

Free Fall Considerations

- Free fall means to fall only under the influence of the force of gravity
- The resultant force is the objects own weight.
- For objects falling near the surface of the Earth, the acceleration is assumed constant at 10m.s^{-2} .
- The acceleration is independent of the objects mass.
- In other words, large objects and small objects would have the same acceleration.

$$a = \frac{F}{m}$$

but F is the weight

$$a = \frac{mg}{m} \text{ (masses cancel)}$$

$$a = g$$

Free Fall equations

$$v = u + gt$$

$$v^2 = u^2 + 2as$$

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

$$s = \frac{1}{2}t(u + v)$$

v	u	at
v	0	10(3,16)
v	31,6	ms ⁻¹

Example 1

A hot-air balloon is hovering 50m above the ground, when a 2kg sand bag is dropped from it.

$$u = 0$$

$$s = 50\text{m}$$

$$g = 10$$

$$t = ?$$

$$v = ?$$

1.1. How long would it take the sand-bag to land on the ground?

s	ut	$\frac{1}{2}gt^2$
50	0t	$\frac{1}{2}(10)t^2$
50	5t ²	
t	3,16s	

1.2. Calculate the velocity with which the sand-bag will strike the floor.

1.3. What is the resultant force that accelerates the sand-bag? (N.B. F_g is the weight W)

W	m	g
W	2	(10)
W	20	N
F _R	20	N down

1.4. What would be the effect on the resultant force and final velocity if the sand-bag was 5kg.
F_R = 50N down (increased)
v = 31,6m.s⁻¹ (unchanged)

Example 3

3. A man stands on the roof of a tall building. He throws a stone upwards at 30m.s^{-1} , and notices that the stone takes a total of 8s to finally land on the ground. Ignore the height of the man.

3.1. What would the velocity and acceleration of the stone be at its highest point?

v = 0m.s⁻¹ a = 10m.s⁻² down
(The object still has weight at the highest point, so from :
a = F/m the a = mg/m = g = 10m.s⁻² down)

3.2. Calculate the height reached by the stone above the roof.

v ²	u ²	2gs
0	(30) ²	2(10)s
s	45m	

3.3. Calculate the time taken to reach the highest point.

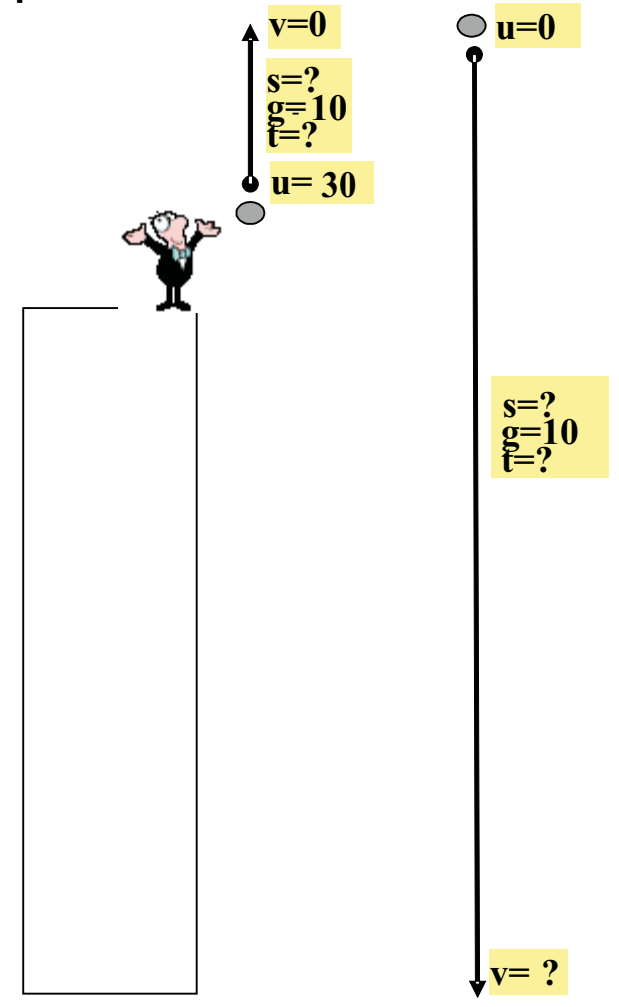
v	u	at
0	30	10t
t	3s	

3.4. How long did the descent take?
Total t = 8s therefore, descent time = 8s - 3s = 5s.

3.5. Determine the height of the building.
125m - 45m = 80m

s	ut	$\frac{1}{2}gt^2$
s	0	$\frac{1}{2}(10)(5)^2$
s	125m	

3.6. Calculate the length of the descent.



Example 2

2. A hot-air balloon is ascending at 4m.s^{-1} . When it reaches a height of 30m, a sand-bag is dropped

2.1. What would the initial velocity of the sand-bag relative to the: from it.

- 2.1.1. balloon? 0m.s^{-1}
2.1.2. ground? 4m.s^{-1} upwards

(This is the velocity the sand-bag started with. The word "dropped" DOES NOT mean u = 0 since the balloon was not at rest.)

2.2. Describe the motion of the sand-bag after it is dropped?
It first ascends on its own, reaches its highest level, and then falls back to the ground.

2.3. Calculate additional height that the sand-bag will reach.

2.4. How long it take the sand-bag to reach this height?

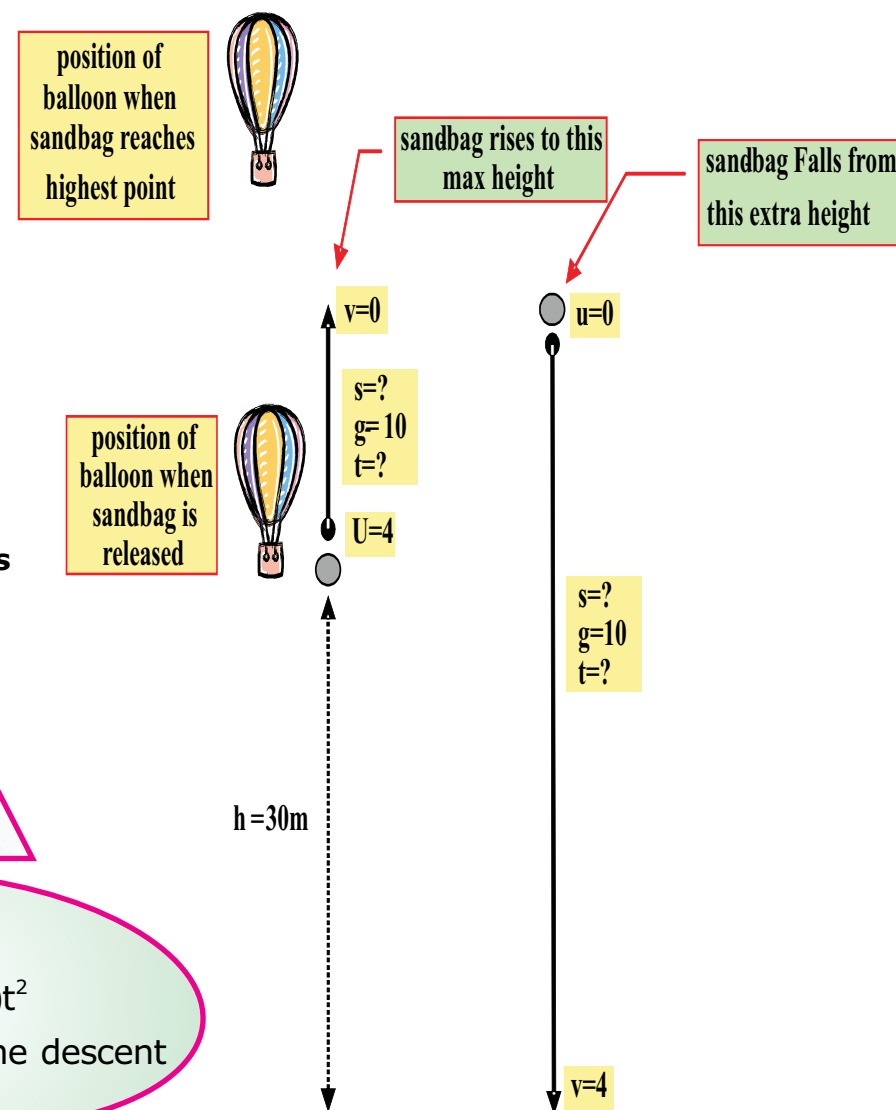
v ²	u ²	2as
0	(4) ²	2(10)s
s	0,8m	

v	u	gt
0	4	10t
t	0,4s	

2.5. How long will it take the sand-bag to land on the ground from the time it was released?

Full height of descent:
30m + 0,8m = 30,8m
Total time = 0,4s + 2,48s = 2,88s

s	ut	$\frac{1}{2}gt^2$
30,8	0	$\frac{1}{2}(10)t^2$
t	2,48s	for the descent



Example 4

Study the following acc-time graph for an object projected vertically upwards at 45m.s^{-1} . The object eventually reached the ground in 12s. Using graph methods, determine the time it took to reach the highest point.

Step 1
Area under acc-time graph = Change in Velocity
 $-10(12) = -120\text{m.s}^{-1}$

Step 2
Draw a vel-time graph and identify the initial velocity of 45m.s^{-1} .

Step 3
The final velocity will be $45 - 120 = -75\text{m.s}^{-1}$

Step 4
Identify -75m.s^{-1} on the v-t graph. (This must correspond with t = 12s)

Step 5
Fill in coordinates (12, -75) and (t, 0)

Step 6
Calculate t from the gradient formula.

The stone took 4,5s to reach the highest point.

grad	$\frac{y}{x}$
10	$\frac{(0 - (-75))}{(t - 12)}$
10	$\frac{75}{(t - 12)}$
t	12
t	12
t	4,5s

