Conceptual Physics I
Classical Mechanics

Lesson 1B – Linear Motion with Constant Acceleration

(free fall)

Lesson 1B - Free Fall

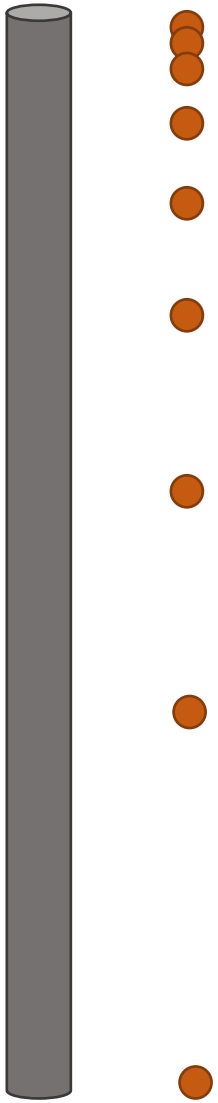
- If gravity is the only thing affecting a falling object, we say the object is in “free fall.”
- This could apply to:

  An object being dropped

  An object thrown upward

  An object thrown downward
- Gravity provides a constant acceleration, always in the “downward” direction.
- The constant acceleration of gravity is denoted as g and is approximately equal to 10 meters/sec per second. This means that gravity is changing the speed of a freely-falling object in the downward direction 10 meters/sec for each second elapsed.

Lesson 1B - Free Fall



Example: A ball dropped off a building (g=10 m/s per second)

Time (s)	Speed (m/s)
0	0
1	10
2	20
3	30
4	40
5	50
6	60
7	70

Lesson 1B - Free Fall

How do you calculate how far something has fallen during free fall?

Case I – Object is Dropped

- The distance traveled turns out to equal the average speed times the time. $v_{avg}t$
- In this case, the average speed during an interval is the beginning speed plus the ending speed divided by 2 (like the usual meaning of average) $v_{avg} = \frac{v_{beg}+v_{end}}{2}$. Since v_{beg}=0 for dropped objects, then

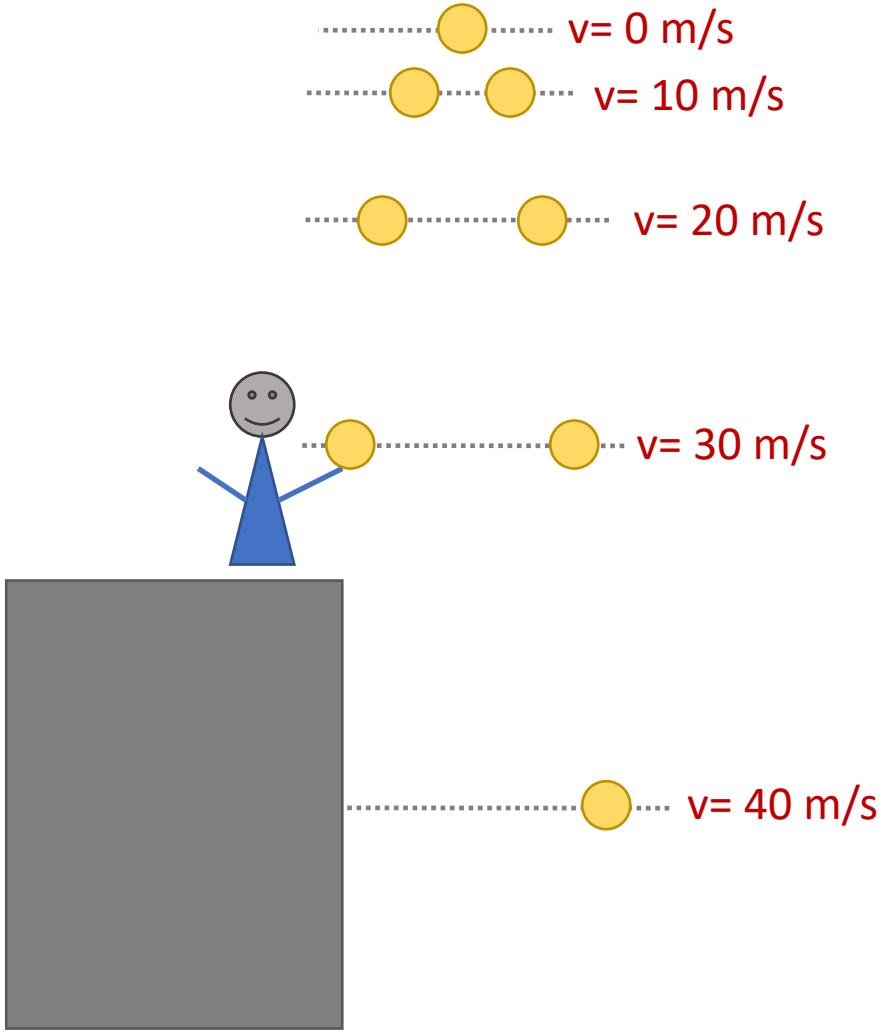
$$v_{avg} = \frac{v_{end}}{2} = \frac{gt}{2}$$

- The easy way to calculate the distance is $\frac{1}{2}gt^2 = 5t^2$

Time (s)	Speed (m/s)	Time squared	Distance traveled (m)
0	0	0	0
1	10	1	5
2	20	4	4x5=20
3	30	9	9x5=45
4	40	16	16x5=80
5	50	25	25x5=125
6	60	36	36x5=180
7	70	49	49x5=245

Extra Problem 1

Lesson 1B - Free Fall



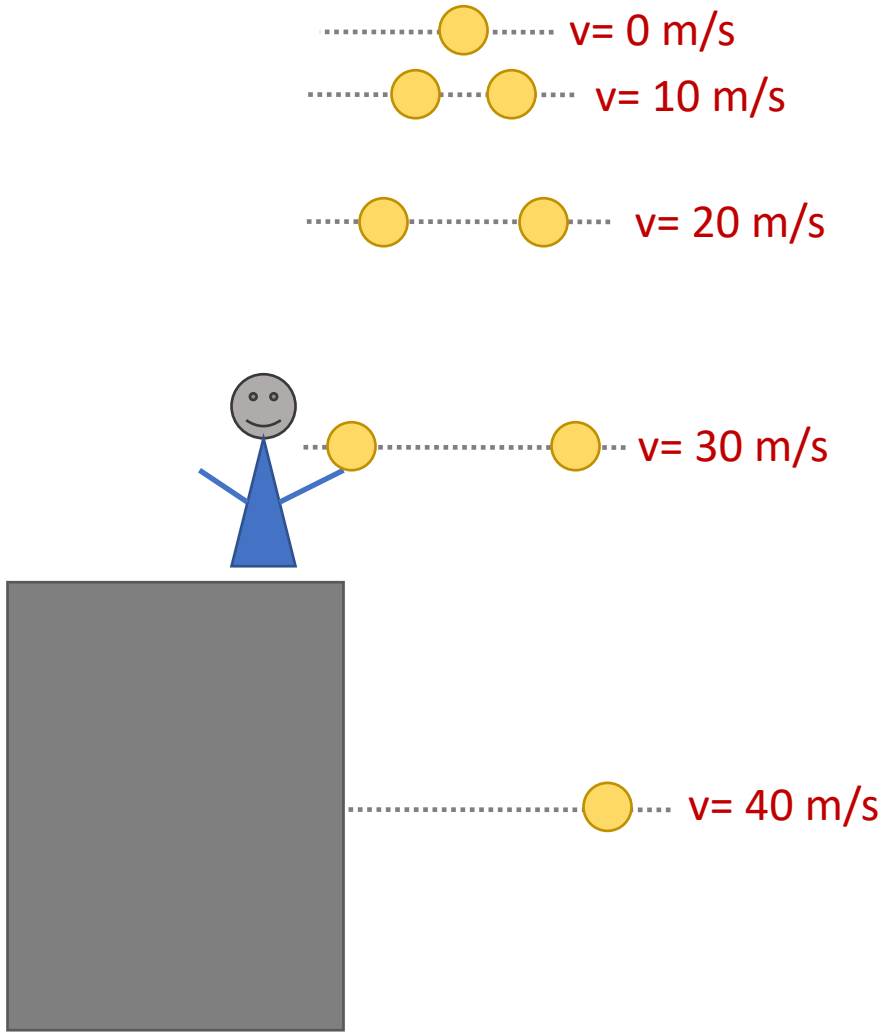
Case II – Object is Thrown Upwards

- Now the object has an initial speed.
- It will travel higher before turning around.
- The distance it travels has two components:

1) the distance it would have traveled based on its initial velocity and without acceleration
2) The distance based on acceleration

Distance = initial velocity x time + $\frac{1}{2}gt^2$

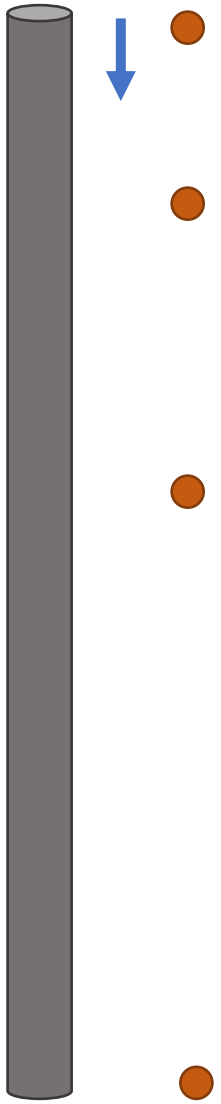
Lesson 1B - Free Fall



Init vel x time 5 x time^2

Time (s)	Speed (m/s)	Distance from initial velocity (m)	Distance from acceleration (m)	Position (m)
0	30	0	0	0
1	20	30	5	30-5=25
2	10	60	4x5=20	60-20=40
3	0	90	9x5=45	90-45=45
4	10	120	16x5=80	120-80=40
5	20	150	25x5=125	150-125=25
6	30	180	36x5=180	180-180=0
7	40	210	49x5=245	210-245=-35

Lesson 1B - Free Fall

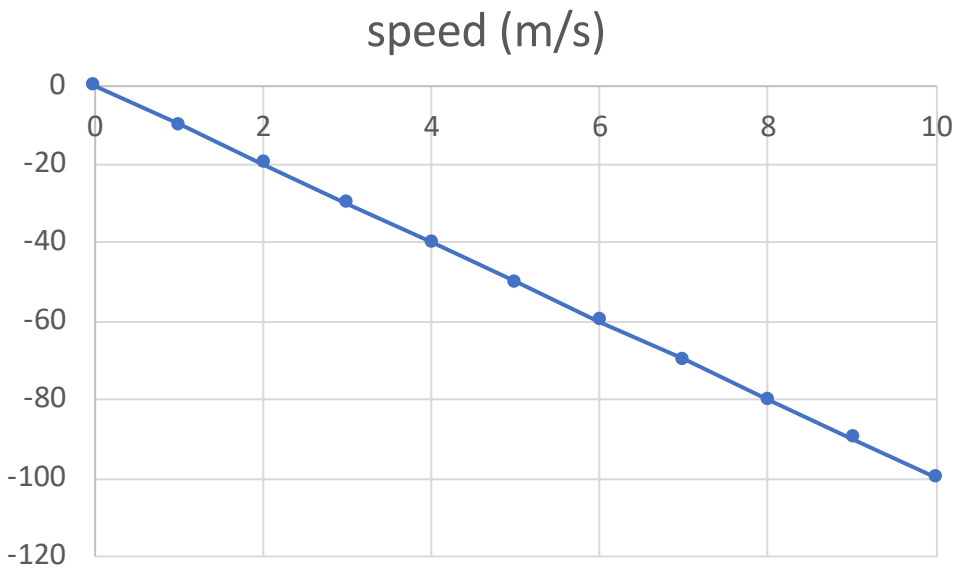


Case III – Object is Thrown Downward

- The distance traveled is calculated much like the case of the object thrown upward
- The distance contributions are added instead of subtracted

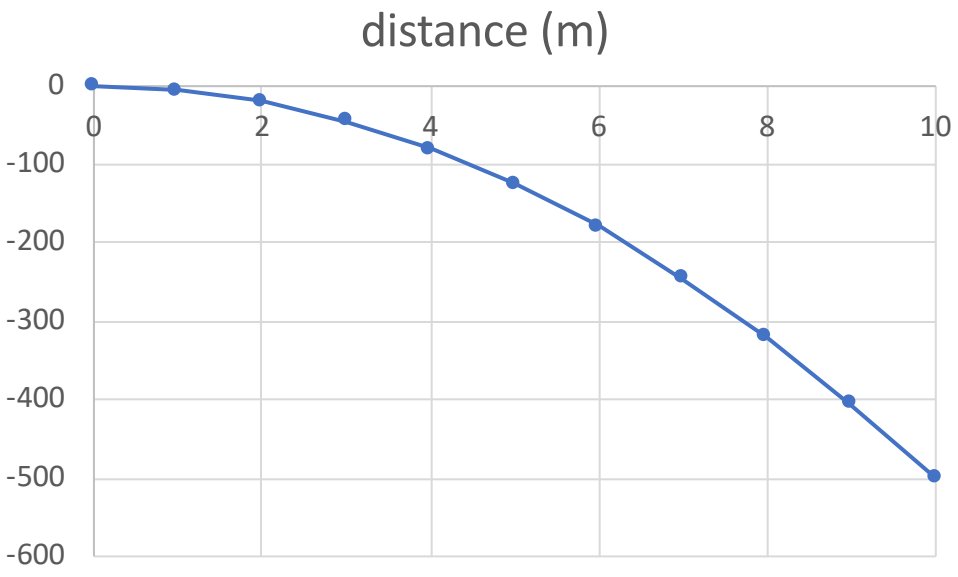
Time (s)	Speed (m/s)	Distance from initial velocity (m)	Distance from acceleration (m)	Position (m)
0	30	0	0	0
1	40	30	5	30+5=35
2	50	60	4x5=20	60+20=80
3	60	90	9x5=45	90+45=135
4	70	120	16x5=80	120+80=200
5	80	150	25x5=125	150+125=275
6	90	180	36x5=180	180+180=360
7	100	210	49x5=245	210+245=455

Lesson 1B - Free Fall from Rest



Time (s)

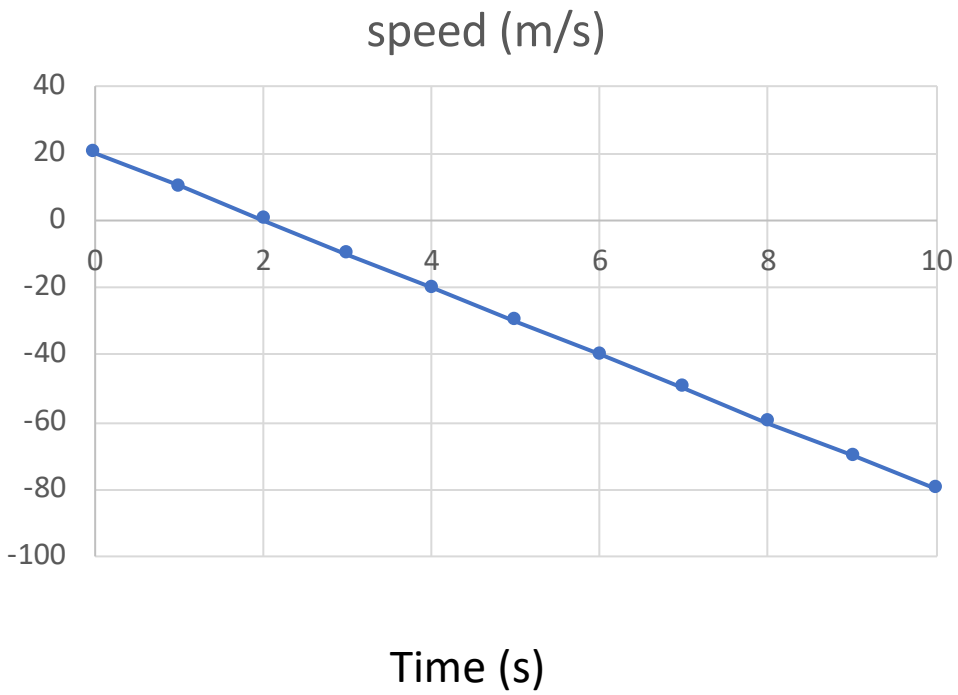
Straight line (constant slope)



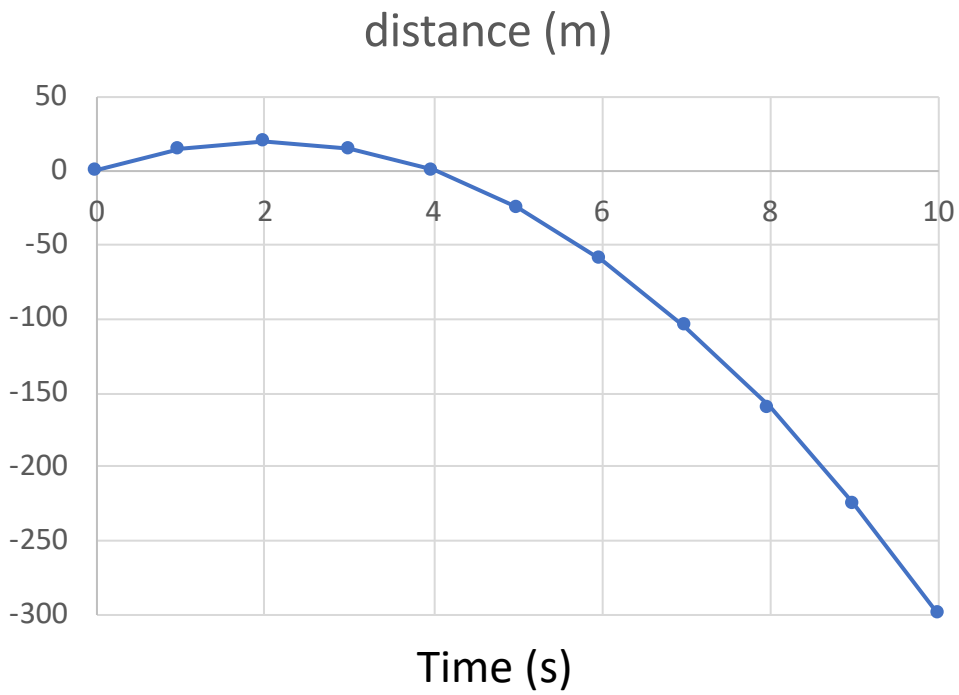
Time (s)

Parabola (increasing slope)

Lesson 1B – Throwing Object Upwards at 20 m/s

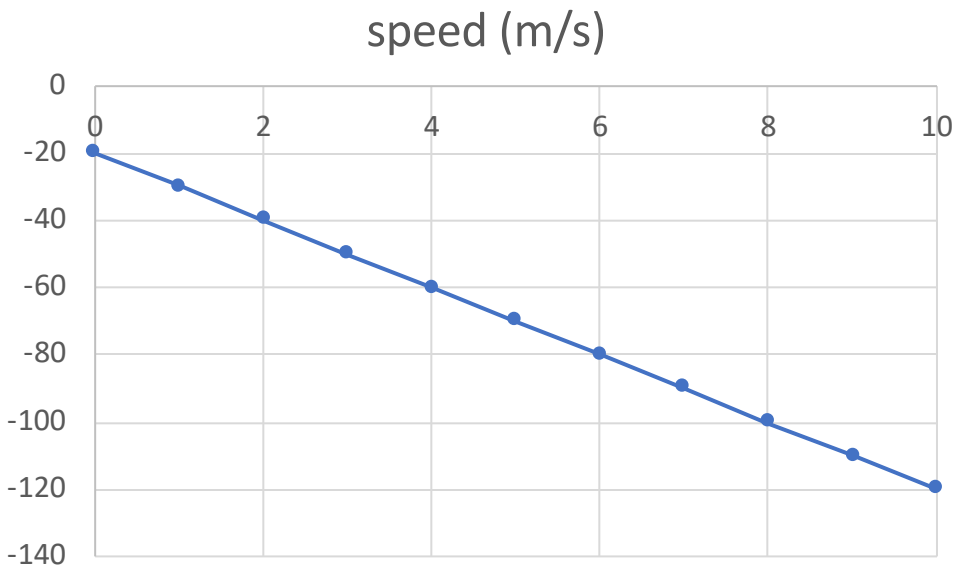


Straight line (constant slope)



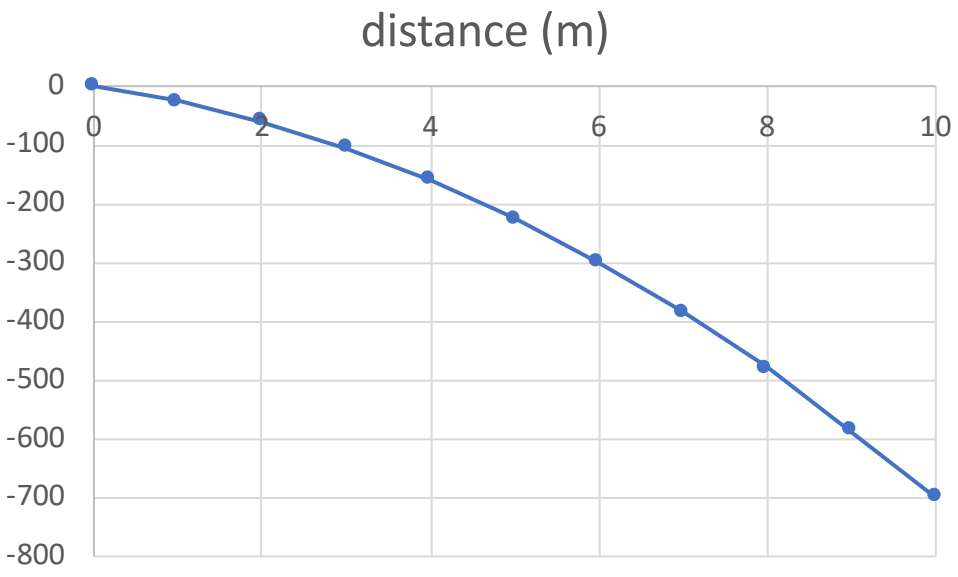
Parabola (increasing slope)

Lesson 1B – Throwing Object Downwards at 20 m/s



Time (s)

Straight line (constant slope)



Time (s)

Parabola (increasing slope)

Lesson 1B - Free Fall

Questions:

1) What is the meaning of free fall? The only influence on the motion is gravity (neglecting air resistance).
2) For a freely falling object dropped from rest, what is the instantaneous speed at the end of the fifth second of fall? 50 m/s What is its acceleration? 10 m/s-s downward
3) Toss a ball upward. What is the change in speed each second on the way up? Decreasing by 10 m/s each second. On the way down? Increasing by 10 m/s each second.
4) A ball is thrown straight up. What will be the instantaneous velocity at the top of its path? Zero. What will be the acceleration at the top? 10 m/s-s downward

Lesson 1B - Free Fall

Questions:

5) What speed is required to throw a ball straight up and have it return 6 seconds later? 30 m/s. How high does it go? It's the same distance it drops from the top of its path to your hand. 5x(3)^2 = 45 meters.