1) A truck on a straight road starts from rest and accelerates at $3.0 \text{ m/s}^2$ until it reaches a speed of $24 \text{ m/s}$. Then the truck travels for $20 \text{ s}$ at constant speed until the brakes are applied, stopping the truck in a uniform manner in an additional $6.0 \text{ s}$.

(a) How long is the truck in motion?

Answer: There are three distinct parts to the truck’s motion. 1) Speeding up; 2) Constant speed; 3) Slowing down. Write what you are given for each of these three stages…

Speeding up: $v_i = 0$ (from rest); $v_f = 24 \text{ m/s}$; $a = 3 \text{ m/s}^2$

Constant speed: $v_i = 24 \text{ m/s}$ (because that is $v_f$ for the first part); $v_f = 24 \text{ m/s}$; $t = 20 \text{ s}$

Slowing down: $v_i = 24 \text{ m/s}$; $v_f = 0 \text{ m/s}$ (it stops); $t = 6 \text{ s}$

Because we already know the times for the second and third parts of the trip, we just need to find the time for the first part. Use $v = v_o + at$ and solve for $t$:

$$t = \frac{v_f - v_i}{a} = \frac{24 \text{ m/s}}{3 \text{ m/s}^2} = 8 \text{ s}$$

Total time = $t_1 + t_2 + t_3 = 8 \text{ s} + 20 \text{ s} + 6 \text{ s} = \boxed{34 \text{ s}}$

(b) What is the average velocity of the truck for the motion described?

$$v_{\text{average}} = \frac{\Delta x}{\Delta t},$$ so you will need to find the total displacement of the truck and divide by the total time that you just calculated in part a.

$$\Delta x_1 = \left(\frac{v_i + v_f}{2}\right)t = \left(\frac{0 + 24 \text{ m}}{2}\right)(8 \text{ s}) = 96 \text{ m}$$

$$\Delta x_2 = \left(\frac{v_i + v_f}{2}\right)t = \left(\frac{24 \text{ m} + 24 \text{ m}}{2}\right)(20 \text{ s}) = 480 \text{ m}$$

$$\Delta x_3 = \left(\frac{v_i + v_f}{2}\right)t = \left(\frac{24 \text{ m} + 0 \text{ m}}{2}\right)(6 \text{ s}) = 72 \text{ m}$$

$$v_{\text{average}} = \frac{\Delta x}{\Delta t} = \frac{96 \text{ m} + 480 \text{ m} + 72 \text{ m}}{34 \text{ s}} = \frac{648 \text{ m}}{34 \text{ s}} = \boxed{19.1 \text{ m/s}}$$

2) A ball is dropped (on earth) from the top of a building. How far does it fall during the first $1.00 \text{ s}$?

Answer: Given: $v_i = 0$ (dropped); $a = +9.8 \text{ m/s}^2$ (defining down as positive direction); $t = 1.00 \text{ s}$; $\Delta x = ?$

$$\Delta x = v_i t + \frac{1}{2} a t^2 = 0 + \frac{1}{2} (9.8 \frac{\text{ m}}{\text{s}^2})(1 \text{ s})^2 = \boxed{4.90 \text{ m}}$$
3) A ball is thrown vertically upward with a speed of 25.0 m/s.

(a) How high does it rise?

Answer: write your given... \( v_i = 25 \text{ m/s} \) (defining up as positive); \( a = -9.80 \text{ m/s}^2 \); \( v_f = 0 \) (at max height); \( \Delta x = ? \)

\[
v_f^2 = v_i^2 + 2a\Delta x
\]

\[
\Delta x = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - (25 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 31.9 \text{ m}
\]

(b) How long does it take to reach its highest point?

\[
t = ?
\]

\[
v_i = v_i + at
\]

\[
t = \frac{v_f - v_i}{a} = \frac{-25 \text{ m/s}}{-9.80 \text{ m/s}^2} = 2.55 \text{ s}
\]

(c) What is its height 3.00 seconds after it is thrown?

\[
\Delta x = v_i t + \frac{1}{2} at^2 = (25 \text{ m/s})(3 \text{ s}) + \frac{1}{2} (-9.80 \text{ m/s}^2)(3 \text{ s})^2 = 30.9 \text{ m}
\]

(d) What is its velocity 4.00 seconds after it is thrown?

\[
v_f = v_i + at = (25 \text{ m/s}) + (-9.8 \text{ m/s}^2)(4 \text{ s}) = -14.2 \text{ m/s}
\]
5. If a ball is thrown upwards with twice the initial speed of another. How much higher will it be at its apex?

   (A) 8 times  (B) 4 times  (C) 2 times  (D) 16 times  (E) the same height

   Answer: (B). At apex \( v_f = 0 \). Using \( v_f^2 = v_i^2 + 2a\Delta x \) and solving for \( \Delta x \) you see \( \Delta x = \frac{v_f^2 - v_i^2}{2a} \)

   Because \( v_f = 0 \), \( \Delta x \) is proportional to \( v_i^2 \). With twice the \( v_i \) you get 4 times the \( \Delta x \).

6. A car starts from rest and uniformly accelerates to a final speed of 20.0 m/s in a time of 15.0 s. How far does the car travel during this time?

   (A) 150 m  (B) 300 m  (C) 450 m  (D) 600 m  (E) 800 m

   Answer: (A) \( \Delta x_2 = \left( \frac{v_i + v_f}{2} \right) t = \left( \frac{0 + 20}{2} \right)(15 \text{ s}) = 150 \text{ m} \)
7. Position as a function of time of two moving objects is presented by the graph. Which of the following statements is true?

I. Object II has a greater velocity than object I
II. Object II has a greater acceleration than object I
III. At time \( t_0 \) they have the same velocity
IV. At time \( t_0 \) object II passes by object I

A. I only           B. I, II, and IV only          C. I and IV only        D. III and IV only       E. II and IV only

Answer: (C). Lets look at each choice…

I. Object II has a greater velocity than object I (true! Slope of x vs. t equals velocity)
II. Object II has a greater acceleration than object I (no! both have \( a = 0 \))
III. At time \( t_0 \) they have the same velocity (no! slope = velocity)
IV. At time \( t_0 \) object II passes by object I (true! At same position and II is faster)

8. In which of the following situations would an object be accelerated?
I. It moves in a straight line at constant speed.
II. It moves with uniform circular motion.
III. It travels as a projectile in a gravitational field with negligible air resistance.

(A) I only     (B) III only      (C) I and II only      (D) II and III only      (E) I, II, and III

Answer: (D) This involves 2d motion, so is not really appropriate for this test. However, the correct answer is (D). Acceleration means changing velocity, which can change in magnitude or direction.
Questions 9, 10, and 11 refer to the motion of a toy car traveling along the x-axis. The graph shown below is a plot of the car’s velocity in the x direction, \( v_x \), versus time, \( t \).

9. During what time interval was the car moving towards its initial position at constant velocity?
   (A) 0-10 s          (B) 10-20 s          (C) 20-25 s          (D) 25-30 s          (E) 30-35 s

Answer: (D). On \( v \) vs. \( t \), constant velocity means horizontal. Moving towards initial position means velocity is negative (since it started out positive).

10. What was the acceleration at 33 s?
    (A) + 0.40 m/s\(^2\)          (B) + 0.20 m/s\(^2\)          (C) 0          (D) - 0.20 m/s\(^2\)          (E) - 0.40 m/s\(^2\)

Answer: (B). On \( v \) vs. \( t \) acceleration = slope. Slope = (0 - 1m)/(5 s – 0) = 0.2 m/s\(^2\)

11. How far did the car travel during the first 15 seconds?
    (A) 0            (B) 3.0 m            (C) 15 m            (D) 30 m            (E) 45 m

Answer: (D). Because acceleration changed at \( t = 10s \), you need to break this into two parts.

From 0 to 10 s, average \( v = 1.5 \) m/s \( t = 10s \) \( \Delta x = (1.5 \) m/s\)*\( 10 \) s = 15 m
From 10 to 15 s, average \( v = 3 \) m/s \( t = 5s \) \( \Delta x = (3 \) m/s\)*\( 5 \) s = 15 m

\( \Delta x \) total = 30 m.
At time $t = 0$, car X traveling with speed $v_0$ passes car Y, which is just starting to move. Both cars then travel on two parallel lanes of the same straight road. The graphs of speed $v$ versus time $t$ for both cars are shown above. Use this graph for questions 13 and 14.

13. Which of the following is true at time $t = 20$ seconds?

(A) Car Y is behind car X
(B) Car Y is passing car X
(C) Car Y is in front of car X
(D) Both cars have the same acceleration
(E) Car X is going faster than car Y

Answer: (A) Y has a smaller velocity than X for the whole 20 s. Therefore, it is behind.

14. Which of the following is true at time $t = 40$ seconds?

(A) Car Y is behind car X
(B) Car Y is passing car X
(C) Car Y is in front of car X
(D) Both cars have the same acceleration
(E) Car X is going faster than car Y

Answer: (B) both cars have the same average velocity for the 40 seconds, so they have gone the same distance, and Y is going faster. It must be passing car X.