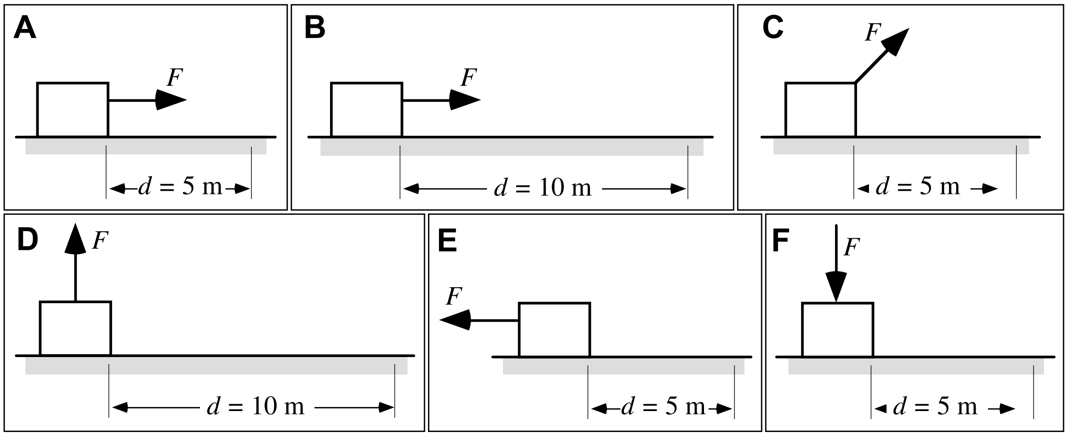
B4-RT08: EQUAL FORCES ON BOXES—WORK DONE ON BOX

In the figures below, identical boxes of mass 10 kg are moving at the same initial velocity to the right on a flat surface. The same magnitude force, F, is applied to each box for the distance, d, indicated in the figures.



Rank the work done on the box by *F* while the box moves the indicated distance.

						OR			
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

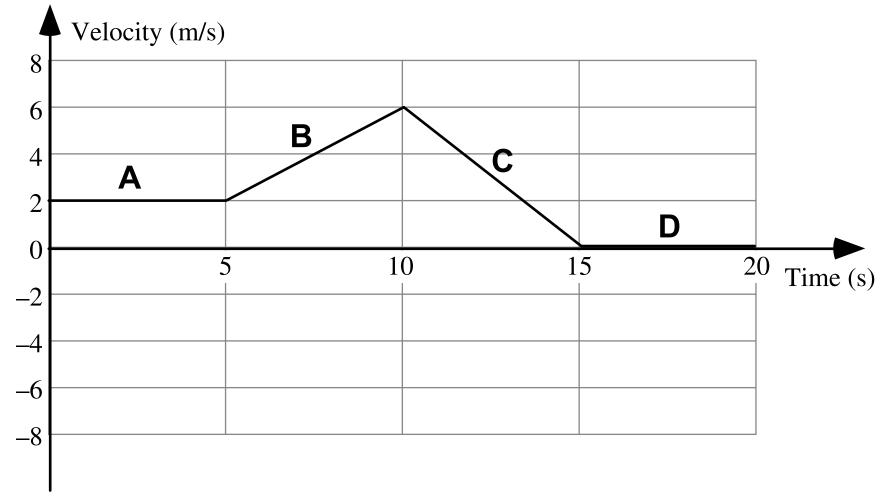
Explain your reasoning.

Answer: B > A > C > D = F > E.

The work done on the box is given by the product of the component of the force in the direction of motion times the distance moved. Positive work is done in A, B, C, zero work in D and F since the force and displacement are perpendicular to each other, and negative work in E, i.e., the box does work on the agent exerting F rather than work being done on the box.

B4-RT09: VELOCITY-TIME GRAPH I—WORK DONE ON BOX

Shown below is a graph of velocity versus time for an object that moves along a straight, horizontal line under the perhaps intermittent action of a single force exerted by an external agent.



Rank the work done on the box by the external agent for the 5-second intervals shown on the graph.

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

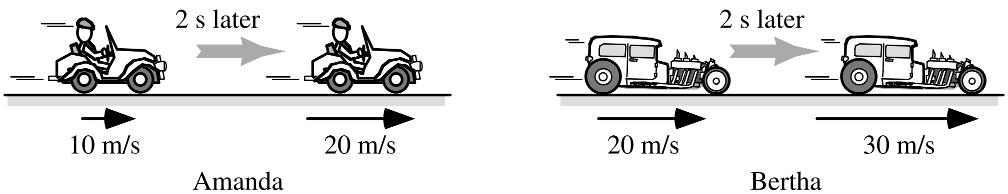
Explain your reasoning.

Answer: B > A = D > C.

In this situation the work done on the box will change its kinetic energy, so to find how much work was done we need to subtract the initial kinetic energy from the final value for each 5 second interval. The external agent will do positive work in interval B, no work in intervals A and D since the kinetic energy doesn't change in those intervals, and negative work in interval C, i.e., the box is doing work on the external agent in C rather than the agent doing work on the box.

B4-CT49: CAR RACE—WORK AND POWER

Amanda and Bertha are in a car race. Their cars have the same mass. At one point in the race, they both change their speeds by 10 m/s in 2 seconds. Ignore air friction.



(a) Is the work that Amanda's car does while speeding up (i) *greater than*, (ii) *less than*, or (iii) *the same as* the work that Bertha's car does while speeding up? _____

Explain your reasoning.

Answer: (ii) less than, since the work done is equal to the change in kinetic energy, which will be proportional to the change in the square of the velocity. For Amanda, it is $(20\ m/s)^2$-$(10\ m/s)^2$ = $400 m^2/s^2$ – $100\ m^2/s^2$ = $300\ m^2/s^2$ and for Bertha, it is $(30\ m/s)^2$ – $(20\ m/s)^2$ = $900 m^2/s^2$ – $400\ m^2/s^2$ = $500\ m^2/s^2$.

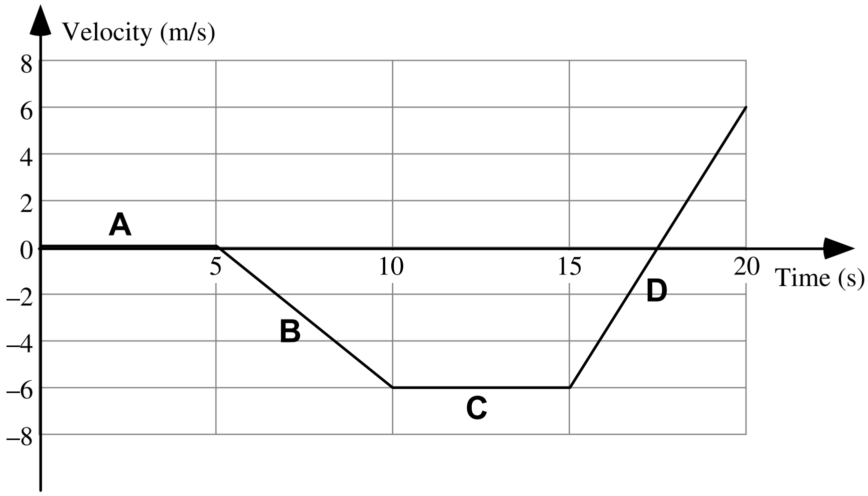
(b) Is the power generated by Amanda's car while speeding up (i) *greater than*, (ii) *less than*, or (iii) *the same as* the power generated by Bertha's car while speeding up? _____

Explain your reasoning.

Answer: (ii) less than, since the power is the rate work is done, so it is the work done divided by the time it takes. Since the time is the same, and the work done is less for Amanda's car, the power generated by Amanda's car will be less.

B4-RT10: VELOCITY-TIME GRAPH II—WORK DONE ON BOX

Shown below is a graph of velocity versus time for an object that moves along a straight, horizontal line under the perhaps intermittent action of a single force exerted by an external agent.



Rank the work done on the box by the external agent for the 5-second intervals shown on the graph.

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

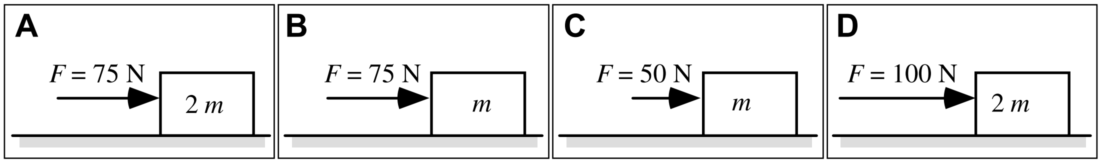
Explain your reasoning.

Answer: D > A = C > B.

In this situation the work done on the box will change its kinetic energy, so to find how much work was done we need to subtract the initial kinetic energy from the final value for each 5 second interval. The external agent will do positive work in interval D, no work in intervals A, and C since the kinetic energy doesn't change in those intervals, and negative work in interval B, i.e., the box does work on the external agent in B rather than the agent doing work on the box.

B4-RT11: Force Pushing Box—Change in Kinetic Energy

A box is pushed 10 m across a floor in each case shown. All boxes have an initial velocity of 10 m/s to the right. The mass of the box and the net horizontal force for each case are given.



Rank the change in kinetic energy of the boxes.

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

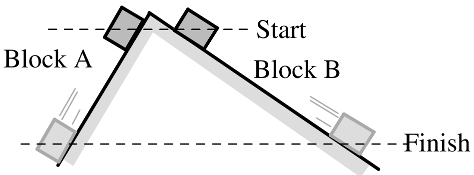
Explain your reasoning.

Answer: D > A = B > C.

The change in kinetic energy will occur because of the energy transfer produced by the external agent working on the box, so, since all of the boxes move the same distance under the action of the external force, the magnitudes of the external forces determine the ranking.

B4-SCT19: BLOCKS SLIDING DOWN FRICTIONLESS RAMPS—WORK BY THE NORMAL FORCE

Two identical blocks are released from rest at the same height. Block A slides down a steeper ramp than Block B. Both ramps are frictionless. The blocks reach the same final height indicated by the lower dashed line. Three students are comparing the work done on the two blocks by the normal force:



Annika: "I think the normal force doesn't do any work on either block. The force on the block by the ramp is perpendicular to the ramp, and the displacement is parallel to the ramp. So the dot product is zero."

BoBae: "Work is force times displacement. The work done on Block A is negative, while the work done on Block B is positive, because the displacement for B is in the positive direction, while the displacement for A is in the negative direction."

Craig: "Since work is force times distance, and the distance the block travels is greater for Block B, the work done is greater for Block B."

With which, if any, of these students do you agree?

Annika _____ *BoBae* _____ *Craig* _____ None of them_____

Explain your reasoning.

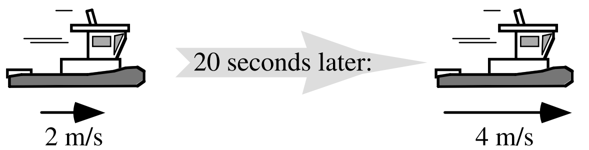
Answer: Annika is correct.

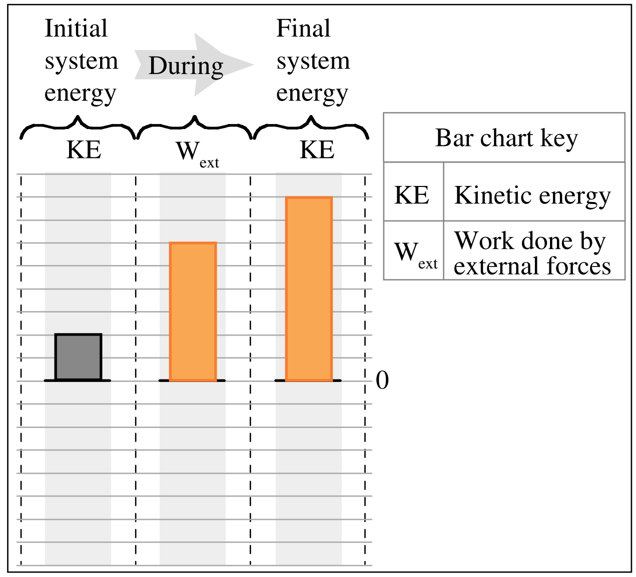
Work is the product of the magnitude of the force and the component of the displacement parallel to the force, and if the force is perpendicular to the displacement, the work done by that force is zero.

B4-BCT14: Tugboat Changing Velocity I—Work & Kinetic Energy Bar Chart

(a) The velocity of a tugboat increases from 2 m/s to 4 m/s in the same direction while a force is applied to the tugboat for 20 seconds.

Complete the work and kinetic energy bar chart for this process. The bar heights should be in correct proportion to one another.

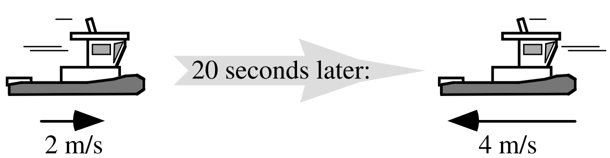


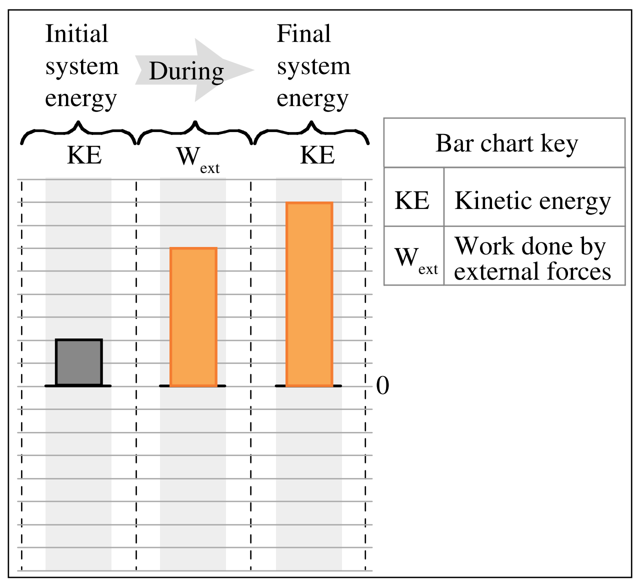


Explain.

(b) The velocity of a tugboat changes from 2 m/s to 4 m/s in the opposite direction while a force is applied to the tugboat for 20 seconds.

Complete the work and kinetic energy bar chart for this process. The bar heights should be in correct proportion to one another.

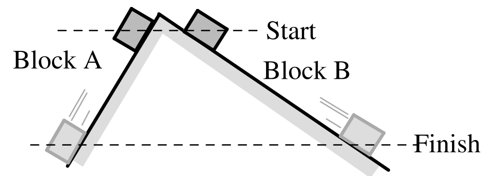




Explain.

Answers (a) and (b) will have the same bar chart graphs. In both cases, the speed of the tugboat doubles and so the kinetic energy quadruples. In both cases, the same net work will have been done on the tugboat.

B4-SCT20: BLOCKS SLIDING DOWN FRICTIONLESS RAMPS—WORK BY THE EARTH



Two identical blocks are released from rest at the same height. Block A slides down a steeper ramp than Block B. Both ramps are frictionless. The blocks reach the same final height indicated by the lower dashed line. Three students are comparing the work done on the two blocks by the gravitational force (the weight of the blocks):

Asmita: "Work is related to the product of force and displacement, and the weight is the same since the blocks are identical. But Block B travels farther, so more work is done on Block B by the gravitational force than on Block A."

Ben: "Both blocks fall the same vertical distance, so the work done is the same."

Cocheta: "By Newton's third law, the force exerted on the block by Earth is exactly cancelled by the force exerted on Earth by the block. The work done is zero."

Danae: "The work depends on the angle that the force makes with the displacement. If we put the displacement and force vectors tail-to-tail, the angle is smaller for Block B than for Block A, and so the work done is greater."

With which, if any, of these students do you agree?

Asmita _____ *Ben* _____ *Cocheta* _____ *Danae* _____ None of them_____

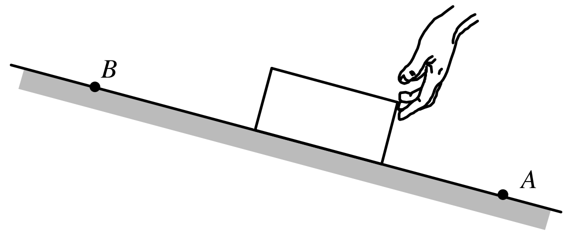
Explain your reasoning.

Answer: Ben is correct.

Work is the product of the magnitude of the force and the component of the displacement parallel to the force, and the force in both cases here is straight down. The work done by the earth is equal to $mgL\cos\theta$, where θ is the angle that the ramp makes with the vertical and L is the distance traveled down the ramp. But $L\cos\theta$ is also the vertical distance between the dashed lines, which is the same for both blocks.

B4-QRT22: BLOCK ON RAMP WITH FRICTION—WORK AND ENERGY

A block is pushed at constant speed up a ramp from point *A* to point *B*. The direction of the force on the block by the hand is horizontal. There is friction between the block and the ramp. The distance between points *A* and *B* is 1 m.



(a) The kinetic energy of the block at point *B*

(i) is *greater than* the kinetic energy of the block at point *A*.
(ii) is *less than* the kinetic energy of the block at point *A*.
(iii) is *equal to* the kinetic energy of the block at point *A*.
(iv) *cannot be compared* to the kinetic energy of the block at point *A* unless we know the height difference between *A* and *B*.

Explain your reasoning.

Answr: (iii) equal
The kinetic energy of the block is the same at A and B since the speed is constant.

(b) The net work done on the block as it travels from point *A* to point *B*

(i) is *zero*.
(ii) is *negative*.
(iii) is *positive*.
(iv) *could be positive or negative* depending on the choice of coordinate systems.

Explain your reasoning.

Answer: (i) greater
Using the work-kinetic energy theorem, since the change in kinetic energy of the block is zero, from point A to point B, the net work done on the block must be zero.

(c) The work done on the block by the hand as the block travels from point *A* to point *B*

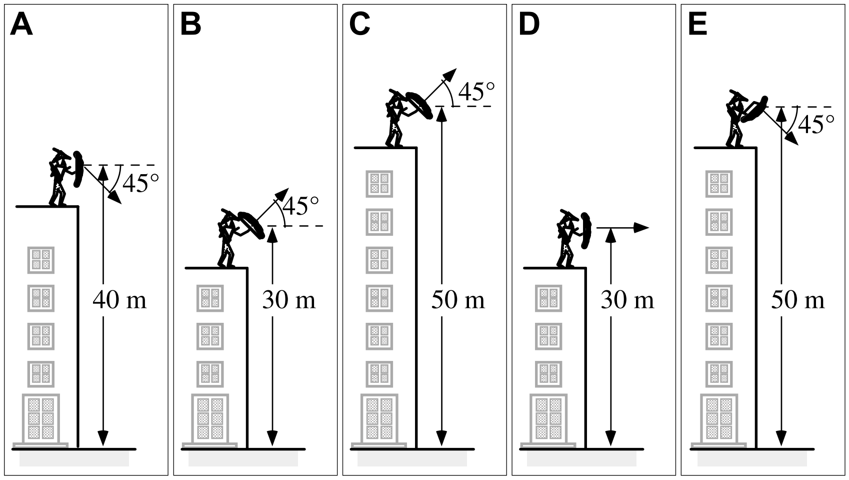
(i) is *equal* to 1 m times the magnitude of the force exerted on the block by the hand.
(ii) is *greater than* 1 m times the magnitude of the force exerted on the block by the hand.
(iii) is *less than* 1 m times the magnitude of the force exerted on the block by the hand but not zero.
(iv) is *zero*.
(v) *cannot be compared* to the magnitude of the force exerted on the block by the hand based on the information given.

Explain your reasoning.

Answer: (iii) less than
The work done on the block by the hand is less than the product of the magnitude of this force and the magnitude of the displacement (one meter) because the force and the displacement are not parallel to one another, and the work done is therefore equal to the magnitude of the force times the magnitude of the

B4-RT25: ARROWS SHOT FROM BUILDINGS—FINAL SPEED

In each case below, an arrow has been shot from the top of a building either up at a 45° angle, straight out horizontally, or down at a 45° angle. All arrows are identical and are shot at the same speed, and the heights of the buildings and the direction the arrows are shot are given. Ignore air resistance.



Rank the speed of the arrows just before they hit the ground below.

					OR			
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

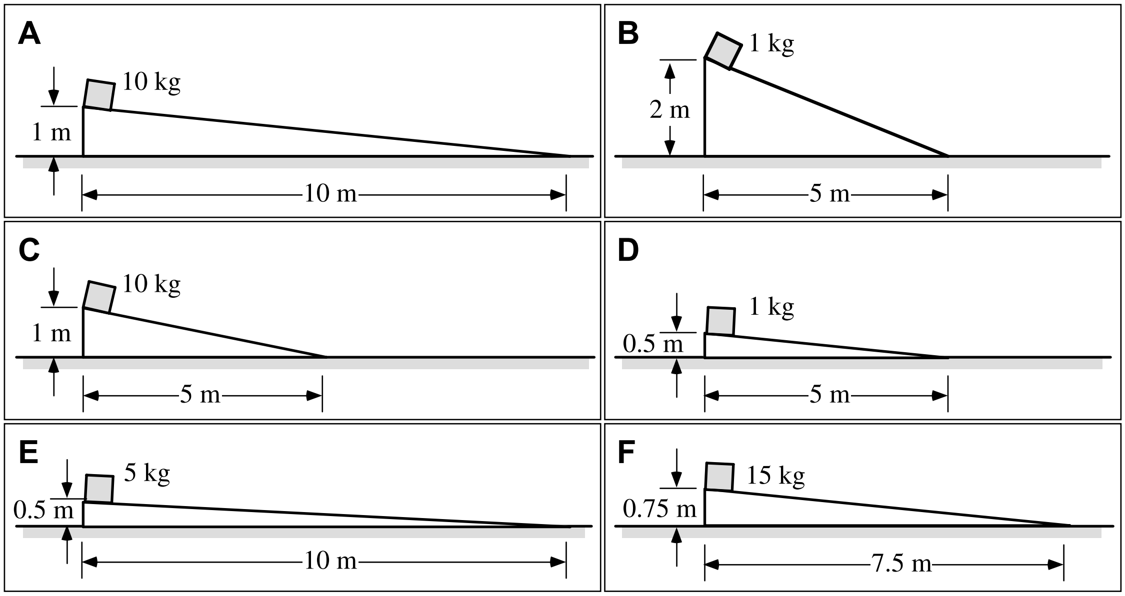
Explain your reasoning.

Answer: C = E > A > B = D.

This is an application of conservation of energy. All have the same kinetic energy at the start because they all are fired at the same speed. All arrows have zero gravitational potential energy at end of their flight, so those with greatest gravitational potential energy at start will have greatest kinetic energy and speed at bottom.

B4-RT45: SLIDING MASSES ON INCLINE—KINETIC ENERGY

Shown are blocks that slide down frictionless inclines. All masses start from rest at the top of the incline.



Rank the kinetic energy of the sliding masses the instant they reach the bottom of the incline.

						OR			
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

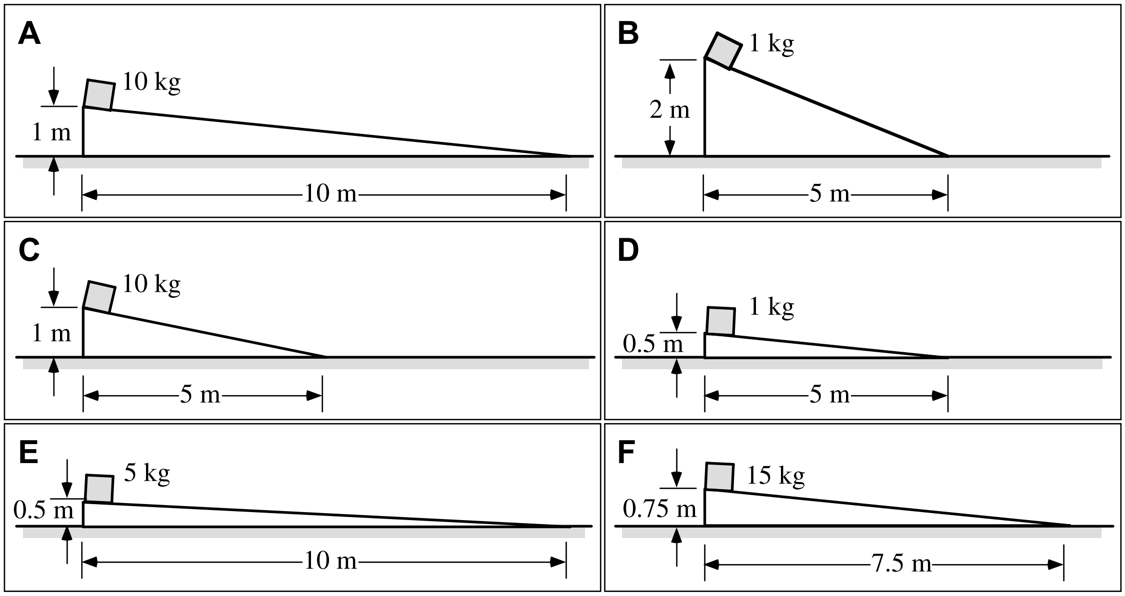
Explain your reasoning.

Answer: F > A = C > B > D = E.

Since the blocks all start from rest so they have zero initial kinetic energy, and they are sliding down frictionless surfaces, the initial gravitational potential energy, which depends on the height of the incline, is converted to the final kinetic energy. The initial gravitational potential energy is proportional to the product of the mass and the height above the horizontal surface, length of the incline is irrelevant.

B4-RT46: SLIDING MASSES ON INCLINE—CHANGE IN POTENTIAL ENERGY

Shown are blocks that slide down frictionless inclines. All masses start from rest at the top of the incline.



Rank the change in gravitational potential energy of the sliding masses from the top of the incline to the bottom of the incline.

						OR			
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: F > A = C > B > D = E.

Since the initial gravitational potential energy depends on the height of the incline and the mass of the block, which does not change as the block slides down the incline, the ranking is based on the product of the height and mass.