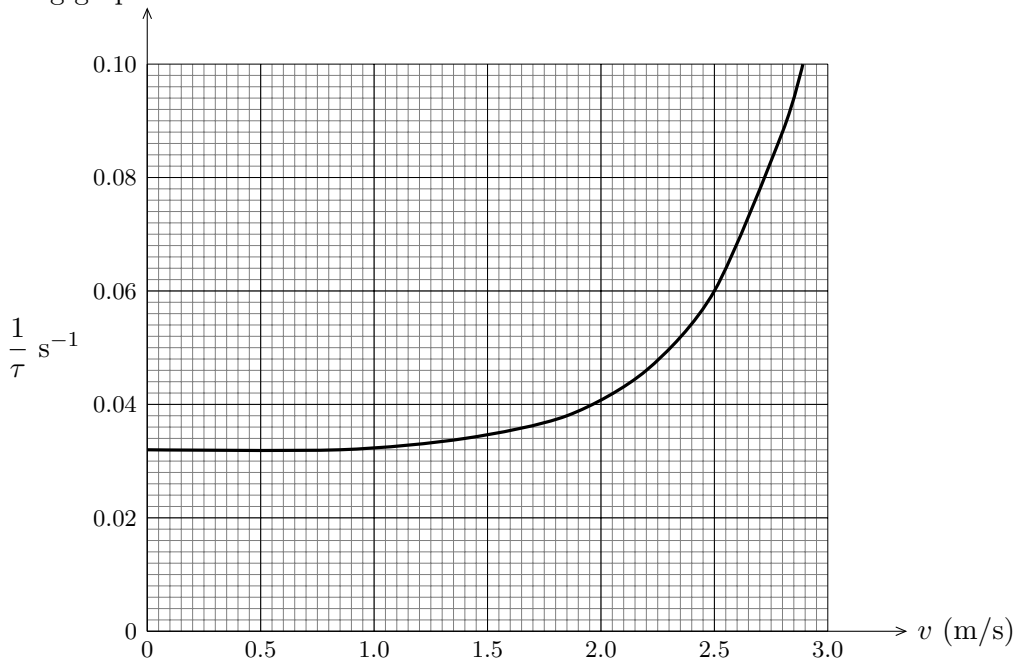
15. A mail train and a goods train are moving on the same track in the same direction with velocities 108 km/h and 36 km/h respectively. The driver of the mail train sights the goods train when the latter is only 175 m ahead of him and immediately puts on brakes to get a deceleration of 0.65 m/s^2. At the same instant the driver of the goods train apprehending danger makes his train pick up an acceleration of 0.5 m/s^2. Determine whether collision can be averted.

16. A rock is dropped from rest into a well. (a) If the sound of the splash is heard 2.40 s later, how far below the top of the well is the surface of the water? The speed of sound in air (at the ambient temperature) is 336 m/s. (b) If the travel time for the sound is neglected, what percentage error is introduced when the depth of the well is calculated?

17. The acceleration of a marble in a certain fluid is proportional to the speed of the marble squared and is given (in SI units) by $a = -3.00\,v^2$ for If the marble enters this fluid with a speed of 1.50 m/s, how long will it take before the marble's speed is reduced to half of its initial value?

18. Two cars left station A simultaneously and reached station B in $t_0 = 2$ hours. The first car traveled half of the distance at a speed of $v_1 = 30$ km/h and the other half at a speed of $v_2 = 45$ km/h. The second car covered the entire distance with a constant acceleration. At what moment of time were the speeds of both cars the same? Will one of them overtake the other en route?

19. An engineer designs a robot that can climb stairs. Time τ in which the battery used in the robot is fully discharged depends on its speed v relative to the stairs. This dependence is shown in the following graph:



With the help of the graph, determine the maximum length of a staircase which the robot can climb with a constant velocity.

20. A stone thrown vertically upward. On its way, it passes point A with speed v, and the point B, 3.00 m higher than A, with speed $v/2$. Calculate: (a) the speed v, and (b) the maximum height reached by the stone above the point B.

21. A particle moves from rest in a straight line with alternate acceleration and deceleration of magnitudes a and a', respectively, during equal intervals of time τ; at the end of $2n$ such intervals, show that it has covered a distance of $\dfrac{n\tau^2}{2}\left[(2n+1)a - (2n-1)a'\right]$.

22. A body moving in a straight line with uniform acceleration describes three successive equal distances in time intervals t_1, t_2 and t_3. Prove that

$$\frac{1}{t_1} - \frac{1}{t_2} + \frac{1}{t_3} = \frac{3}{t_1 + t_2 + t_3}$$

23. The velocity of a particle moving in the positive x direction varies as $v = \alpha\sqrt{x}$, where α is a positive constant. Assuming that at moment $t = 0$, the particle was located at the point $x = 0$, determine the acceleration of the particle.

24. Two steel balls freely drop onto an elastic plate, the first one from a height of $h_1 = 44$ cm and the second from a height $h_2 = 11$ cm but after time τ measured from the instant the first ball was

dropped. After a certain time the velocities of the balls coincide in magnitude and direction. Find the time τ and the interval during which the velocities of the two balls remain the same. The balls do not collide.

25. A clown in circus juggles with n balls using only one hand. He throws each ball vertically upwards with the same speed at equal time intervals τ. Denote acceleration due to gravity by g.

(i) Find expressions for the speed of projection and height of the i^{th} ball above his hand when he throws the n^{th} ball.

Suppose he used $n = 4$ balls and when he throws the fourth ball, the distance between the second and third ball is $d = 50$ cm.

(ii) Where is the first ball, when the clown throws the fourth ball?

(iii) What is the maximum height attained by each ball above the hand of the clown?

26. The position x versus time t for a particle moving along the axis is given by $t = px^2 + qx + r$, where p, q, and r are constants. (a) Find the velocity of the particle as a function of x. (b) Prove that the acceleration is inversely proportional to the cube of the distance from a certain fixed point on the line of motion, and find the coordinate of the fixed point with respect to the origin.

27. The position of a particle along the x-axis is given by $x = (t^3 - 9t^2 + 15t)$ m, where t is in seconds. Determine the maximum acceleration and maximum velocity during the time interval $0 \leq t \leq 10s$.

Answers

1. (a) 2.3 m/s (b) 16.1 m/s (c) 11.5 m/s
2. (a) 5 m/s (b) 1.25 m/s (c) -2.5 m/s (d) -3.33 m/s (e) 0
3. (a) 12 m/s for both instants (b) 252 m
4. 45 s
5. 9/20
6. (a) 2.00 m (b) -3.00 m/s (c) -2.00 m/s^2
7. (a) 35 s (b) 15.7 m/s
8. (a) 41.1 s (b) 1.73 km (c) -184 m/s
9. (a) 3.00 s (b) 15.2 m/s (c) first stone: 31.4 m/s, second stone: 34.8 m/s
10. 1.25 m
11. $t = 155$ s, $t_1 = 129$ s
13. 1 : 3 : 5
14. (a) Maggie: 5.43 m/s^2, Judy: 3.83 m/s^2 (b) Maggie: 10.9 m/s, Judy: 11.5 m/s (c) Maggie was at 54.5 m mark and Judy was at 51.8 m mark, so Maggie was ahead by 2.70 m.
15. The collision will *not* take place.
16. (a) 28.4 m (b) 0.7%
17. 0.222 s
18. After 50 min and 75 min from the start. No.
19. 50 m
23. $\alpha^2/2$
24. 0.30 s
25. (a) $u = \frac{1}{2}gn\tau$, $h = gi(n - i)$ (b) $h = 1.5$ m (c) 2.0 m
27. Maximum velocity = 135 m/s, maximum acceleration = 42 m/s^2