2.1 MOTION *HW/Study Packet*

SL/HL	
Required: READ Tsokos, pp 35-53 Hamper pp 17-31	Supplemental: Cutnell and Johnson, pp 28-52 Giancoli, pp 19-38

REMEMBER TO….

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

UNIT OUTLINE

I. GENERAL KINEMATICS
- A. DISTANCE AND DISPLACEMENT
- B. SPEED AND VELOCITY
- C. ACCELERATION
- D. 'INSTANTANEOUS' AND 'AVERAGE'
- E. FLUID RESISTANCE AND TERMINAL VELOCITY

III. GRAPHING KINEMATICS
- A. DISPLACEMENT-TIME GRAPHS
- B. VELOCITY-TIME GRAPHS
- C. ACCELERATION-TIME GRAPHS
- D. HOW THE GRAPHS ARE RELATED

IV. CONSTANT ACCELERATION AND THE EQUATIONS OF MOTION
- A. FALLING BODIES NEAR THE EARTH'S SURFACE
- B. THE EQUATIONS OF MOTION

V. PROJECTILE MOTION
- A. INDEPENDENCE OF HORIZONTAL AND VERTICAL VELOCITY COMPONENTS
- B. TRAJECTORIES
- C. THE EFFECT OF AIR RESISTANCE

FROM THE IB DATA BOOKLET

$$v = u + at \qquad s = ut + \frac{1}{2}at^2 \qquad v^2 = u^2 + 2as \qquad s = \frac{(v+u)t}{2}$$

WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC

- □ Differentiate between instantaneous and average speeds and velocities.
- □ Describe and quantify the effects of fluid resistance and terminal velocity.
- □ Recognize situations of accelerated motion and solve problems for motion in a straight line with constant acceleration using the equations of motion.
- □ Solve problems of motion in a straight line both with constant and varying acceleration.
- □ Use graphs in describing motion, and be able to draw graphs of motion scenarios.
- □ Understand how to interpret graphs (the slope of a **s**-t graph is **v**, and the slope of a **v**-t graph is **a**, the area under a **v**-t graph is Δ**s**, and the area under an **a**-t graph is Δ**v**).
- □ Analyze motion from pictures, videos, photogate data, and tickertape analysis.
- □ Be aware that different frames of reference can give different but equally valid descriptions of motion.

- □ Understand parabolic motion as a combination of two independent straight line motions (vertical and horizontal)
- □ Realize that in parabolic motion there is acceleration in the vertical direction only (due to gravity)
- □ Derive expressions for maximum height and maximum range by imposing conditions on equations of motion
- □ Describe and sketch trajectories of motion with and without taking into account air resistance
- □ Solve problems involving parabolic motion
- □ Draw velocity and acceleration vectors of a projectile at various points along its path

HOMEWORK PROBLEMS:

1. An object has a displacement of -5 m. It moves a distance to the right equal to 15 m and then a distance of 10 m to the left.

a) What is the total distance travelled by the object? **[25 m]**

b) What is the final displacement of the object? **[0 m]**

c) What is the change in displacement of the object? **[+5 m]**

2. A student walks a distance of 3.5 km from home to college. He returns home via the chip shop, covering a distance of 5.5 km. Find the total distance he was walking and his displacement from home at the end of the day. **[9.0 km, 0 km]**

3. Calculate the average speed in ms^{-1} of:

a) a sprinter who completes 100.0 m in a time 10.0 s **[10.0 ms^{-1}]**

b) a marathon runner who takes $2^1/_4$ hours to run 42.5 km. **[5.2 ms^{-1}]**

4. Starting from home, a jogger runs 4.0 km. She returns home after 20 minutes. What is:

a) her average speed? **[3.3 ms^{-1}]**

b) her average velocity? **[0 ms^{-1}]**

5. The speed of light is 3.00 x 10^8 ms^{-1}. Calculate:

a) the distance travelled by the light in 1 complete earth year. **[9.46 x 10^{15} m]**

b) The time taken, in minutes, for the light to travel from the Sun to the Earth, a distance of 150 million km. **[8.3 min]**

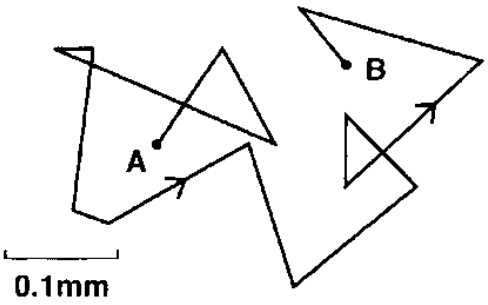
6. A cyclist travels to work at an average speed of 3.0 ms^{-1} and returns home for tea at an average speed of 9.0 ms^{-1}. Calculate her average speed for the whole journey. *(The answer is **not** 6 ms^{-1}!)* **[4.5 ms^{-1}]**

7. The diagram shows the movement of a smoke particle in a Brownian motion experiment.

(a) Use a ruler to find *(measure it properly!):*

(i) the total distance moved by the smoke particle in going from A to B. **[1.5 mm]**

(ii) the displacement AB. **[0.17 mm at 23°]**

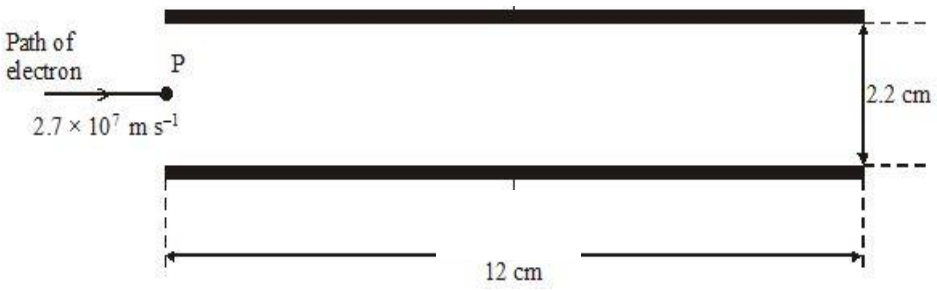


(b) If it took 1.20 s to travel from A to B, calculate

(i) the average speed **[1.33 mms^{-1}]**

(ii) the average velocity of the smoke particle. **[0.14 mms-1 at 23°]**

8. An electron enters a tube as shown at point P. How long does the electron spend inside the tube? **[4.4 x 10^{-9} s]**



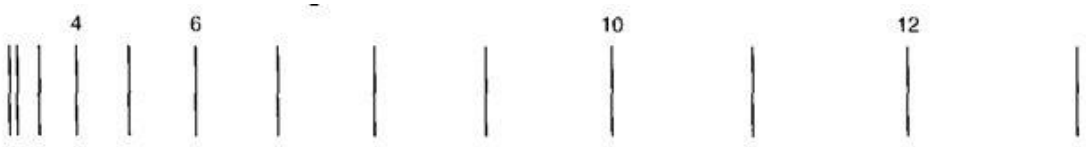
9. Sketch the shape of a tickertape chart produced from a tape attached to a trolley moving:

a) with a constant acceleration

b) at a constant speed

c) with a constant deceleration

10. The diagram shows the positions of a line drawn on an accelerating air track glider every 100 milliseconds. The scale of the diagram is one twentieth that of the real situation.



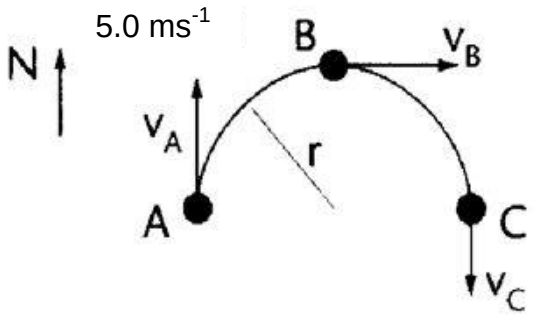
a) How far did the glider move between:
i) Positions 4 and 6 ? **[31.0 cm]** ii) Positions 10 and 12? **[76.0 cm]**

b) Write down the average velocities of the glider between these two sets of positions.
[4-6: 1.55 ms^{-1}; 10-12: 3.80 ms^{-1}]

c) How long did the glider take to accelerate from position 4 to position 10 (or from position 6 to 12)? **[0.600 s]**

d) What was the acceleration of the glider? **[4.09 ms^{-2}]**

11. An object is travelling in a circular path as shown, starting at A and going through B and C. The radius of it's path is *r* and it take a time *t* to get from A to C. It's speed is a constant 5.0 ms^{-1} and initially the object is heading due north.
Determine, in terms of appropriate variables…



a) how far the object has travelled going from A to C. **[πr]**

b) the displacement from A to C. **[2r m E]**

c) the time taken to get from A to B. **[t/2 or πr/5]**

d) the change in velocity from A to B. **[7.1 ms^{-1} SE]**

e) the change in velocity from B to C. **[7.1 ms^{-1} SW]**

f) the change in velocity from A to C. **[10. ms^{-1} S]**

g) the average acceleration between A and B. **[14/t ms^{-2} SE]**

h) the average acceleration between A and C. **[10/t ms^{-2} S]**

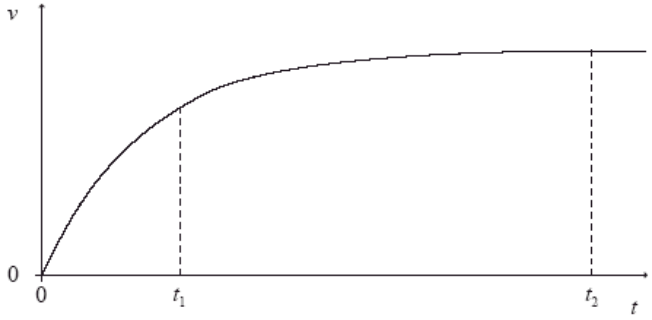
i) Determine the direction of the force(s) acting on the object (if any) at points A, B, and C.

12. Calculate the acceleration of an airplane if it accelerates from 15.0 ms^{-1} to 80.0 ms^{-1} in 1 minute. **[1.08 ms^{-2}]**

13. Calculate the time taken for a car to increase its speed from 5.0 ms^{-1} to 25 ms^{-1} if its acceleration is 2.0 ms^{-2} . **[10 s]**

14. A car accelerates away from traffic lights with an acceleration of 5.0 ms^{-2} for 6.0 seconds. It then brakes with an acceleration of –3.0 ms^{-2} for 2.0 seconds. What was its final speed? **[24 ms^{-1}]**

15. A small steel ball of mass *m* is dropped from rest into a long vertical tube that contains oil. The sketch graph shows how the speed *v* of the ball varies with time *t*.



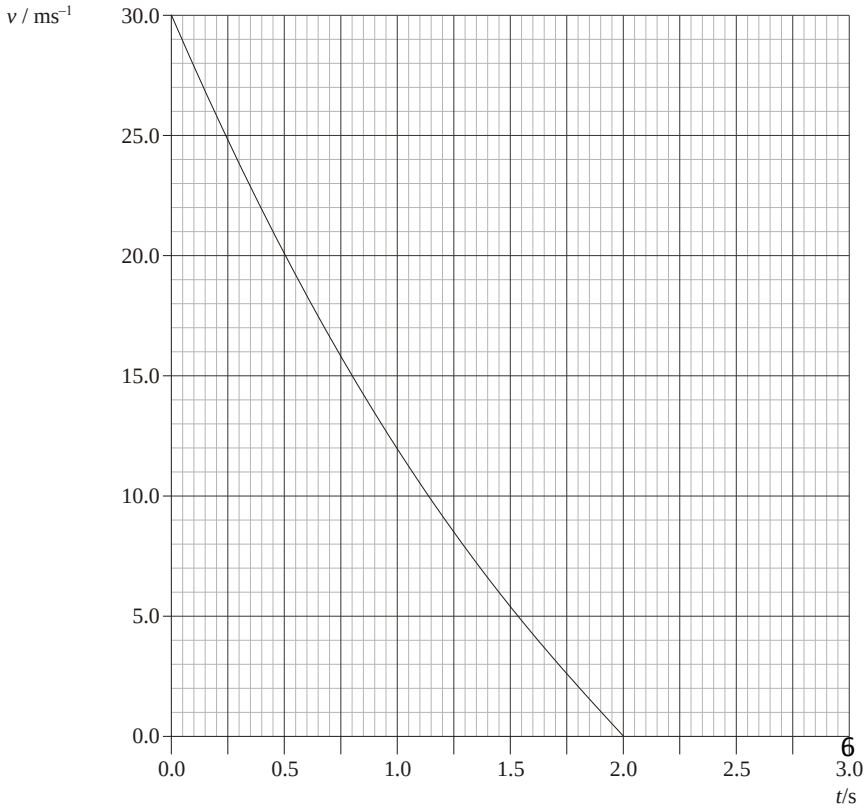
a) Explain how you would use the graph to find the average speed of the ball between $t = 0$ and $t = t_1$.

b) The gradient of the graph at $t = t_1$ is k. Deduce an expression in terms of k, m and g, the acceleration of free fall, for the magnitude of the frictional force F acting on the ball at $t = t_1$.

[F = m(g-k)]

c) State and explain the magnitude of the frictional force acting on the ball at $t = t_2$.

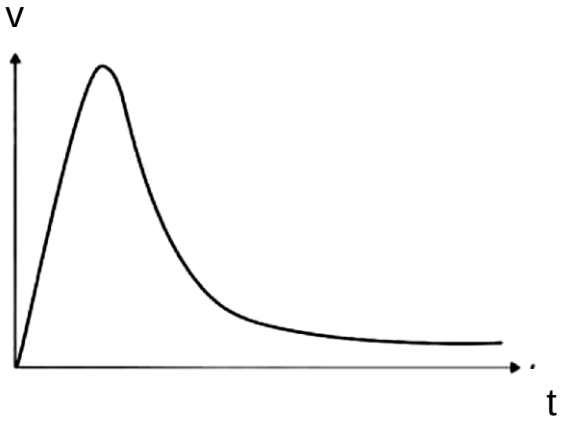
16. A ball of mass 0.25 kg is projected vertically upwards from the ground with an initial velocity of 30 m s^{-1}. The acceleration of free fall is 9.81 m s^{-2}, but air resistance **cannot** be neglected. The graph shows the variation with time *t* of the velocity *v* of this ball for the upward part of the motion.



Determine, for the ball at $t = 1.0$ s, the acceleration and the magnitude of the force of air resistance.

[≈ 14-15 ms^{-2}, F ≈ 1.1 N]

17. The v-t graph shown is for the vertical motion of a person who jumps from a helicopter and a few seconds later opens a parachute.



a) When does the parachute open? Mark this point on the graph and explain your answer.

b) When does the force of air resistance reach a maximum? Mark this point on the graph and explain your answer.

c) Is the air resistance force constant? Explain.

18. This problem is about cars driving along a straight road.

a) Complete the table showing the speeds of a car at 1 second intervals from starting out, if the acceleration of the car was 5.0 ms^{-2}.

Time / s	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Speed / ms^{-1}	0.0						

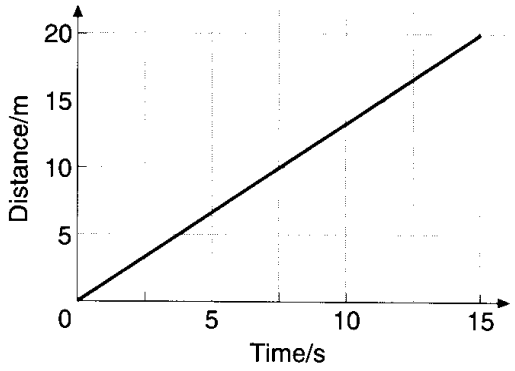
b) Repeat for an acceleration of 8.0 ms^{-2}.

Time / s	0.0	1.0	2.0	3.0	5.0	6.0
Speed / ms^{-1}	0.0					

c) Draw a graph of data on the graph provided. Clearly label the graphs ‘a’ and ‘b’.

d) Deduce, using data from your graph, that the car in part (b) travelled further than the car in part (a) after 6.0 s.

19. Use the distance-time graph to find:



a) how far the body has moved after 10 s **[13 m]**

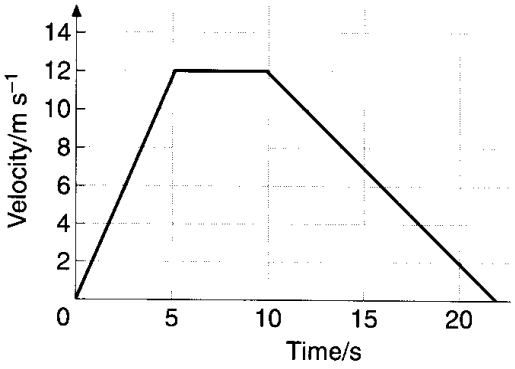
b) how long the body takes to travel 8 m **[6.5 s]**

c) the average speed of the body after 15s **[1.3 ms^{-1}]**

d) the instantaneous speed when t = 5s **[1.3 ms^{-1}]**

e) the equation of the line **[s(t) = 1.3t]**

20. Use the velocity-time graph to find:



a) the acceleration during the first 5s **[2.4 ms^{-2}]**

b) the distance travelled during this acceleration **[30 m]**

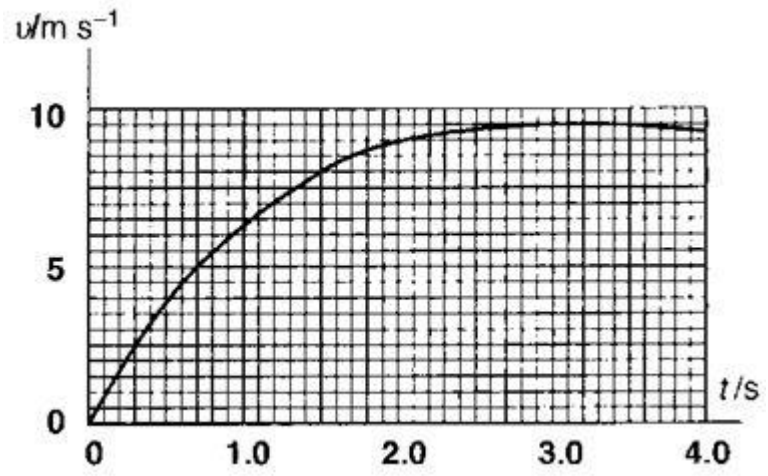
c) the total distance covered between 'stops' **[60 m]**

d) the average speed during the 22s journey. **[7.4 ms^{-1}]**

e) the equation of the graph

21. Sketch the acceleration-time graph corresponding to the velocity-time graph in question 17.

22. The graph shows the result of studying a sprint start.



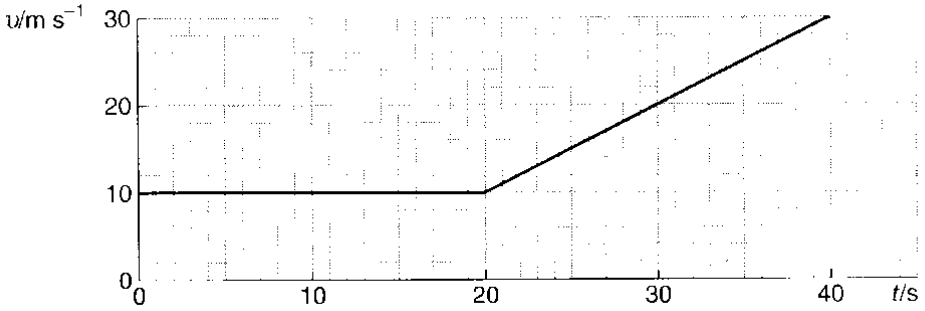
a) What, in m.p.h., was the maximum velocity reached? *(take 1.0 ms^{-1} to equal 2.24 m.p.h.)* **[21.3 mph]**

b) Calculate the acceleration of the sprinter in ms^{-2}….

i) as she leaves her blocks. **[8.3 ms^{-2}]**

ii) after 2.0 s. **[1.2 ms^{-2}]**

23. The graph describes the motion of a train moving in a speed- restricted area and then accelerating as it clears the area. *You are to calculate the total distance travelled by the train in the 40 s shown in two different ways.*



a) Use the average velocity of the train during each 20s interval to calculate two separate distances and add them together. **[600 m]**

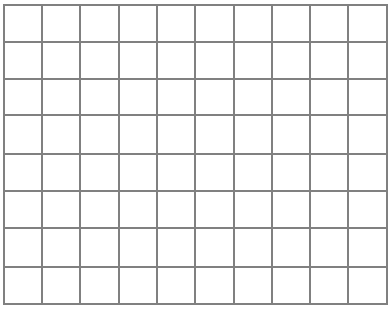
b) Find the number of squares under the graph and the distance represented by one square.

24. At the instant the traffic light turns green, a car that has been waiting at a junction starts ahead with a constant acceleration of 2.00 ms^{-2}. At the same instant a truck, travelling with a constant speed of 18.0 ms^{-1}, overtakes and passes the car.

a) How far beyond its starting point does the car overtake the truck? **[324 m]**

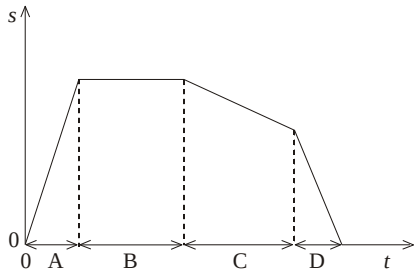
b) How fast is the car travelling when it overtakes the truck? **[36.0 ms^{-1}]**

c) On a single graph, sketch the position of each vehicle as a function of time. *Take s = 0 at the junction.*

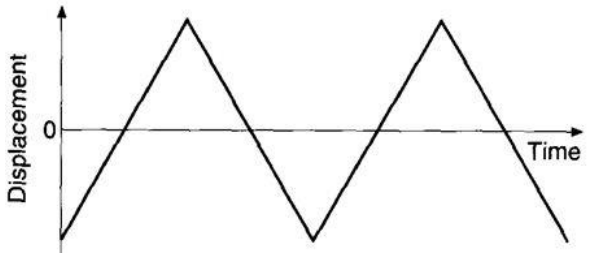


25. At t = 0 a car is stopped at a traffic light. When the light turns green, the car starts to speed up. It gains speed at a constant rate until it reaches a speed of 20 ms^{-1} eight seconds after the light turns green. The car continues at a constant speed for 40 m. Then the driver sees a red light up ahead at the next intersection and starts slowing down at a constant rate. The car stops at the red light, 180 m from where it was at t = 0. Draw accurate a-t, v-t, and s-t graphs for the motion of the car.

26. The graph below shows the variation with time *t* of the displacement *s* of a car. In which time interval is the speed greatest? Explain.



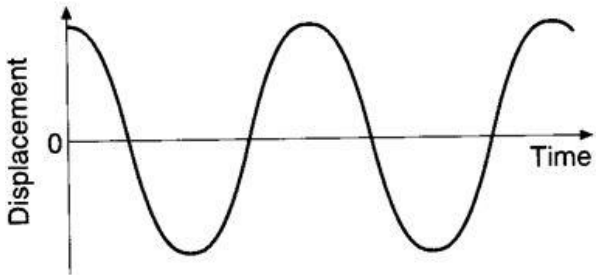
27. This displacement-time graph is for the motion of a glider between two elastic buffers on an air track.



a) From what point on the track is the displacement being measured?

b) Sketch two more graphs, using the same time scale, showing how the velocity and acceleration of the glider vary with time.

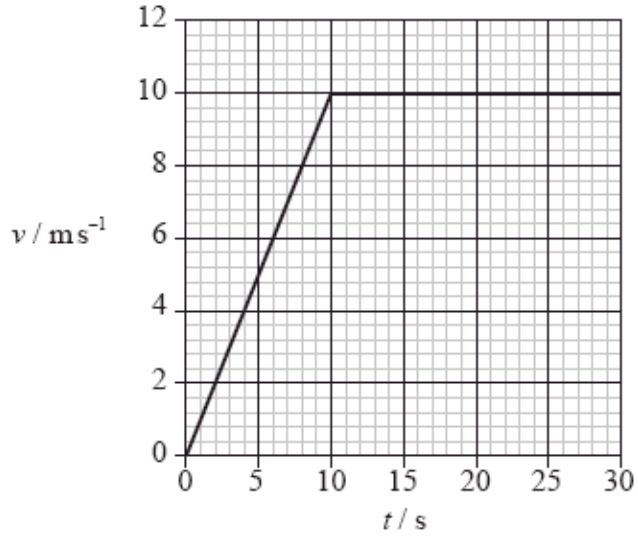
28. This displacement-time graph is for the motion of a swinging pendulum.



a) From what point is the displacement being measured?

b) Sketch two more graphs, using the same time scale, showing how the velocity and acceleration of the pendulum vary with time.

29. Joseph runs along a long straight track, starting from rest at t = 0 s. The variation of his speed v with time t is shown. At t = 25 s, determine:



a) how far he has run **[200 m]**

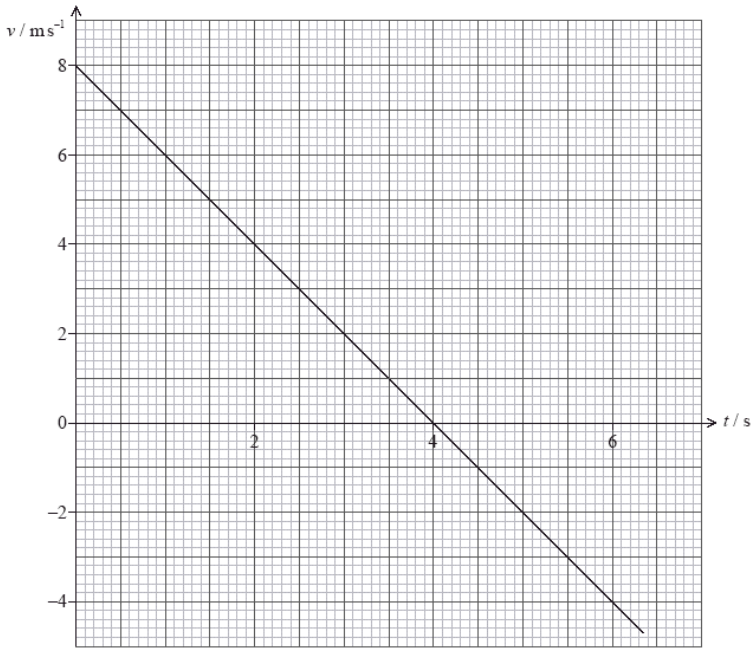
b) his instantaneous speed **[10 ms^{-1}]**

c) his average speed since he started **[8 ms^{-1}]**

d) his instantaneous acceleration **[0 ms^{-2}]**

e) his average acceleration since he started **[0.4 ms^{-2}]**

30. The graph shows the variation with time t of the velocity v of an object moving along a straight line. For the time interval $0 \le t \le 6$ s determine:



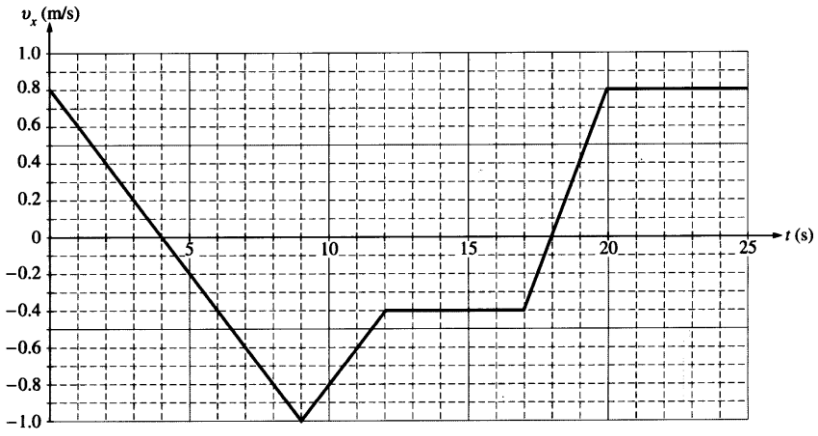
a) the displacement of the object. **[+12 m]**

b) the average speed of the object. **[3.3 ms^{-1}]**

c) the average velocity of the object. **[+2 ms^{-1}]**

d) the acceleration of the object. **[-2 ms^{-2}]**

31. A 0.50 kg cart is moving along a horizontal track. The graph of velocity v_x against time t for the cart is given:



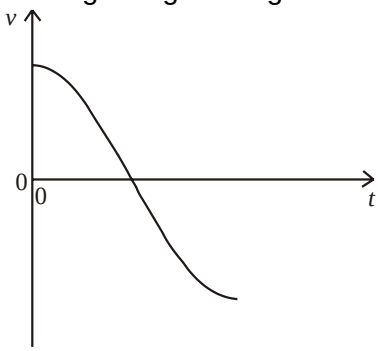
a) Indicate every time t for which the cart is at rest.
[t = 4 s and t = 18 s]

b) Indicate every time interval for which the speed (the magnitude of the velocity) of the cart is increasing.
[from 4-9 s, and from 18-20 s]

c) Determine the horizontal position x of the cart at t = 9.0 s if the cart is located at x = 2.0 m at t = 0.
[+1.1 m]

d) Find the maximum acceleration of the cart and determine the time(s) at which this occurs.
[0.4 ms^{-2} between 17 and 20 s]

32. The graph shows the variation with time *t* of the velocity *v* of an object moving along a straight line. On the same graph, sketch the variation of time *t* of the acceleration *a*.



33. A projectile is fired vertically upwards and reaches a height of 78.4 m. Find the velocity of the projection and the time it takes to reach its highest point. **[+39.2 ms^{-1} , 4.00 s]**

34. A stone dropped from rest down a well takes 1.9 s to hit the surface of the water. Calculate the depth of the well. **[-18 m]**

35. A stone is thrown vertically upwards with an initial velocity of 29.4 ms^{-1} from the top of a tower 34.3 m high. Find:

a) the time taken to reach the maximum height. **[3.00 s]**

b) the total time which elapses before it reaches the ground. **[10.0 s]**

36. A small iron ball is dropped from the top of a vertical cliff and takes 2.5 s to reach the sandy beach below. Find:

a) the velocity with which it strikes the sand. **[-25 ms^{-1}]**

b) the height of the cliff. **[-31 m]**

37. A particle starts from rest and moves in a straight line with a constant acceleration until it reaches a velocity of 15 ms^{-1}. It is then brought to rest again by a constant retardation of 3.0 ms^{-2}. If the particle is then 60.0 m from its starting point, find the time for which the particle is moving. **[8.0 s]**

38. A car brakes with a deceleration of 2.5 ms^{-2} (an acceleration of –2.5 ms^{-2}) Calculate the distance it needs to stop, if its initial speed is

a) 20. ms^{-1} **[80 m]** b) 40. ms^{-1} **[320 m]**

39. An antelope moving with constant acceleration covers the distance between two points 80.0 m apart in 7.00 s. Its speed as it passes the second point is 15.0 ms^{-1}.

a) What is its speed at the first point? **[7.86 ms^{-1}]**

b) What is its acceleration? **[+1.02 ms^{-2}]**

40. One type of airplane has a maximum acceleration on the ground of 3.5 ms^{-2}.

a) For how many seconds must it accelerate along a runway in order to reach its take off speed of 115 ms^{-1} ? **[33 s]**

b) What is the minimum length of runway needed to reach this speed? **[1900 m]**

41. An airplane travels 420 m down the runway before taking off. It starts from rest, moves with constant acceleration, and becomes airborne in 16.0 s. What is its speed, in ms^{-1}, when it takes off? **[53 ms^{-1}]**

42. A bullet travelling at a speed of 110 ms^{-1} penetrates a tree trunk to a depth of 65 mm. Calculate

a) the impact time of the bullet **[1.2×10^{-3} s]**

b) the deceleration of the bullet. **[-9.3×10^{4} ms^{-2}]**

43. Electrons in a particle accelerator are moving at 8.0×10^{5} ms^{-1} when they enter a tube where they are accelerated to 6.5×10^{6} ms^{-1} in 3.0×10^{-7}s.

a) What is their acceleration in the tube? **[$+1.9 \times 10^{13}$ ms^{-2}]**

b) What is the length of the tube? **[1.1 m]**

44. An electron moving at a speed of 1.30×10^5 ms^{-1} travels 20.0 cm through an electric field. It leaves in the same direction with a speed of 9.30×10^5 ms^{-1}. Find:

a) The acceleration of the electron while it is in the electric field. **[$+2.12 \times 10^{12}$ ms^{-2}]**

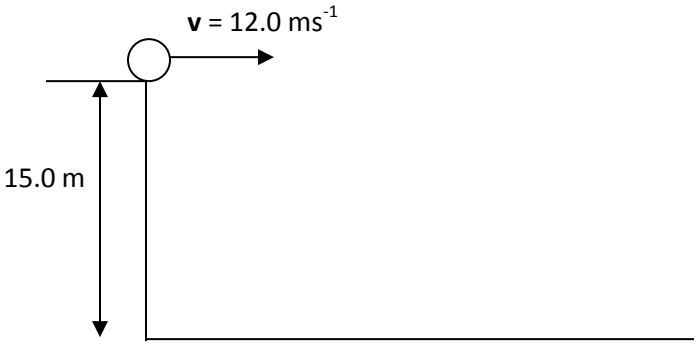
b) The time it spends in the electric field. **[3.77×10^{-7} s]**

45. The human body can survive a negative acceleration trauma incident (sudden stop) if the magnitude of the acceleration is less than 250 ms^{-2} (approximately 25 **g**). If you are in an automobile accident with an initial speed of 88 km/h and are stopped by an airbag that inflates from the dashboard, over what distance must the airbag stop you if you are to survive the crash? **[1.2 m]**

46. A car driver, travelling in his car at a steady speed of 8.0 ms^{-1}, sees a dog walking across the road 30.0 m ahead. The driver's reaction time is 0.20 s, and the brakes of producing a deceleration of 1.2 ms^2. Calculate the distance from where the car stops to where the dog is crossing. **[1.7 m]**

47. Consider a speeding motorist travelling at 140 km/hr along a highway. A police car travelling at 180 km/hr is chasing him but is 10.0 km behind the motorist. How long does it take the police car to catch up to the speeding motorist? **[15 minutes]**

48. A ball is kicked horizontally off a 15.0 m cliff at a velocity of 12.0 m/s as shown. Find:

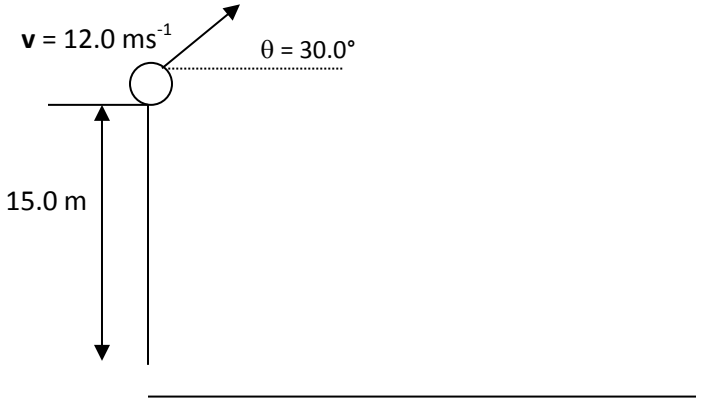


a) the time of flight of the ball. **[1.75 s]**

b) the range of the ball. **[20.1 m]**

c) the velocity of the ball at impact. **[20.9 ms^{-1} at 55.0° below +x axis]**

49. The same ball in the previous exercise is now initially kicked at an angle of 30.0° above the horizontal. Find:



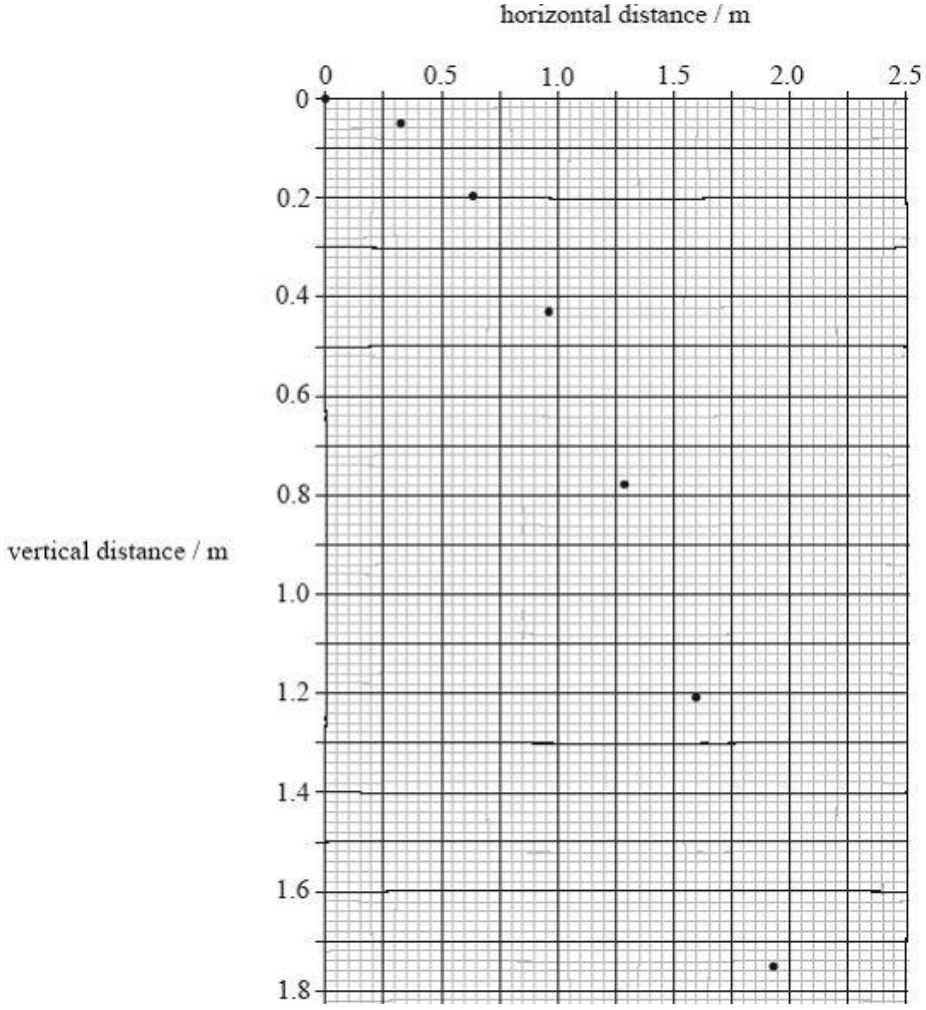
a) the time of flight of the ball. **[2.46 s]**

b) the range of the ball. **[25.6 m]**

c) the velocity at impact. **[20.9 ms^{-1} at 60.3° below the +x axis]**

d) the maximum height of the ball. **[16.8 m]**

50. A sphere is projected horizontally. The sphere is photographed at intervals of 0.10 s. The images of the sphere are shown against a grid on the diagram. Air resistance is negligible.

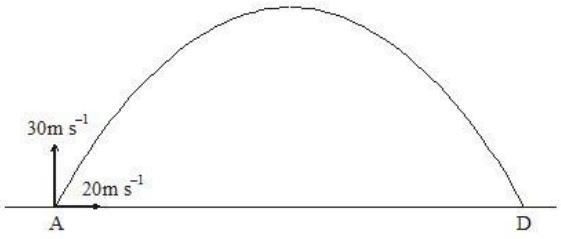


(a) Use data from the diagram to determine the acceleration of free fall. **[9.7 ms^{-2}]**

(b) Determine the speed of the sphere 1.2 s after release. **[12 ms^{-1}]**

(c) On the grid, draw the path of the sphere assuming air resistance is not negligible.

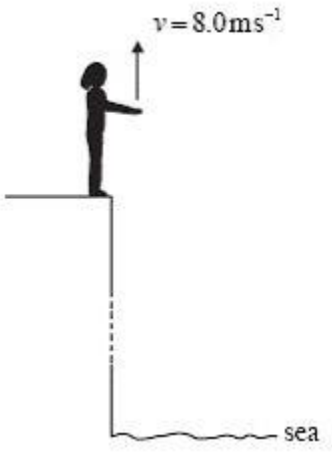
51. A golfer hits a golf ball at point A on a golf course. The ball lands at point D as shown on the diagram. Points A and D are on the same horizontal level. The initial horizontal component of the velocity of the ball is 20 m s^{-1} and the initial vertical component is 30 m s^{-1}. The time of flight of the golf ball between point A and point D is 6.0 s. Air resistance is negligible. Calculate:



a) the maximum height reached by the golf ball. **[45 m]**

b) the range of the golf ball. **[120 m]**

52. A girl stands at the edge of a vertical cliff and throws a stone vertically upwards. The stone leaves the girl's hand with a speed v = 8.0 ms^{-1}. Ignore air resistance and determine:

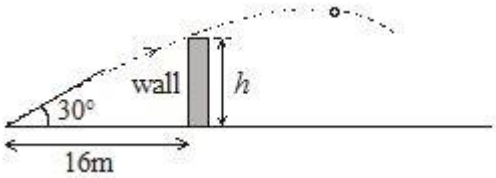


a) the maximum height reached by the stone. **[3.3 m]**

b) the time taken by the stone to reach its maximum height. **[0.80 s]**

c) The time between the stone leaving the girl's hand and hitting the sea is 3.0 s. Determine the height of the cliff. **[21 m]**

53. A ball is projected from ground level with a speed of 28 m s^{-1} at an angle of 30° to the horizontal as shown below.



There is a wall of height h at a distance of 16 m from the point of projection of the ball. Air resistance is negligible. Calculate the initial magnitudes of:

a) the horizontal velocity of the ball; **[24 ms^{-1}]**

b) the vertical velocity of the ball. **[14 ms^{-1}]**

c) The ball just passes over the wall. Determine the maximum height of the wall. **[7.1 m]**