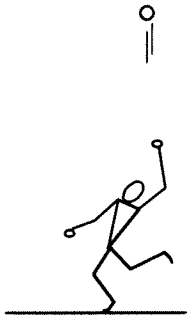
Unit 1 - Kinematics - Projectile motion

Tipper Friday #2

B1-WWT32: Ball Thrown Straight Upward—Time to Reach Top

A student throws a ball straight upward. A friend times how long it takes the ball to reach its maximum height.



The student predicts:

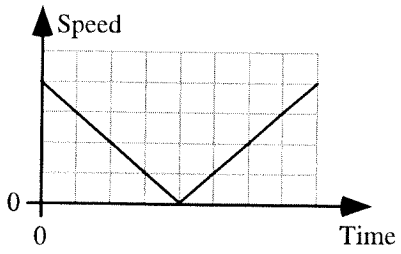
"Faster things take less time. If I throw the ball faster, it will reach its highest point in less time."

What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

Answer: The statement is incorrect. The ball that is thrown faster will also go higher. Faster things take less time to travel the same distance, but in this case the two balls don't travel the same distance. Both balls will have the same acceleration, 10 m/s² downward, so both balls slow down at the same rate, by 10 m/s for every second they are in the air. Since the faster ball starts with a greater initial speed, it will take more time to reach a speed of zero, when it is at its maximum height.

B1-WWT12: Ball Thrown Upward and Comes Back Down—Speed-Time Graph

A ball is thrown straight upward and falls back to the same height. A student makes this graph of the speed of the ball as a function of time.



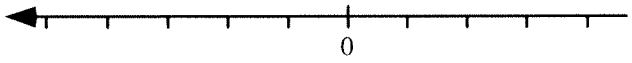
What, if anything, is wrong with the student's graph? If something is wrong, explain the error and how to correct it. If the graph is correct, explain why.

Answer: The graph is correct for the speed of the object because the ball will slow down, stop at an instant, and then speed up as it falls.

B1-QRT49: Position, Velocity, and Acceleration Signs—Position, Direction, and Rate

Eight possible signs of combinations for the instantaneous position, velocity, and acceleration of an object moving in one dimension are given in the table. Above the table is a coordinate axis that shows the origin, marked 0, and that indicates that the positive direction is to the left. The three columns on the right-hand side of the table are to describe the location of the object (either left or right of the origin), the direction of the motion of the object (either toward or away from the origin), and what is happening to the speed of the object (either speeding up or slowing down at the given instant). The appropriate descriptions for the first case are shown.

Complete the table for the object's location and direction of motion relative to the origin and how its speed is changing.



	Position	**Velocity**	**Acceleration**	**Position** (Left or Right)	**Direction** (Toward or Away from)	**Rate** (Speeding up or Slowing down)
A	+	+	+	Left	Away from	Speeding up
B	+	+	–			
C	+	–	+			
D	+	–	–			
E	–	+	+			
F	–	+	–			
G	–	–	+			
H	–	–	–			

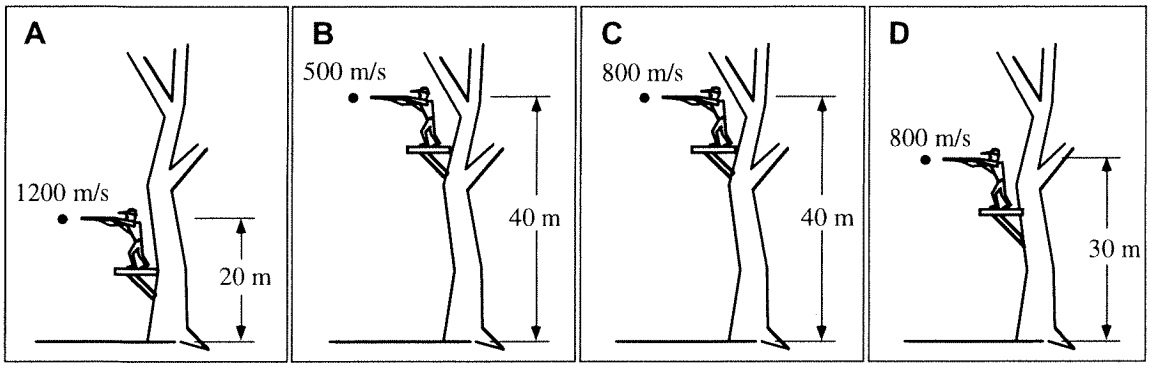
Explain your reasoning.

Answer: A positive position indicates that the object is to the left of the origin, and a negative position indicates that the object is to the right of the origin. When the position and the velocity have the same sign, the object is moving away from the origin, and when they have opposite signs the object is moving toward the origin. When the object's acceleration is the same sign as its velocity, it is speeding up, and when the signs are opposite, it is slowing down.

	Position	Velocity	Acceleration	Position (Left or Right)	Direction (Toward or Away from)	Rate (Speeding up or Slowing down)
A	+	+	+	Left	Away from	Speeding up
B	+	+	–	*Left*	*Away from*	*Slowing down*
C	+	–	+	*Left*	*Toward*	*Slowing down*
D	+	–	–	*Left*	*Toward*	*Speeding up*
E	–	+	+	*Right*	*Toward*	*Speeding up*
F	–	+	–	*Right*	*Toward*	*Slowing down*
G	–	–	+	*Right*	*Away from*	*Slowing down*
H	–	–	–	*Right*	*Away from*	*Speeding up*

B2-RT15: Rifle Shots—Time to Hit Ground

The rifles in the figures are being fired horizontally (straight outward, off platforms). The bullets fired from the rifles are all identical, but the rifles propel the bullets at different speeds. The speed of each bullet and the height of each platform are given. All of the bullets miss the targets and hit the ground.



Rank the time it takes the bullets to hit the ground.

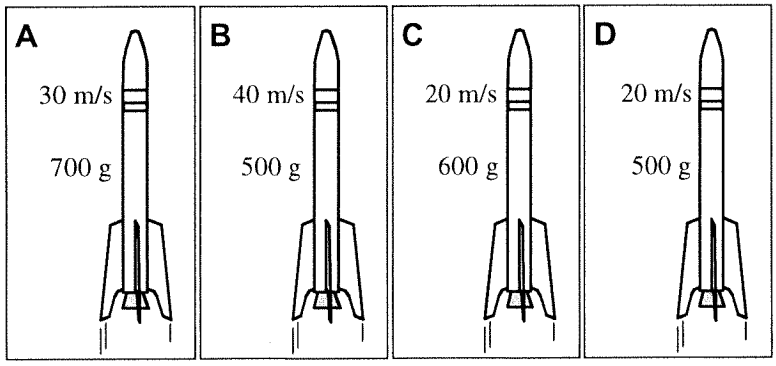
				OR			
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

Explain your reasoning.

Answer $B = C > D > A$. Motions along axes which are perpendicular to each other are independent of each other. The time in the air is determined by the time it takes the bullet to fall from the heights of the platforms in the vertical direction. Since all of the bullets start from rest in the vetical direction and have the same acceleration, that due to the gravitational force, the time in air is determined by the heights of the platforms.

B1-RT15: Vertical Model Rockets—Maximum Height

The model rockets depicted below have just had their engines turned off when they are at the same height. All of the rockets are aimed straight up, but their speeds differ. Although they are the same size and shape, the rockets carry different loads, so their masses differ. The specific mass and speed for each rocket is given in each figure.



Rank the maximum height the model rockets will reach.

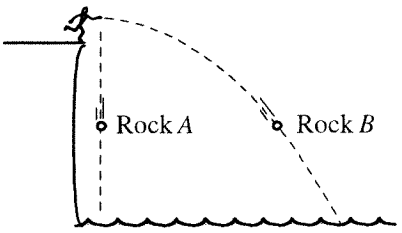
				OR			
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

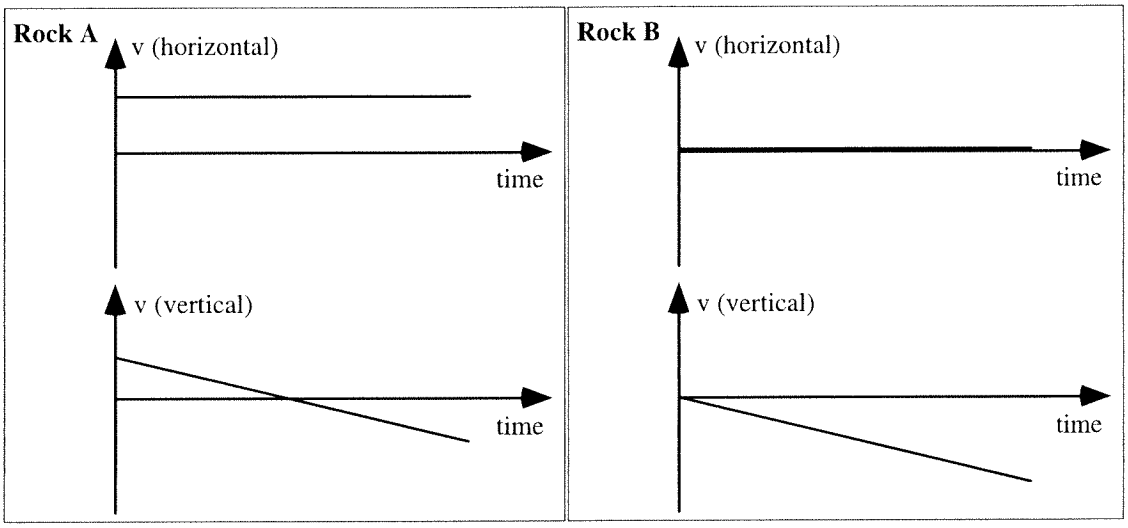
Explain your reasoning.

Answer: $B > A > C = D$.
All four experience the same acceleration of 9.8 m/s^2 downward, so their maximum heights are determined by their speed. Ignoring air resistance all objects have the same acceleration in the Earth's gravitational field whatever their masses.

B2-WWT08: Falling Rock and Thrown Rock—Velocity-Time Graphs

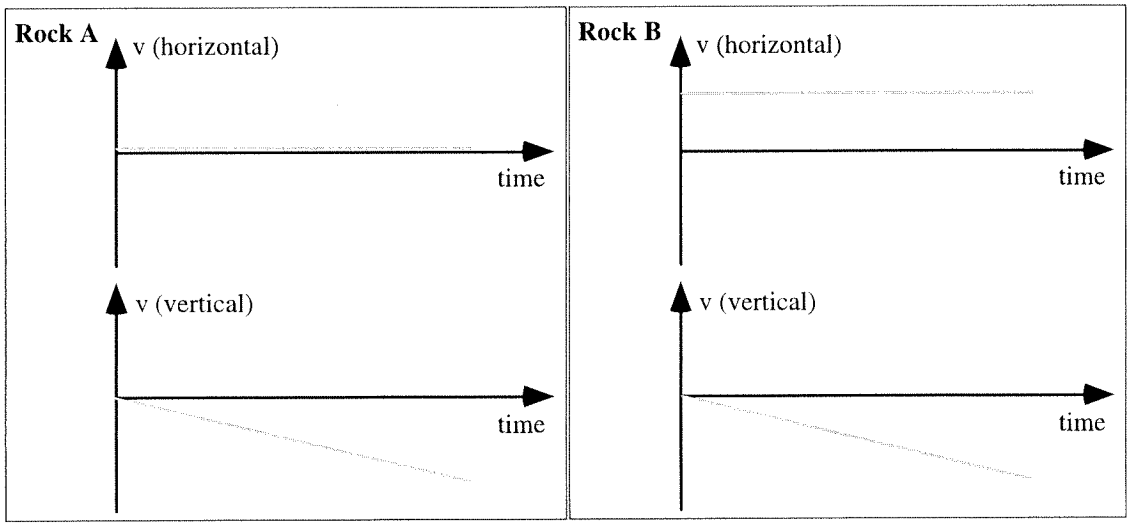
Rock A is dropped from the top of a cliff at the same instant that Rock B is thrown horizontally away from the cliff. The rocks are identical. A student draws the following graphs to describe part of the motion of the rocks, using a coordinate system in which the positive vertical direction is up, the positive horizontal direction is away from the cliff, and the origin of the coordinate system is the point the rocks were released from.





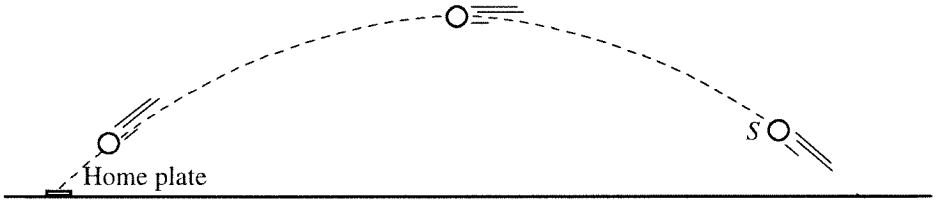
What, if anything, is wrong with these graphs for the motions of the two rocks? If something is wrong, identify it and explain how to correct it. If the graphs are correct, explain why.

The horizontal velocity graphs need to be switched, because Rock A has no horizontal velocity, and Rock B has a constant horizontal velocity. The vertical graph for Rock B is correct for both rocks.



B2-QRT11: Baseball Projectile Motion—Velocity-Time and Acceleration-Time Graphs

A baseball is thrown from point *S* in right field to home plate. The dashed line shows the path of the ball.



Use a coordinate system with up as the positive vertical direction and to the left as the positive horizontal direction, and with the origin at home plate.

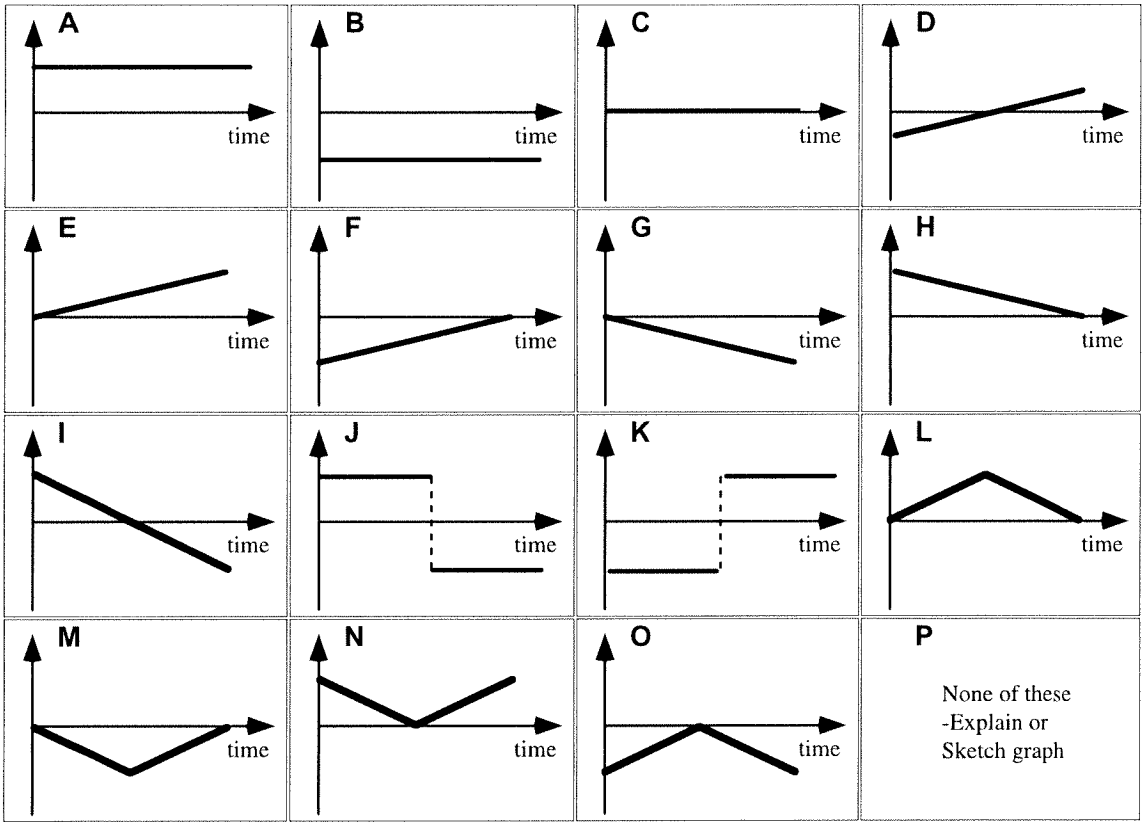
Select the graph from the choices below that best represents:

(i) horizontal velocity versus time graph ____ Explain your reasoning.

(ii) horizontal acceleration versus time graph____ Explain your reasoning.

(iii) vertical velocity versus time graph____ Explain your reasoning.

(iv) vertical acceleration versus time graph____ Explain your reasoning.

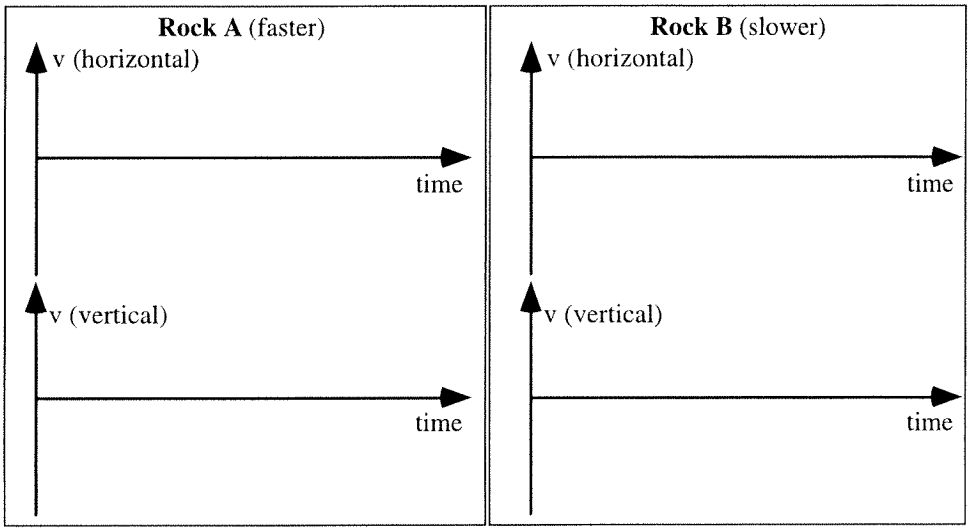


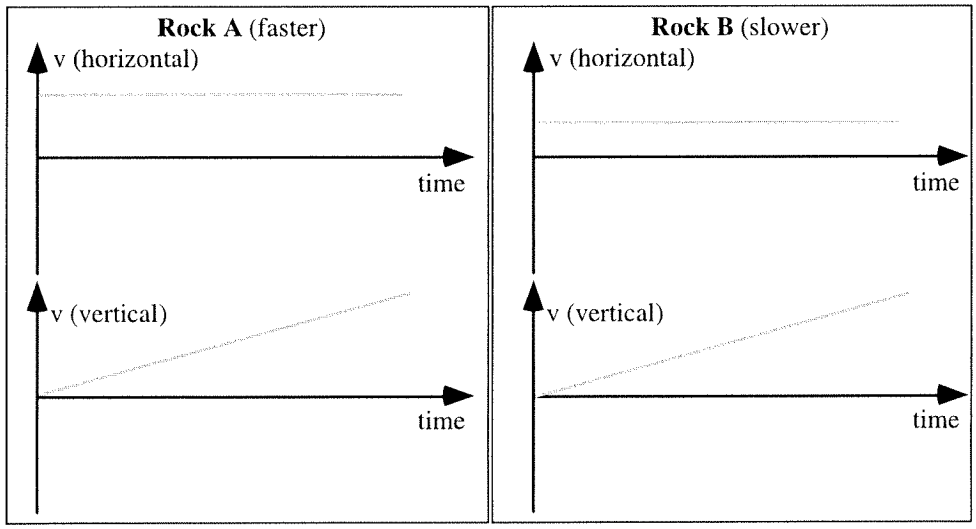
Answer: (1) A; (2) C; (3) I; and (4) B.
There are no horizontal forces (neglecting air resistance) and the ball will have no horizontal acceleration, so the horizontal velocity will be constant. The positive direction is to the left, so the horizontal velocity will be positive. Since up is positive, the initial vertical velocity is positive, and the final vertical velocity is negative. The only vertical force is gravity acting downward, and so the acceleration is constant, negative, and equal in magnitude to g. Since the acceleration is constant, the slope of the velocity must be constant, so the vertical velocity must be a straight line sloping downward from its initial positive value to its final negative value.

B2-QRT10: Projectile Motion for Two Rocks—Velocity-Time and Acceleration-Time Graphs

Two identical rocks are thrown horizontally from a cliff, with Rock A having a greater velocity at the instant it is released than Rock B. Use a coordinate system with down as the positive vertical direction, away from the cliff as the positive horizontal direction, and with the origin of the coordinate system at the bottom of the cliff directly below the release point.

(a) Sketch the velocity versus time graphs for each of the rocks.





(b) Which rock hits the ground first?

Explain your reasoning.

Both hit at the same time. Both rocks have the same vertical acceleration and travel the same vertical distance.

(c) Which rock lands farthest from the base of the cliff?

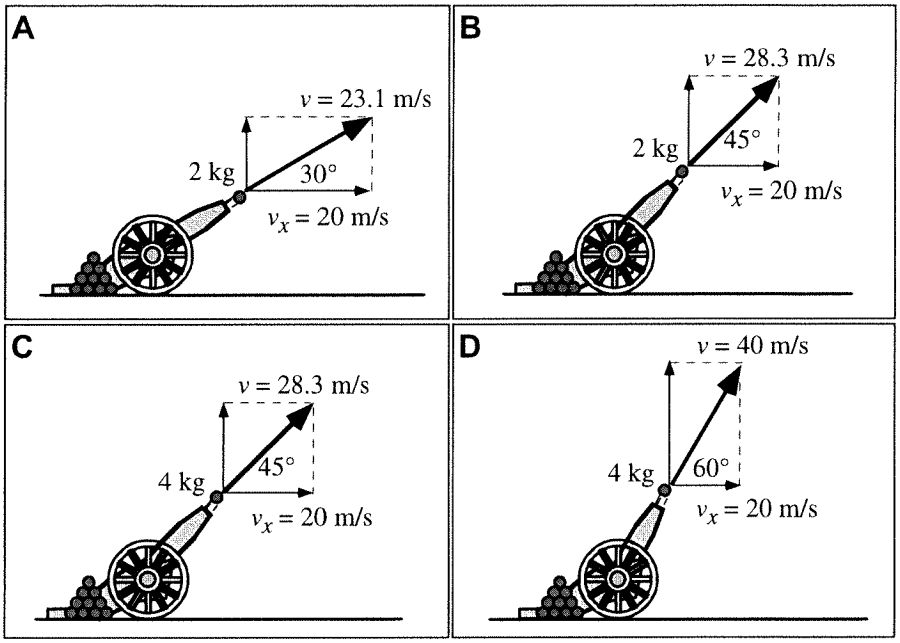
Explain your reasoning

Rock A, the faster rock.

There are no forces in the horizontal direction (ignoring air resistance) so both rocks will have a constant horizontal velocity. Since Rock B is slower than Rock A, it will have a smaller horizontal velocity. Both rocks are thrown horizontally, so they have no initial vertical velocity. Both are acted on by gravity, so the slopes of their vertical velocity graphs are constant and equal to g, and both are positive because gravity is acting down and the positive direction is defined as down. Both rocks hit at the same time but rock A hits farther from the cliff since it travels faster in the horizontal direction.

B2-RT19: CANNONBALLS—HORIZONTAL DISTANCE

Cannonballs of different masses are shot from cannons at various angles above the horizontal. The velocity of each cannonball as it leaves the cannon is given, along with the horizontal component of that velocity, which is the same.



Rank the horizontal distance traveled by the cannonballs.

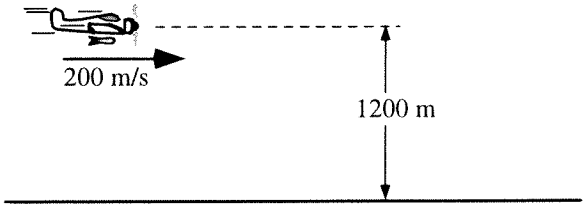
				OR			
1	2	3	4		All	All	Cannot
Greatest			Least		the same	zero	determine

Explain your reasoning.

Answer: D > C = B > A. The horizontal distance is based on $x_f = v_o (\cos \theta) t_f$. Thus, the range, as x_f is sometimes called, is determined by the initial speed, the angle, and the time of flight. As stated in the problem and in the diagrams, the horizontal component of the velocity ($v_o \cos \theta$) is the same value for all six cases, 20 m/s. So, the range for this ranking task is determined by the time of flight, t_f. The time of flight is determined by the y-component of the initial velocity (since for all cases the cannonballs start and end at the same height). Hence, the larger the y-component of the initial velocity, the longer the cannonball will be in the air and the larger its range

B2-LMCT14: Dropped Practice Bomb—Horizontal Distance Traveled

An airplane is flying 1200 m above the ground at a speed of 200 m/s. It drops a practice bomb that hits the ground after traveling a horizontal distance of 3130 m.



For each of the changes below, use the choices below (i)-(v) to identify what will happen to the horizontal distance the bomb travels while falling compared to the situation above.

(i) The horizontal distance will be ***greater than*** 3130 m.
(ii) The horizontal distance will be ***less than*** 3130 m but not zero.
(iii) The horizontal distance will be ***equal to*** 3130 m.
(iv) The horizontal distance will be ***zero*** (the bomb will drop straight down).
(v) We ***cannot determine*** how this change will affect the horizontal distance.

For each of the following changes, only the feature(s) identified is(are) modified from the given situation above.

(a) The plane's speed is tripled. _____
Explain your reasoning.
A: The time it takes to hit the ground is the same, but the bomb has a greater horizontal velocity.

(b) The plane is climbing straight up at the release point. _____
Explain your reasoning.
D: Since there is no horizontal velocity it will come straight back down if it misses the plane.

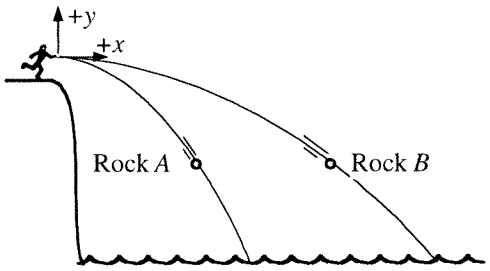
(c) The plane is flying in level flight at an altitude of 1,100 m. _____
Explain your reasoning.
B: It will take less time to reach the ground from a lower height, and the horizontal speed is the same.

(d) The mass of the bomb is increased. _____
Explain your reasoning.
C: The vertical acceleration is still g and is independent of the mass, so the path the bomb takes will remain the same.

(e) The bomb is thrown from the plane with a vertical downward velocity of 15 m/s. _____
Explain your reasoning.
B: The acceleration of the bomb is the same, but with an initial downward vertical velocity it will reach the fground faster, and so will travel less horizontal distance.

B2-CT25: Projectile Motion for Two Rocks—Velocity and Acceleration

Two identical rocks are thrown horizontally from a cliff with different velocities. The rocks are thrown at the same time and are shown below while they are still in the air after a few seconds.



For the instant shown:

(a) Will the magnitude of the horizontal velocity of Rock A be (i) *greater than,* (ii) *less than,* or (iii) *equal to* the magnitude of the horizontal velocity of Rock B? _____

Explain your reasoning.

Answer: less, since the picture shows Rock A lands closer to the cliff than Rock B and thus the horizontal velocity of Rock A is smaller than Rock B

(b) Will the magnitude of the vertical velocity of Rock A be (i) *greater than,* (ii) *less than,* or (iii) *equal to* the magnitude of the vertical velocity of Rock B? _____

Explain your reasoning.

Answer: equal, due to both being released with zero vertical velocity and having the same downward acceleration.

(c) Will the magnitude of the horizontal acceleration of Rock A be (i) *greater than,* (ii) *less than,* or (iii) *equal to* the magnitude of the horizontal acceleration of Rock B? _____

Explain your reasoning.

Answer: equal, both have zero horizontal acceleration since we are ignoring air friction.

(d) Will the magnitude of the vertical acceleration of Rock A be (i) *greater than,* (ii) *less than,* or (iii) *equal to* the magnitude of the vertical acceleration of Rock B? _____

Explain your reasoning.

Answer: equal, due to the fact that both have the same acceleration of gravity.