PHYSICS 534

ANSWERS

EXERCISE-30 Free Fall Part-1 /2

HERTZ

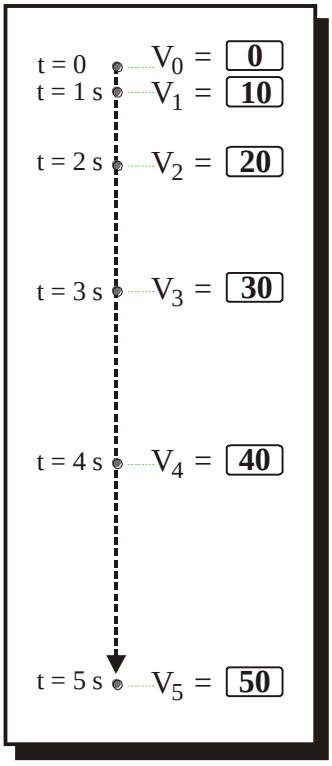
Gustav Hertz was awarded the Nobel prize for physics in 1925 for his work on the impact of electrons on atoms.

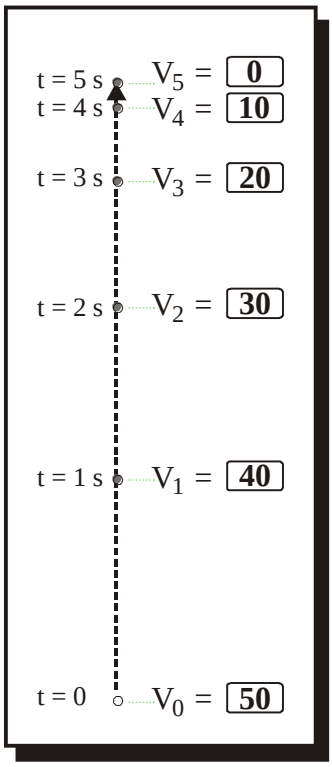
➢ **Note**: **To keep the math as simple as possible, use a value of 10 m/s^2 rather than 9.8 m/s^2 for the Earth's acceleration due to gravity.**

1. As you know, when an object falls from rest, the initial velocity is zero and ***increases*** 10 m/s each second.

a) In the diagram on the right, fill in the velocity, in m/s, for each second the object falls. (You need not include the units)

b) What is the acceleration? **10 m/s^2**





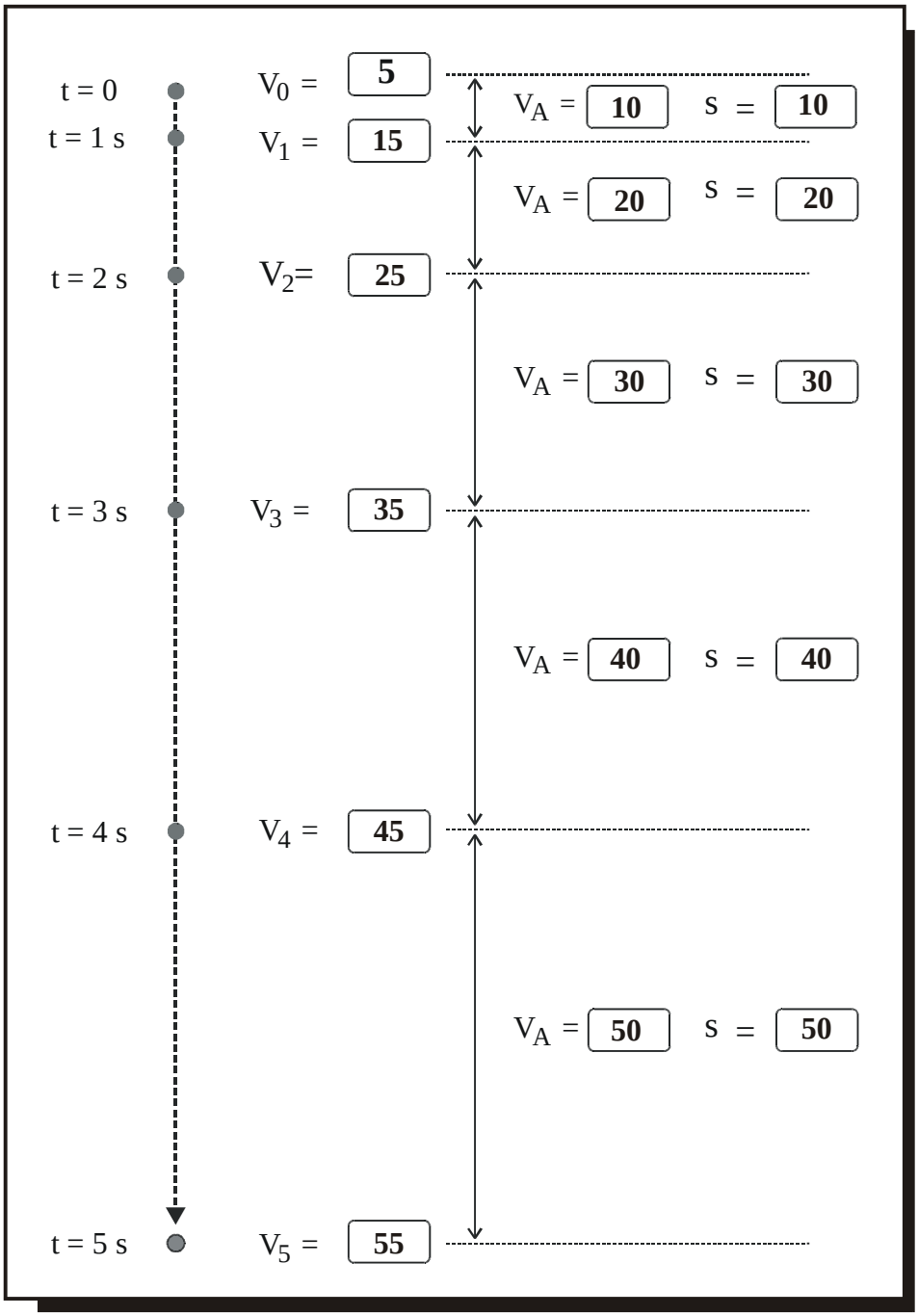
2. When an object is thrown vertically into the air, its velocity **decreases** 10 m/s each second. The diagram on the left illustrates an object with an initial vertical velocity of 50 m/s.

a) Fill in the velocity, in m/s, for each second the object rises. (You need not include the units)

b) What is the acceleration? **-10 m/s^2**

3. A ball is thrown vertically downward with a velocity of 5 m/s. The diagram below illustrates its velocity for a period of 5 seconds.

Fill in the velocities (in m/s), average velocities and distances (in m) as indicated. (You need not include the units)



4. A stone is dropped into a well. Six seconds later, it strikes the bottom of the well. How deep is the well? [180 m]

$$s = v_i t + \frac{1}{2} a t^2$$
$$= 0 + \frac{1}{2}(10\ \text{m/s}^2)(6\ \text{s})^2$$
$$= 180\ \text{m}$$

5. A stone is dropped from a bridge 20 meters above the water. How long does it take the stone to hit the water? [2 s]

$$s = v_i t + \frac{1}{2} a t^2$$
$$20\ \text{m} = 0 + \frac{1}{2}(10\ \text{m/s}^2)t^2$$
$$20\ \text{s}^2 = 5t^2$$
$$t^2 = 4\ \text{s}^2$$
$$t = 2\ \text{s}$$

6. A ball is thrown straight downward from a high cliff with an initial velocity of 5 m/s. After 2 seconds, the ball strikes the ground. What is the height of the cliff? [30 m]

$$s = v_i t + \frac{1}{2} a t^2$$
$$= (5\ \text{m/s})(2\ \text{s}) + \frac{1}{2}(10\ \text{m/s}^2)(2\ \text{s})^2$$
$$= 10\ \text{m} + 20\ \text{m}$$
$$= 30\ \text{m}$$

7. A ball is thrown straight up into the air with a velocity of 20 m/s.

a) For how long does it stay in the air? [4 s]

Calculation of rise time

$v_i = 20\ m/s$

$v_f = 0$

$\Delta v = -20\ m/s$

$\because\ a = \dfrac{\Delta v}{t}$

$\therefore\ t = \dfrac{\Delta v}{a} = \dfrac{-20\ m/s}{-10\ m/s^2} = 2\ s$

Thus, the total time is 4 s (2 s up and 2 s down)

b) How high does it go? [20 m]

$$s = v_i t + \frac{1}{2}at^2 = (20\ m/s)(2\ s) + \frac{1}{2}(-10\ m/s^2)(2\ s)^2 = 40\ m - 20\ m = 20\ m$$

8. From rest, a ball rolls down a smooth (frictionless) inclined plane whose angle of incline is 28^o.

a) What was the acceleration of the ball? [4.7 m/s^2]

$$\mathbf{a = g\,Sin\,A = (10\ m/s^2)(Sin\,28^o) = (10\ m/s^2)(0.4695) = 4.7\ m/s^2}$$

b) How far did it travel after half a second? [0.6 m]

$$\mathbf{s = v_i t + \frac{1}{2}at^2}$$

$$\mathbf{= 0 + \frac{1}{2}(4.7\ m/s^2)(0.5\ s)^2}$$

$$\mathbf{= 0.6\ m}$$

c) How fast was it traveling after two seconds? [9.4 m/s]

$$\mathbf{\because\ a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}}$$

$$\mathbf{\therefore\ v_f = v_i + at}$$

$$\mathbf{= 0 + (4.7\ m/s^2)(2\ s) = 9.4\ m/s}$$

9. A stone is dropped from a helicopter at an altitude of 500 m.

a) How long does it take to strike the ground? [10 s]

$$s = v_i t + \frac{1}{2}at^2$$

$$500\ m = 0 + \frac{1}{2}(10\ m/s^2)t^2 \quad \text{or} \quad 5t^2 = 500\ s^2$$

$$\therefore\ t = 10\ s$$

b) How fast is it travelling after one second? [10 m/s]

Since the acceleration is $10\ m/s^2$ therefore the velocity is $10\ m/s$.

c) What distance does it fall during the ***first*** second? [5 m]

$$s = v_i t + \frac{1}{2}at^2$$

$$= 0 + \frac{1}{2}(10\ m/s^2)(1\ s)^2 = 5\ m$$

d) What distance does it fall during the ***second*** second? [15 m]

Note that during the second second is from $t = 1\ s$ to $t = 2\ s$

Since $v_i = 10\ m/s$ and $v_f = 20\ m/s$ thus $v_A = \frac{v_f + v_i}{2} = \frac{20\ m/s + 10\ m/s}{2} = 15\ m/s$

$s = v_A t = (15\ m/s)(1\ s) = 15\ m$

e) What distance does it fall during the ***third*** second? [25 m]

Note that during the third second is from $t = 2\ s$ to $t = 3\ s$

Since $v_i = 20\ m/s$ and $v_f = 30\ m/s$ thus $v_a = \frac{v_f + v_i}{2} = \frac{30\ m/s + 20\ m/s}{2} = 25\ m/s$

$s = v_A t = (25\ m/s)(1\ s) = 25\ m$

f) What distance does it fall during the time ***interval*** from t = 3 s to t = 7 s? [200 m]

Since $v_i = 30\ m/s$ and $v_f = 70\ m/s$ thus $v_A = \frac{v_f + v_i}{2} = \frac{30\ m/s + 70\ m/s}{2} = 50\ m/s$

$s = v_A t = (50\ m/s)(4\ s) = 200\ m$

10. Starting from rest, a block of wood slides down a smooth incline plane inclined at 40^o. What distance does it travel after two seconds? [12.8 m]

$$a = g\,SinA = (10\,m/s^2)(Sin40^o) = (10\,m/s^2)(0.6429) = 6.4\,m/s^2$$

$$s = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(6.4\,m/s^2)(2\,s)^2 = 12.8\,m$$

11. A ball is thrown downward from a 25 m high balcony with a velocity of 8 m/s. With what velocity does it strike the ground? [24 m/s]

$$2as = v_f^2 - v_i^2$$

$$v_f = \sqrt{2as + v_i^2}$$

$$= \sqrt{2(10\,m/s^2)(25\,m) + (8\,m/s)^2} = \sqrt{564\,m^2/s^2} = 23.7\,m/s = 24\,m/s$$

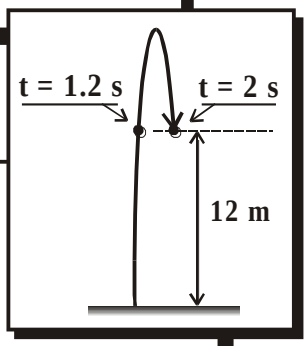
12. Starting from rest, a small sphere rolls down an inclined plane 4 meters long with an acceleration of 40 cm/s^2. How long does it take the sphere to reach the bottom? [4.5 s]

$$s = v_i t + \frac{1}{2}at^2$$

$$4\,m = 0 + \frac{1}{2}(0.4\,m/s^2)t^2$$

$$t = \sqrt{\frac{4\,m}{0.2\,m/s^2}} = 4.47\,s = 4.5\,s$$

13. A stone is thrown upward into the air with a velocity of 16 m/s. Determine the time at which it is at a height of 12 m ***coming down***.



$$s = v_i t + \frac{1}{2}at^2$$

$$12 = 16t + \frac{1}{2}(-10)t^2$$

or $5t^2 - 16t + 12 = 0$

$A = 5 \quad B = -16 \quad C = 12$

$$t = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$= \frac{-(-16) \pm \sqrt{(-16)^2 - 4(5)(12)}}{2(5)}$$

$$= \frac{16 \pm \sqrt{256 - 240}}{10} = \frac{16 \pm \sqrt{16}}{10} = \frac{16 + 4}{10} = \frac{20}{10} = 2\,s$$

6.0 m

14. A cart moving along a horizontal surface at a constant speed of 2.0 m/s travels 6.0 m between point-A and point-B as illustrated in the diagram. A 0.10 kg mass is suspended 20 m above point-B.

How long ***after*** the cart passes point-A should the mass be dropped so that it falls into the center of the cart as the cart passes point-B? [1 s]

Calculation of time mass takes to fall 20 m

$$s = v_i t + \frac{1}{2}at^2$$

$$20\text{ m} = 0 + \frac{1}{2}(10\text{ m/s}^2)t^2$$

or $5t^2 = 20\,s^2$

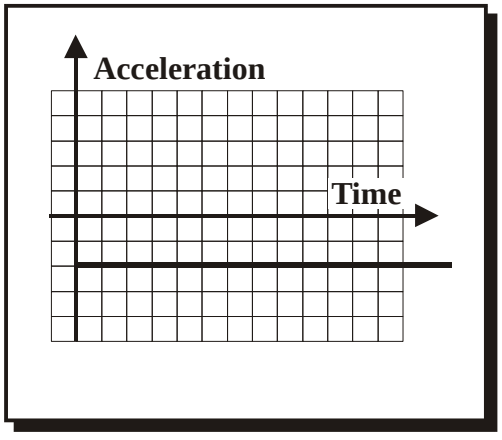
$t = 4\,s$

Calculation of time cart takes to go from point – A to point – B

$$s = v_a t \quad \text{or} \quad t = \frac{s}{v_a} = \frac{6.0\text{ m}}{2.0\text{ m/s}} = 3\,s$$

Answer: $4\,s - 3\,s = 1\,s$

15. An object is thrown vertically upward. Draw the acceleration versus time graph of the object that describes its ***upward motion***.



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