Sample: Physics - Kinematics

QUESTION 1 *(Total Marks: 6)*

A. Explain the difference between scientific models and scientific theories (1 short paragraph).

A scientific theory is a collection of concepts, including abstractions of observable phenomena expressed as quantifiable properties, together with rules (called scientific laws) that express relationships between observations of such concepts.
On the other hand a scientific model is a representation of an object or system, e.g. diagram, equation, etc.

B. For each of the following motions below, state whether the acceleration is **constant** or **not constant**. (For your answer, write either CONSTANT or NOT CONSTANT)

(a) A rock falling from a tall building:

CONSTANT;

(b) A rock thrown upwards from a tall building:

CONSTANT;

(c) A lift moving from the ground floor to the 12th floor making stops along the way:

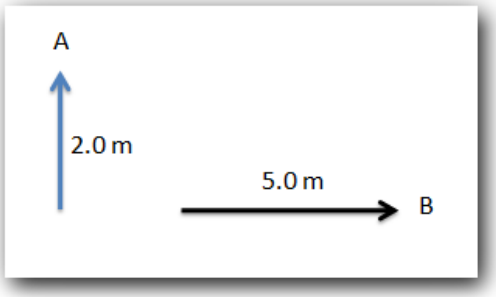
NOT CONSTANT;

(d) A car with it engine switched off rolling down a slope with an angle of 25□:

CONSTANT;

QUESTION 2 *(Total Marks: 3)*

Find the resultant vector **C** by **adding** the two vector quantities **A** and **B** below. Calculate both magnitude and the direction (angle) of the resultant vector.

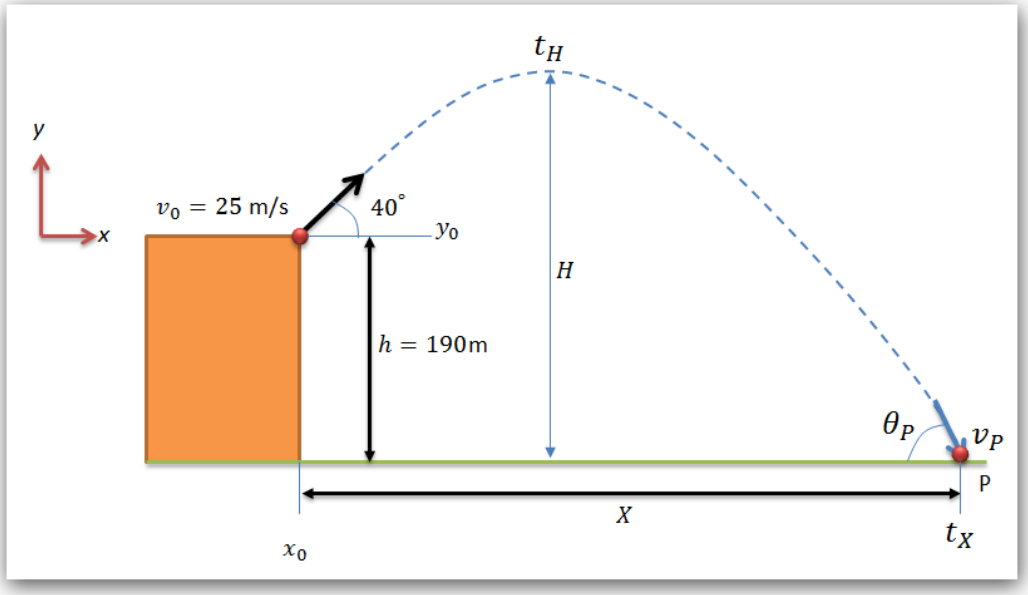


Answer. Vector C has coordinates (5,2). Its magnitude is equal to
$|C| = \sqrt{2^2 + 5^2} = \sqrt{4 + 25} = \sqrt{29}$
The angle of C is

$$\varphi = arctan\frac{}{5} \approx 0{,}380506\ radian \approx 21{,}8°$$

QUESTION 3 *(Total Marks: 12)*

A ball is thrown off the top of a 190 m tall building with an initial speed of 25 m/s at an angle of 40 with the horizontal as shown in the figure below. The ball hits the ground at point P. (*Hint: Study and Complete Problem 31 Chapter 3*)



(a) Find the magnitudes of the horizontal component ( ) and vertical component ( ) of the initial velocity vector ( ).

Answer.

$$_x(0) = 25\cos(40°) \approx 19{,}15 \text{ m/s}$$
$$_y(0) = 25\sin(40°) \approx 16{,}07 \text{ m/s}$$

(b) Is the ball accelerating in the vertical direction? **Why/Why not?**

Answer. In the ideal situation unique force acting on the ball is the gravitation force. It has constant magnitude and directed downward. So the ball accelerates in the vertical direction with acceleration g=9.8 m/s^2.

(c) Is the ball accelerating in the horizontal direction? **Why/Why not?**

Answer. Since gravitation force has no horizontal components, the velocity of the ball in the horizontal direction is constant, so the ball does not accelerates in the horizontal direction.

(d) What is the *vertical velocity* of the ball at its maximum height ?

Answer. At maximum height the *vertical velocity* of the ball is equal to zero.

(e) Calculate the time taken ( ) to reach the maximum height.

Answer. Notice that vertical velocity of the ball changes by the following formula:

$$_y(t) = \ _y(0) - gt$$

At the maximum height $_y(t) = 0$, so the time taken to reach the maximum height can be calculated by the following formula:

$$t = \frac{v_y(0)}{g} = \frac{16{,}07}{9{,}8} = 1{,}64 \text{ s}$$

(f) Calculate the maximum height reached by the ball (*Hint: don't forget the cliff height*).

Answer. The maximum height can be calculated by the following formula:

$$h_{max} = h_0 + \ v_y(0)t + \frac{g\ t^2}{},$$

where $h_0 = 190m$ is the height of the cliff, $_y(0) = \ 16{,}07$m/s and, $t = 1{,}64$s. Thus

$$h_{max} = 190 + 16{,}07 \cdot 1{,}64 + \frac{9{,}8 \cdot 1{,}64^2}{2} = 229{,}53 \text{ m}$$

(g) Calculate the time taken for the ball to fall from its maximum height to the point P on the ground (*Hint: This time will be **different** from the time taken to reach the maximum height from the cliff top calculated in (e) above*).

Answer. The ball moves from the maximal height

$$h_{max} = 229{,}53 \text{ m},$$

with the initial vertical velocity $_y = 0$, whence the time to move to point P can be calculated by the formula:

$$h_{max} = \frac{g\ t^2}{}.$$

Whence

$$t = \sqrt{\frac{h_{max}}{g}} = \sqrt{\frac{\cdot 229{,}53}{9{,}8}} = 46{,}84\ s$$

(h) What is the horizontal velocity of the ball at the instant it hits point P? (*Hint: The answer is NOT zero).*

Answer. The horizontal velocity of the ball will not be changed during all its move, therefore the horizontal velocity of the ball at the instant it hits point is 19,15 m/s

(i) Calculate the vertical velocity of the ball at the instant the ball hits the ground at point P (*Hint: This velocity is **NOT** 25 m/s or the answer you calculated in (d) above or zero.*)?

Answer. The ball moves from the maximal height to the point P by the time $46{,}84\ s$. Its vertical velocity accelerates from the zero velocity with constant acceleration g=9,8m/s^2. Hence the vertical velocity of the ball at point P is equal to

$$_y = gt = 9{,}8 \cdot 46{,}84 = 459{,}06 \text{ m/s}.$$

(j) Calculate the final velocity of the ball at point P. (*Hint: vector addition of the horizontal and vertical components of the final velocity is needed*).

Answer. The final velocity v has the coordinates

$$= (19{,}15\ ;\ -459{,}06).$$

Hence its magnitude it equal to

$$= \sqrt{19{,}15^2 + 459{,}06^2} = 459{,}46\ m/s$$

(k) Calculate the angle the ball makes at the instant it hits the ground at point P.

Answer. The angle the ball makes at the instant it hits the ground at point P is equal to

$$\theta_P = arctan\frac{459{,}06}{19{,}15} = 1{,}53 \text{ rad} = 87{,}6°$$

(l) What is the total time of the ball's flight?

Answer. Using calculations of (e) and (g) we get that the total time of the ball's flight is equal to

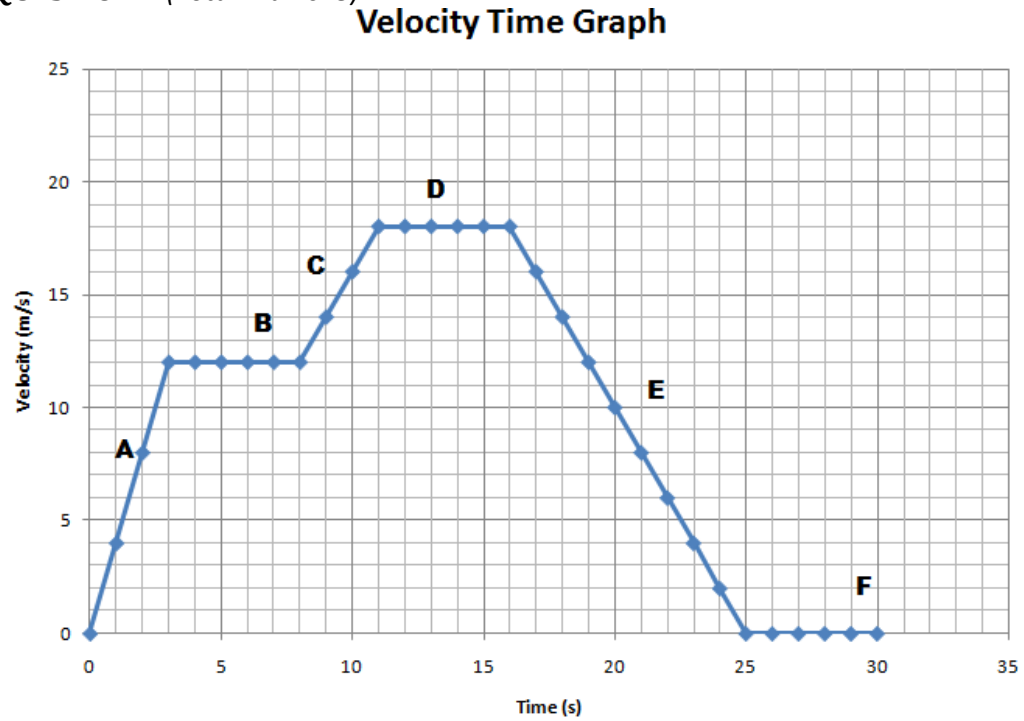
$$1{,}64 + 46{,}84 = 48{,}48\ s$$

(m) Calculate the horizontal distance travelled by the ball.

Answer. Since the ball moves $48{,}48s$ in the horizontal direction with constant velocity $19{,}15$ m/s, it travels the horizontal distance

$$S = 19{,}15 \cdot 48{,}48 = 928{,}4m$$

QUESTION 4 *(Total Marks: 8)*



The *Velocity vs Time* behavior for an object in motion is shown in the graph above.

(a) Identify the region or regions (A, B, C, D, E, F) in which the object is accelerating.

Answer. The object accelerates on the regions A and C.

(b) Calculate the acceleration for **ONE (1)** of the regions in which the object is accelerating.

Answer. Let us calculate the acceleration on the region A. We have that the object pass this region by the time 3s and it change its velocity form 0m/s to 12 m/s, whence its acceleration is equal to

$$= \frac{12}{3} = 4\ m/s^2.$$

(c) In which region or regions (A, B, C, D, E, F) is the object at rest (that is, not moving)?
Answer. The object is at rest **only on region F**. On regions B and D it has constant but non-zero velocity, so it moves on these regions.

(d) How far does the object travel in the first 8 seconds of motion? Show all working for your calculation.
Answer. By the time 8s the object passes regions A and B. It passes region A with zero initial velocity and acceleration 4m/s^2 by 3s, whence the path corresponding to the region A is equal to

$$S_A = \frac{t^2}{} = \frac{4 \cdot 3^2}{} = 18\ m$$

Moreover it passes region B with constant velocity v=12m/s by 5s, so the path corresponding to the region B is equal to

$$S_B = vt = 12 \cdot 5 = 60\ m,$$

whence in the first 8 seconds of motion the object travel

$$S = S_A + S_B = 18 + 60 = 78m.$$

(e) Identify the region or regions (A, B, C, D, E, F) in which the object is decelerating.
Answer. The object decelerates on the region E.