Physics 151
February 16, 2007

Roster No.: SOLUTIONS

Score: Part A: 20 pts. possible
Entire Exam: 50 pts. total (+2 pts. Bonus)

Midterm Exam #1, Part A

Exam time limit: 50 minutes. You may use a calculator and both sides of ONE sheet of notes, ***handwritten only.*** **Closed book; no collaboration.** Ignore friction and air resistance in all problems, unless told otherwise.

Part A: For each question, fill in the letter of the one best answer on your bubble answer sheet.

Physical constants: $g = 9.80\ \text{m/s}^2$

(2 pts. each) **Convert** the following quantities into the given units:

1. 550 nm = ________________ m

A. 5.5×10^{-10} m
B. 5.5×10^{-7} m
C. 5.5×10^{8} m
D. 5.5×10^{9} m
E. 5.5×10^{11} m

$$550\ \cancel{\text{nm}} \cdot \left(\frac{10^{-9}\ \text{m}}{1\ \cancel{\text{nm}}} \right) = 5.5 \times 10^{-7}\ \text{m}$$

2. 1.3×10^{-8} kg = ________________ μg

A. 1.3×10^{-5} μg
B. 0.013 μg
C. 13 μg
D. 1.3×10^{4} μg
E. 1.3×10^{7} μg

$$1.3 \times 10^{-8}\ \cancel{\text{kg}} \cdot \left(\frac{1000\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \right) \left(\frac{1\ \mu\text{g}}{10^{-6}\ \cancel{\text{g}}} \right) = 13\ \mu\text{g}$$

3. $4.4\ \text{m}^2$ = ________________ cm^2

A. $4.4 \times 10^{-4}\ \text{cm}^2$
B. $0.044\ \text{cm}^2$
C. $440\ \text{cm}^2$
D. $4.4 \times 10^{4}\ \text{cm}^2$
E. $4.4 \times 10^{6}\ \text{cm}^2$

$$4.4\ \cancel{\text{m}^2} \left(\frac{100\ \text{cm}}{1\ \cancel{\text{m}}} \right)^2 = 4.4 \times 10^{4}\ \text{cm}^2$$

You know that your friend's car starts at UH Manoa at 1:30 p.m. and finally arrives at Aloha Tower at 2:15 p.m., but you don't know the route that your friend took. (It is not necessarily the shortest or most efficient route, and it may have included stops, detours, or side trips.) The straight-line distance ("as the bird flies") between UH Manoa and Aloha Tower is 4.8 km, but the car's final odometer reading shows that the car traveled a total distance of 8.5 km from start to finish.

4. (2 pts.) What is the magnitude of the car's **average velocity** over the entire trip?

A. 5.5 km/h
B. 6.4 km/h
C. 7.7 km/h
D. 9.1 km/h
E. 11 km/h

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{4.8\ \text{km}}{0.75\ \text{h}} = \boxed{6.4\ \frac{\text{km}}{\text{h}}}$$

← displacement from origin

5. (2 pts.) What was the car's **average speed** over the entire trip?

A. 5.5 km/h
B. 6.4 km/h
C. 7.7 km/h
D. 9.1 km/h
E. 11 km/h

$$\text{speed}_{av} = \frac{\text{total distance traveled}}{\Delta t} = \frac{8.5\ \text{km}}{0.75\ \text{h}} = \boxed{11.3\ \frac{\text{km}}{\text{h}}}$$

6. (1 pt.) A **scalar** is a physical quantity which…

A. never has a negative value
B. never has a zero value
C. has only one digit
D. has no units
E. has no direction

Vectors have both "magnitude" (value, including units) AND direction; scalars have only a value, but NO directional sense.

$v = v_0 + at, \quad x = x_0 + v_0 t + \frac{1}{2}at^2, \quad v^2 = v_0^2 + 2a \cdot \Delta x$

7. (1 pt.) Our **3 main equations of kinematics** CANNOT be used for which one of the following cases?

A. An object whose acceleration varies over time
B. An object whose velocity varies over time
C. An object whose acceleration is zero at all times
D. An object with a force acting on it
E. An object in freefall (near the surface of the Earth)

These equations can only be used over time intervals during which acceleration is constant (unchanging), so "A" is NOT valid.

Valid cases: B: constant non-zero accel. ⇒ changing velocity! So, $\Delta v/\Delta t$ is okay.
C: constant acceleration includes $a = 0$ (a constant value of zero).
D: constant accel. ⇒ ΣF = constant, so there can be one or more forces acting on m.
E: freefall ⇒ $a_y = -g$, a constant.

8. (1 pt.) Which one of the following is equal to a **newton**?

A. kg/s^2
B. $kg{\cdot}m/s$
C. $kg{\cdot}m/s^2$
D. $kg{\cdot}m^2/s^2$
E. $kg^2{\cdot}m^2/s^2$
F. scrumptious dried fruit with a delightful cookie coating

[force] = [mass]·[acceleration]
⇒ $[N] = [kg] \cdot [\frac{m}{s^2}]$

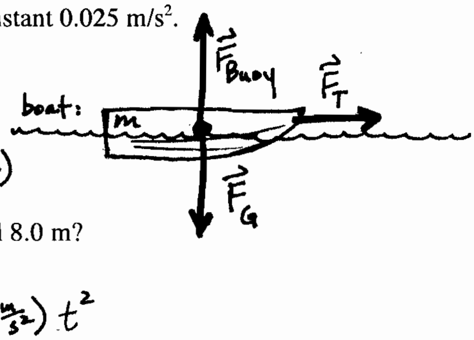
9. (1 pt.) On Earth, which one of the following statements about **weight** is TRUE?

A. An object's weight always has a magnitude of $m{\cdot}g$ – Yes!
B. Weight always points perpendicular to the surface of contact. – No, always points toward center of Earth.
C. Valid units for weight include pounds (British) and kilograms (MKS system). – No, pounds and newtons.
D. An object's weight depends on the velocity of the object. – No, independent of $\vec{v}$.

A 2350-kg motorboat is at rest. Standing on a nearby dock, its owner pulls with a constant horizontal force on a rope tied to the boat. As a result, the boat accelerates horizontally at a slow but constant 0.025 m/s^2.

10. (2 pts.) What is the magnitude of the **tension force** in the rope?

A. 41 N
B. 59 N
C. 71 N
D. 89 N
E. 110 N



$\Sigma F_x = m \cdot a_x$
$F_T = m \cdot a_x$
$= (2350 \text{ kg})(0.025 \text{ m/s}^2)$
$\boxed{F_T = 58.8 \text{ N}}$

11. (2 pts.) Starting from rest, how much **time** will it take for the boat to travel 8.0 m?

A. 19 s
B. 22 s
C. 25 s
D. 28 s
E. 31 s

$x = x_0 + v_0 t + \frac{1}{2}at^2$
$8.0\text{m} = 0 + 0 + \frac{1}{2}(0.025 \frac{m}{s^2}) t^2$
⇒ $\boxed{t = 25.3 \text{ s}}$

12. (2 pts.) Instead of "normal" force, the supportive force of the water acting upward on the boat is called the "buoyancy" force. If the boat never has any vertical motion, what is the magnitude of the **buoyancy force**?

A. 240 N
B. 9800 N
C. 12,000 N
D. 23,000 N
E. 180,000 N

$\Sigma F_y = m \cdot a_y$
$F_B - F_G = m(0)$
⇒ $F_B = F_G = m \cdot g = (2350 \text{ kg})(9.80 \text{ m/s}^2)$
⇒ $\boxed{F_B = 23{,}030 \text{ N}}$

Physics 151
February 16, 2007

Roster No.: SOLUTIONS

Score: Part B: 30 pts. possible

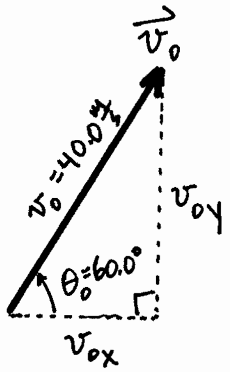
Midterm Exam #1, Part B

Part B: Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers. For any multiple-choice questions, circle the letter of the one best answer (unless more than one answer is asked for).

1. At Mike's old college, the clever (and rascally) students had a pastime called "funnelation": the use of a huge slingshot made from a funnel and rubber tubing to launch water balloons over the roof of one dorm into the courtyard of another.

Suppose that Mike's "funnelator" gives all water balloons an initial velocity v_0 of 40.0 m/s (almost 90 mph!). Mike aims his slingshot at an angle of 60.0° above the horizontal, on *level ground*, and fires one balloon. (Ignore air resistance for this entire problem. Assume that the water balloon is launched from the origin, and that the $+y$-direction is upward.)

a. (4 pts.) Calculate $\mathbf{v}_{0x}$ **and** $\mathbf{v}_{0y}$ (the x- and y-components of the initial velocity $\mathbf{v}_0$) for the water balloon. Show your work clearly.



For any vector, if magnitude and direction are given, then components are:

$$v_{0x} = v_0 \cdot \cos\theta_0 = \left(40.0\tfrac{m}{s}\right)\cos(60.0°) = \boxed{20.0\tfrac{m}{s}}$$

$$v_{0y} = v_0 \cdot \sin\theta_0 = \left(40.0\tfrac{m}{s}\right)\sin(60.0°) = 34.64\tfrac{m}{s} = \boxed{34.6\tfrac{m}{s}}$$

b. (4 pts.) What is the water balloon's total **time** of flight? (*Recall:* The launch and landing take place on *level ground.*) Clearly show your work and/or explain your reasoning.

Let: $y_0 = 0\,m$. Also know: $v_{0y} = 34.64\tfrac{m}{s}$, $a_y = -9.80\tfrac{m}{s^2}$.

At what time t does projectile arrive at $y_f = 0\,m$?

$$y_f = y_0 + v_{0y} \cdot t + \tfrac{1}{2} a_y t^2$$

$$0\,m = 0\,m + \left(34.64\tfrac{m}{s}\right)\cancel{(t)} + \tfrac{1}{2}\left(-9.80\tfrac{m}{s^2}\right) \cdot t^{\cancel{2}}$$

$$\Rightarrow \boxed{t = 7.07\,s}$$

OR: We can use symmetry of projectile's path to see that time of ascent = time of descent.

Solving for time of ascent: t_{peak}, knowing that $\underline{v_y = 0}$ at peak:

$$(v_y)_{peak} = v_0 + a_y \cdot t_{peak}$$

$$0\tfrac{m}{s} = 34.64\tfrac{m}{s} + \left(-9.80\tfrac{m}{s^2}\right) t_{peak}$$

$$\Rightarrow \underline{t_{peak} = 3.535\,s}.$$

$$\therefore t_{total} = 2 \cdot t_{peak} = \boxed{7.07\,s}$$

Continued next page…

1. continued:

Let: $y_0 = 0\,m$.

Know: $v_{0y} = 34.64\,\frac{m}{s}$, $a_y = -9.80\,\frac{m}{s^2}$.

c. (4 pts.) What **maximum height** does the water balloon reach?

We know that $\underline{v_y = 0}$ at peak:

$$(v_y)_{pk}^2 = v_{0y}^2 + 2 \cdot a_y \cdot (\Delta y)_{pk}$$

$$0^2 = (34.64\,\tfrac{m}{s})^2 + 2(-9.80\,\tfrac{m}{s^2})(\Delta y)_{pk} \Rightarrow \Delta y_{pk} = 61.22\,m = \boxed{61.2\,m}$$

$\boxed{\text{OR:}}$ We found in part (b) that $t_{pk} = 3.535\,s$. Then:

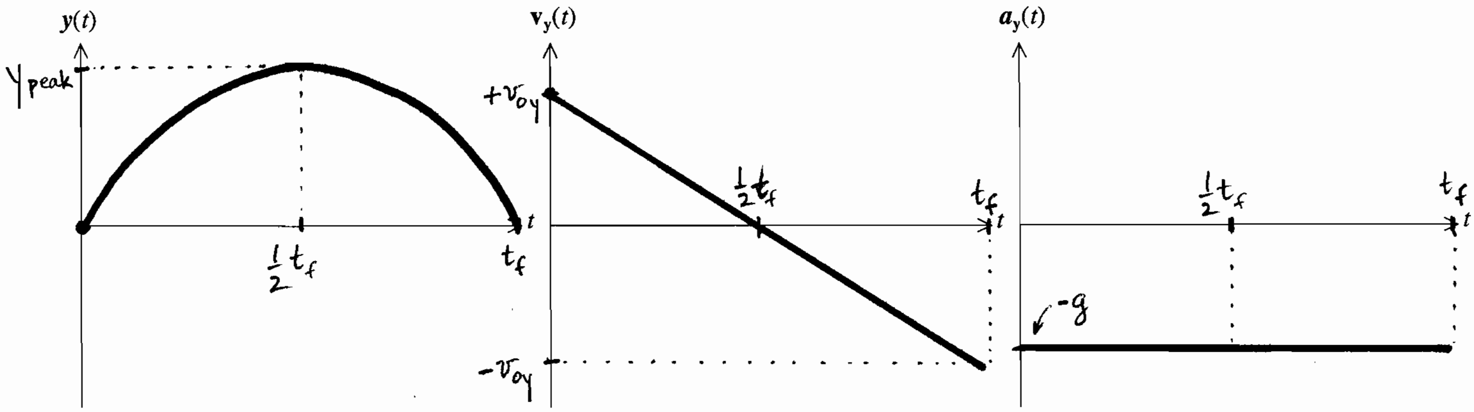
$$y_{pk} = y_0 + v_{0y} \cdot t_{pk} + \tfrac{1}{2} a_y t_{pk}^2$$

$$y_{pk} = 0 + (34.64\,\tfrac{m}{s})(3.535\,s) + \tfrac{1}{2}(-9.80\,\tfrac{m}{s^2})(3.535\,s)^2$$

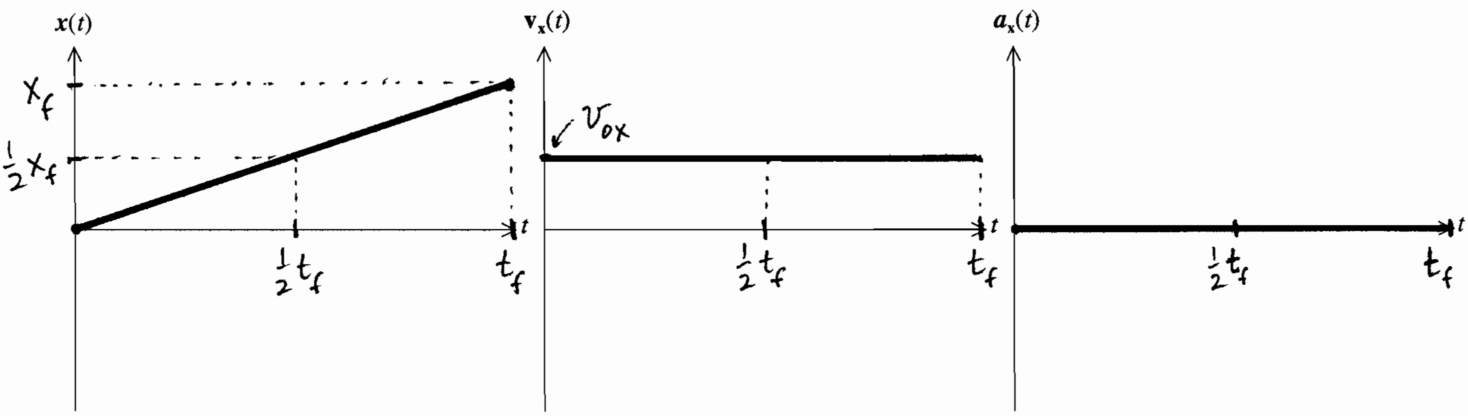
$$y_{pk} = 61.22\,m$$

$$\boxed{y_{pk} = 61.2\,m}$$

d. (5 pts.) On the three pairs of axes below, *qualitatively* (without precise numerical values) graph the projectile's **VERTICAL** components of **position**, **velocity**, and **acceleration**, from *launch to landing*:

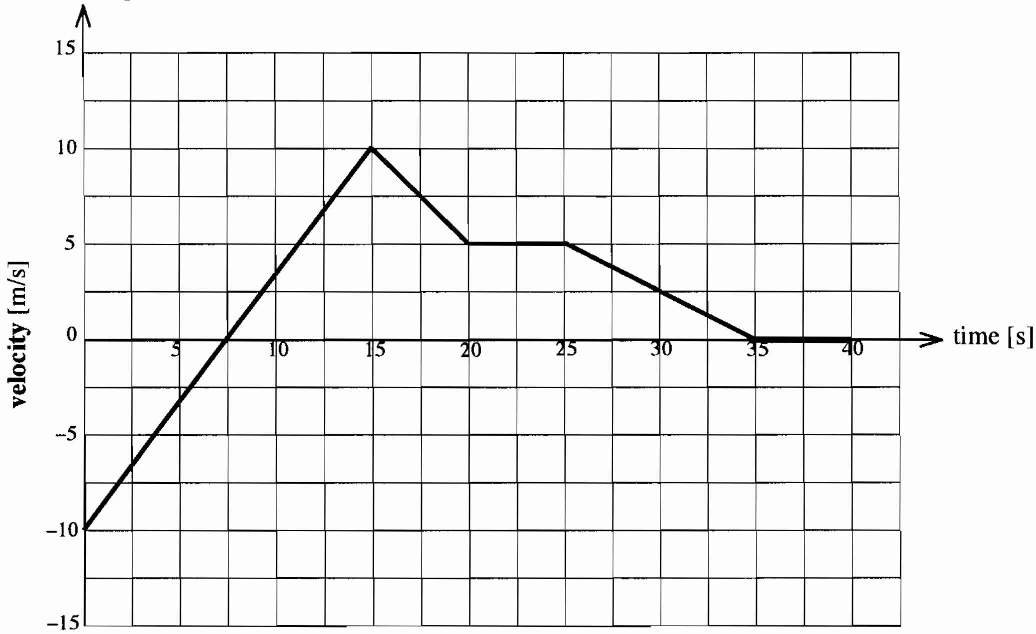


e. (3 pts.) On the three pairs of axes below, *qualitatively* (without precise numerical values) graph the projectile's **HORIZONTAL** components of **position**, **velocity**, and **acceleration**, from *launch to landing*:



2. A small spacecraft is constrained to move only along the x-axis. It faces in the $+x$ direction. The spacecraft has two rocket thrusters that can be used to accelerate it along the x-axis with either constant positive or constant negative acceleration. (Ignore friction/air resistance. Assume that all numerical values have *at least 2 significant figures.*)

The spacecraft's **VELOCITY** as a function of time is shown below:



Parts (a),(b),(c): −1 pt. for each error, up to −2 pts. max.

a. (2 pts.) During which time interval(s) is the spacecraft **at rest**? *Circle ONE or MORE:*

A. 0 to 7.5 s
B. 7.5 s to 15 s
C. 15 s to 20 s
D. 20 s to 25 s
E. 25 s to 35 s
F. 35 s to 40 s

intervals when $v = 0$.

b. (2 pts.) During which interval(s) is the spacecraft **moving backwards** (i.e., "in reverse")? *Circle ONE or MORE:*

A. 0 to 7.5 s
B. 7.5 s to 15 s
C. 15 s to 20 s
D. 20 s to 25 s
E. 25 s to 35 s
F. 35 s to 40 s

intervals when $v < 0$ (v is negative)

c. (2 pts.) During which interval(s) is the spacecraft **slowing down** (i.e., speed decreasing)? *Circle ONE or MORE:*
(*Note:* This one can be tricky!)

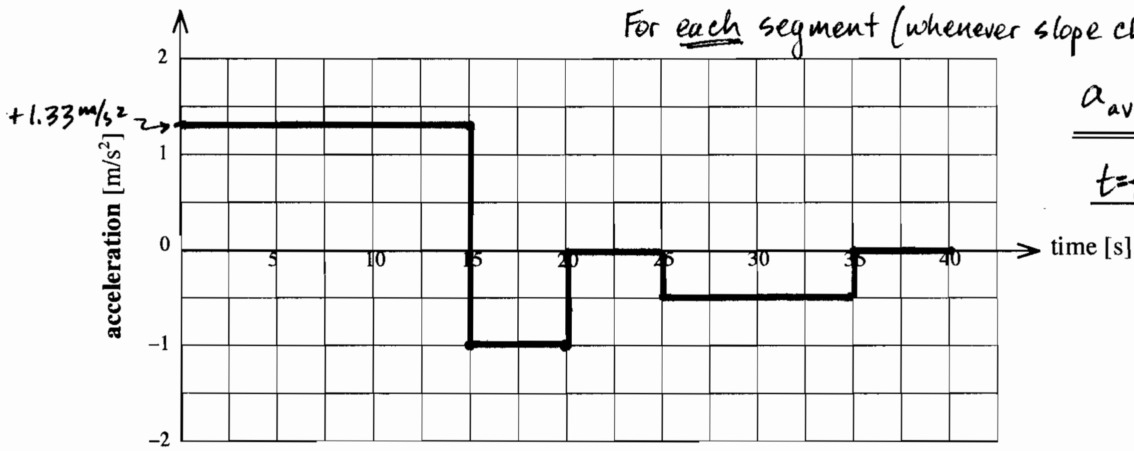
A. 0 to 7.5 s
B. 7.5 s to 15 s
C. 15 s to 20 s
D. 20 s to 25 s
E. 25 s to 35 s
F. 35 s to 40 s

intervals when v is getting closer to zero.

d. (4 pts.) Carefully and accurately, **graph** the spacecraft's **ACCELERATION** vs. time on the axes provided below. (You do NOT need to show your work.)

At all times, acceleration is the slope of $v(t)$ graph (above).
For each segment (whenever slope changes), recalculate:

$a_{av} = \frac{\Delta v}{\Delta t}$. For example:



$t = \{0 \text{ to } 15 \text{ seconds}\}$ segment:

$a = \frac{v_{15} - v_0}{t_{15} - t_0}$

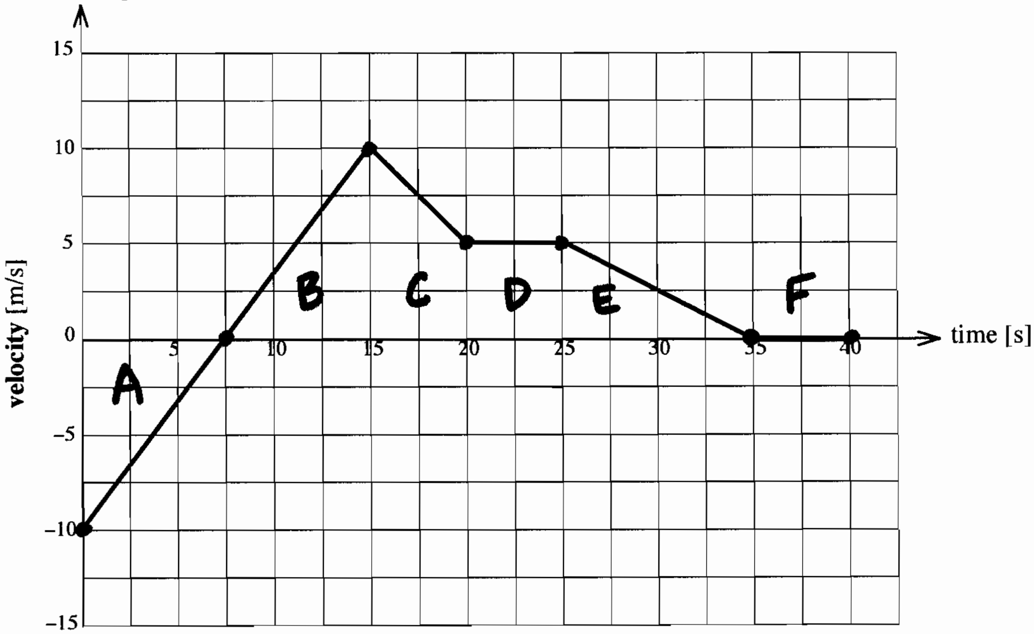
$= \frac{10 \text{ m/s} - (-10 \text{ m/s})}{15 \text{ s} - 0 \text{ s}}$

$a = 1.33 \text{ m/s}^2$.

Continued next page…

2. continued:

The spacecraft's **VELOCITY** as a function of time is repeated here for your reference:



BONUS (2 pts.): Calculate the spacecraft's [net **displacement** from its starting position] at $t = 40$ s. Show your work completely and/or explain your reasoning:

ΔX = cumulative area of $v(t)$ graph (shown above). Dividing graph into segments A–F:

$$\Rightarrow \Delta X_A = \tfrac{1}{2}(\text{base}\cdot\text{height})_A = \tfrac{1}{2}(7.5\,s)(-10\,\tfrac{m}{s}) = -37.5\,m.$$

$$\Delta X_B = \tfrac{1}{2}(\text{base}\cdot\text{height})_B = \tfrac{1}{2}(7.5\,s)(10\,\tfrac{m}{s}) = 37.5\,m.$$

$$\Delta X_C = (\text{base})_C\cdot(\text{average height})_C = (5\,s)\left[\tfrac{1}{2}(10\,\tfrac{m}{s} + 5\,\tfrac{m}{s})\right] = 37.5\,m$$

$$\Delta X_D = (\text{base}\cdot\text{height})_D = (5\,s)(5\,m/s) = 25\,m.$$

$$\Delta X_E = \tfrac{1}{2}(\text{base}\cdot\text{height})_E = \tfrac{1}{2}(10\,s)(5\,\tfrac{m}{s}) = 25\,m.$$

$$\Delta X_F = 0\,m.$$

$$\Delta X_{tot} = \Delta X_A + \cdots + \Delta X_F = -37.5m + 37.5m + 37.5m + 25m + 25m + 0$$

$$\boxed{\Delta X_{tot} = 87.5\,m}$$

OR: Over intervals when acceleration is constant, we can apply: $X = X_0 + v_0 t + \tfrac{1}{2}at^2$.

(A/B) $t = 0 \rightarrow 15\,s$: $X_{15} = X_0 + v_0(\Delta t) + \tfrac{1}{2}a_{AB}(\Delta t)^2 = X_0 + (-10\,\tfrac{m}{s})(15\,s) + \tfrac{1}{2}(1.33\,\tfrac{m}{s^2})(15\,s)^2 = X_0 \cancel{-150m} + \cancel{150m} = X_0.$

(C) $t = 15 \rightarrow 20\,s$: $X_{20} = X_{15} + v_{15}(\Delta t) + \tfrac{1}{2}a_C(\Delta t)^2 = (X_0) + (10\,\tfrac{m}{s})(5\,s) + \tfrac{1}{2}(-1\,\tfrac{m}{s^2})(5\,s)^2 = X_0 + 50m - 12.5m = X_0 + 37.5m.$

(D) $t = 20 \rightarrow 25\,s$: $X_{25} = X_{20} + v_{20}(\Delta t) + \tfrac{1}{2}a_D(\Delta t)^2 = (X_0 + 37.5m) + (5\,\tfrac{m}{s})(5\,s) + \tfrac{1}{2}(0)(5\,s)^2 = X_0 + 37.5m + 25m = X_0 + 62.5m.$

(E) $t = 25 \rightarrow 35\,s$: $X_{35} = X_{25} + v_{25}(\Delta t) + \tfrac{1}{2}a_E(\Delta t)^2 = (X_0 + 62.5m) + (5\,\tfrac{m}{s})(10\,s) + \tfrac{1}{2}(-0.5\,\tfrac{m}{s^2})(10\,s)^2 = X_0 + 62.5m + 50m - 25m = X_0 + 87.5m.$

(F) $t = 35 \rightarrow 40\,s$: $X_{40} = X_{35} + v_{35}(\Delta t) + \tfrac{1}{2}a_F(\Delta t)^2 = (X_0 + 87.5m) + 0\cdot(5\,s) + \tfrac{1}{2}(0)(5\,s)^2 = X_0 + 87.5m.$

$$\Rightarrow \Delta X_{tot} = X_{40} - X_0 = (X_0 + 87.5m) - X_0 = \boxed{87.5m}$$