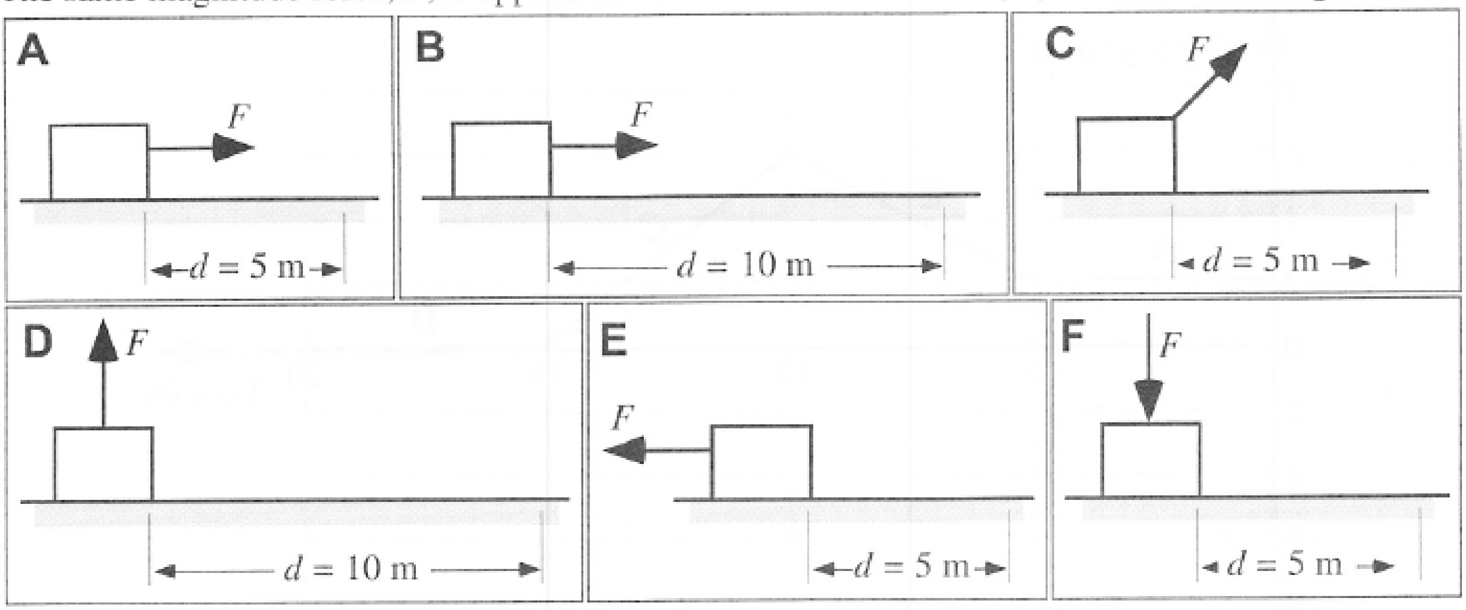
B4-RT08: EQUAL FORCES ON BOXES—WORK DONE ON BOX

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

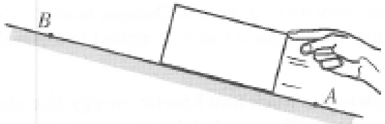
Explain your reasoning.

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-LMCT18: Block Pushed on Incline—Work Done

A block is pushed so that it moves up a ramp at constant speed.



Identify from choices (i)–(iv) below the appropriate description for the work done by the specified force while the block moves from point *A* to point *B*.

(i) is *zero*.

(ii) is ***less than*** zero.

(iii) is ***greater than*** zero.

(iv) could be ***positive or negative*** depending on the choice of coordinate systems.

(v) ***cannot*** *be determined.*

(a) The work done on the block by the hand. _____
Explain your reasoning.

(b) The work done on the block by the normal force from the ramp. _____
Explain your reasoning.

(c) The work done on the block by friction. _____
Explain your reasoning.

(d) The work done on the block by the gravitational force. _____
Explain your reasoning.

(e) The net work done on the block. ______
Explain your reasoning.

(a) The work done on the block by the hand. _____
Explain your reasoning.
Answer: iii, greater than zero.

The force by the hand has a component in the same direction as the displacement, so the work done is positive.

(b) The work done on the block by the normal force from the ramp. _____
Explain your reasoning.
Answer: i, zero.

The normal force is always perpendicular to the displacement, so the product of force and the component of the displacement parallel to the force is zero.

(c) The work done on the block by friction. _____
Explain your reasoning.
Answer: ii, less than zero.

The angle between the friction force and the displacement is 180°, so the product of magnitude of the frictional force and the component of the displacement parallel to the frictional force is negative.

(d) The work done on the block by the gravitational force. _____
Explain your reasoning.
Answer: ii, less than zero.

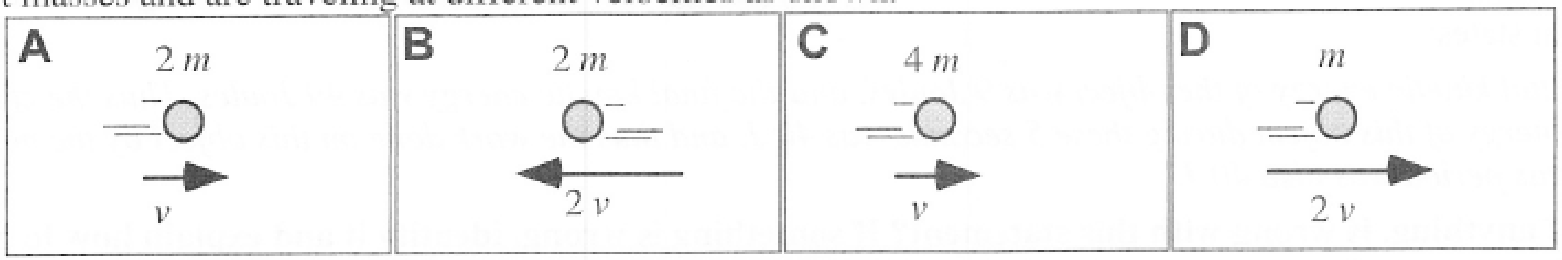
The angle between the gravitational force and the displacement is greater than 90°, so the product of the magnitude of the gravitational force and the component of the displacement parallel to the gravitational force is negative.

(e) The net work done on the block. ______
Explain your reasoning.
Answer: i, zero.

The block is moving at a constant speed, so there is no change in kinetic energy. From the work-kinetic energy theorem, the net work done equals the change in kinetic energy.

B4-RT01: MOVING BALLS I—KINETIC ENERGY

In the figures below, balls are traveling in different directions. The balls have the same size and shape, but they have different masses and are traveling at different velocities as shown.



Rank the kinetic energy of the balls.

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

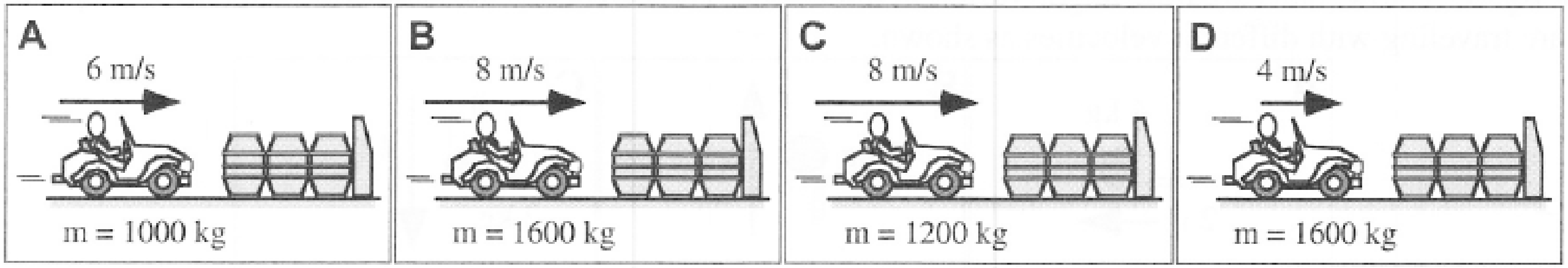
Explain your reasoning.

Answer: B > C = D > A

Based on the definition of kinetic energy as the product of the mass and the square of the velocity, which is a scalar since it is the dot product of the velocity with itself.

B4-RT04: CARS AND BARRIERS—STOPPING FORCE IN SAME DISTANCE

Cars that are moving along horizontal roads are going to be stopped by plowing into barrel barriers. All of the cars are the same size and shape, but they are carrying loads with different masses. All of the cars are going to be stopped in the same distance.



Rank the strength (magnitude) of the forces that will be needed to stop the cars in the same distance.

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

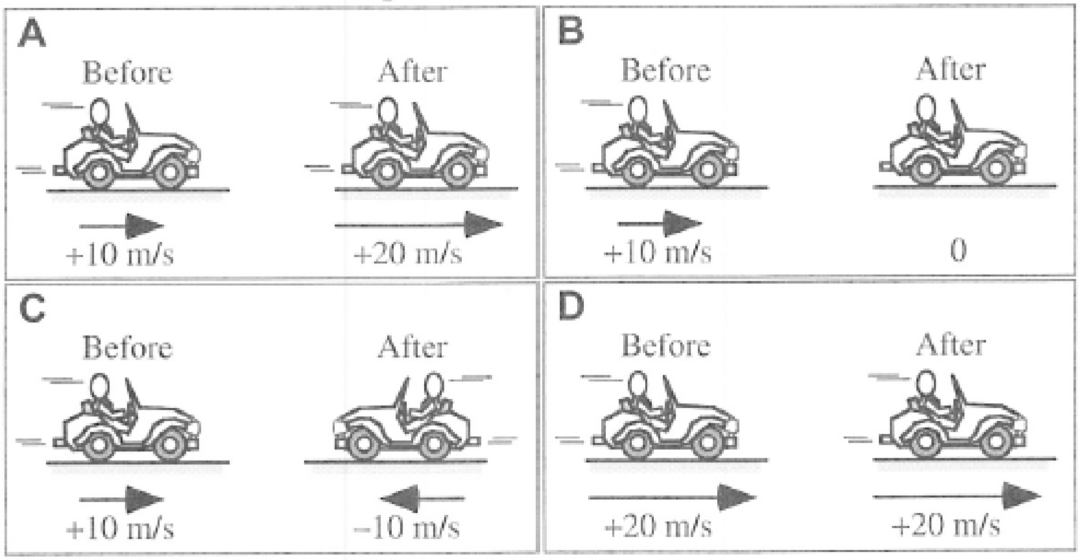
Explain your reasoning.

Answer: B > C > A > D.

The product of the stopping (average) force and the distance through which it acts is the work done on the cars. That work will go into changing the kinetic energy of the cars. Since they are all stopping, i.e., zero final kinetic energy, in the same distance the ranking is based on the initial kinetic energies of the cars

B4-RT06: Cars Changing Velocity—Work Done

The situations below show before and after "snapshots" of a car's velocity. All cars have the same mass.



Rank the work done on the cars to create these changes in velocity for the same distance traveled.

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

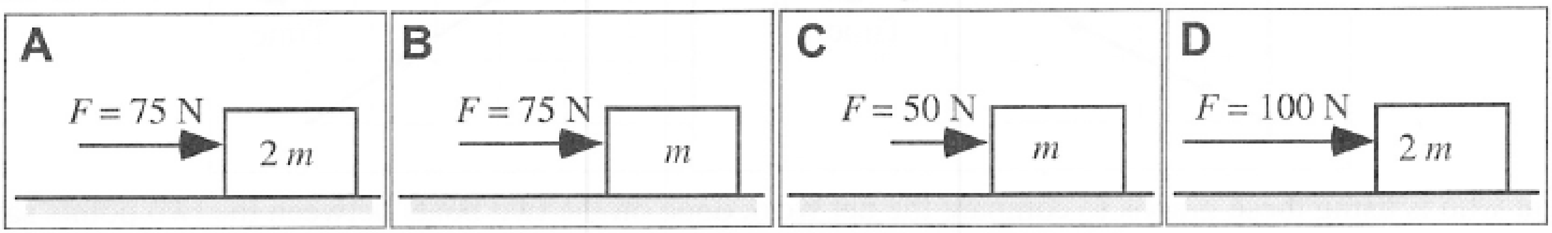
Explain your reasoning.

Answer: A > C = D > B.

The work in these situations changes the kinetic energy of the cars, which here is determined by the difference in the squares of the speeds, final minus initial. Since all cars have the same mass, the car with the greatest change in the squares of the speeds had the greatest energy change through working.

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

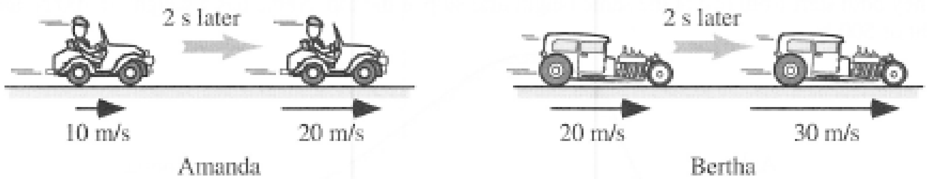
Explain your reasoning.

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-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.

(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.

(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 $(30\ m/s)^2 - (20\ m/s)^2 = 900 m^2/s^2 - 400\ m^2/s^2 = 500\ m^2/s^2$.

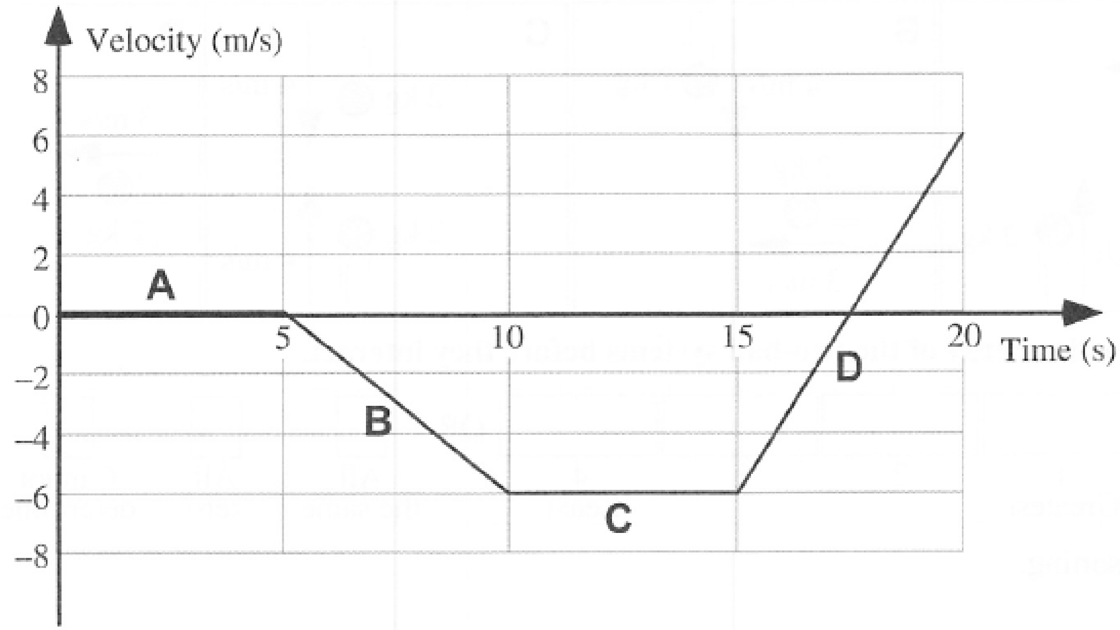
(b) Is the power generated by Amanda's car while speeding up (i) *greater than*, (ii) *less than*, or (iii) *the same as* the power generated by Bertha's car while speeding up? _____

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.

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

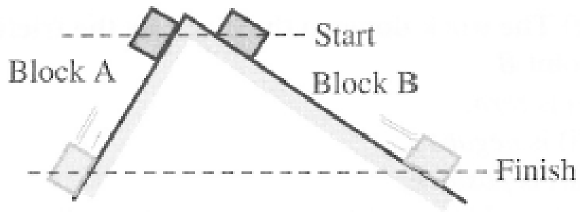
Explain your reasoning.

B > A = C = D

For A and C, there is no change in speed, hence no change in kinetic energy and no work done. For D, the speed changes, but there is no change in kinetic energy (final K = initial K), so no work is done (negative work from 15 s to 17.5 s is canceled by positive work from 17.5 s to 20 s). For B, the speed increases, as does the kinetic energy, so positive work is done.

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_____

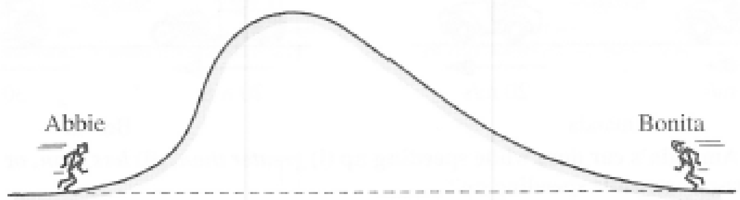
Explain your reasoning.

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 mgLcosθ, where θ is the angle that the ramp makes with the vertical and L is the distance traveled down the ramp. But Lcosθ is also the vertical distance between the dashed lines, which is the same for both blocks.

B4-CT48: RACE UP A HILL II—WORK AND POWER

Abbie and Bonita decide to race up a hill that is 30 m high. Abbie takes a path that is 60 m long while Bonita uses a path that is 100 m long. It takes Abbie 40 seconds because her route is steep, while Bonita runs up her path in 30 seconds. They both start from rest at the same height and stop at the top. Abbie has a weight of 700 N, and Bonita has a weight of 500 N.



(a) Is the work that Abbie does in going up the hill (i) *greater than*, (ii) *less than*, or (iii) *the same as* the work that Bonita does in going up the hill? _____

Explain your reasoning.

(b) Is the power generated by Abbie in going up the hill *greater than*, *less than*, or *the same as* the power generated by Bonita in going up the hill? _____

Explain your reasoning.

(a) Is the work that Abbie does in going up the hill (i) *greater than*, (ii) *less than*, or (iii) *the same as* the work that Bonita does in going up the hill? _____

Explain your reasoning.

Answer: (i) greater than, since the work done is equal to the gain in gravitational potential energy, which is the weight times the height, and both went up the same height, but Abbie weighs more than Bonita.

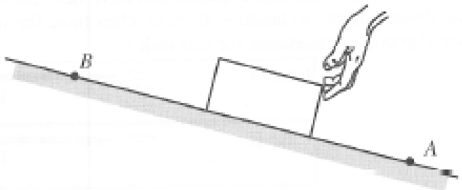
(b) Is the power generated by Abbie in going up the hill *greater than*, *less than*, or *the same as* the power generated by Bonita in going up the hill? _____

Explain your reasoning.

Answer: (i) greater than, since the power is the rate that work is done so it will be the work/time. For Abbie it is (700 N)(30 M)/40 s while for Bonita, it is (500 N)(30 m)/30 s.

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.

(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.

(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.

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-SCT24: SKATERS PUSHING OFF EACH OTHER—FORCE

Two skaters—a small girl and a large boy—are initially standing face-to-face but then push off each other. After they are no longer touching, the girl has more kinetic energy than the boy. Three physics students make the following contentions about the forces the boy and girl exerted on each other:

Arianna: *"I think the boy pushed harder on the girl because he is bigger, so she ended up with more kinetic energy than he did."*

Boris: *"I disagree. They pushed equally hard on each other, but the girl moved farther while they were pushing on each other, so she ended up with more kinetic energy."*

Carmen: *"I think the girl had to push harder to get the boy moving since he is bigger, but that caused her to accelerate more as she recoiled."*

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

Arianna _____ Boris _____ Carmen _____ None of them_____

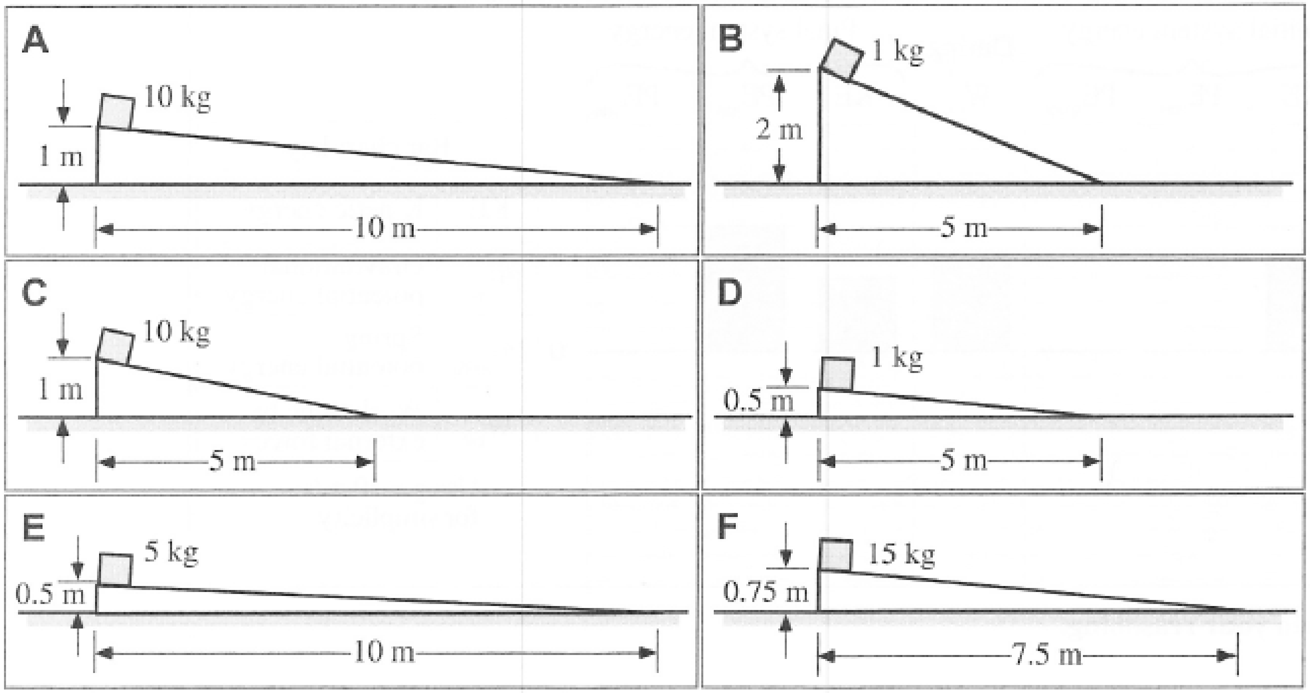
Explain your reasoning.

Answer: Boris is correct.

Newton's Third Law requires that they exert forces of equal magnitude on each other and they are in contact for the same time. Equal force on the smaller mass of the girl will give her a larger acceleration. The larger acceleration for the same time means that she moves farther. Equal force applied through a larger distance means more work was done on her and so she ends up with more kinetic energy.

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.

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

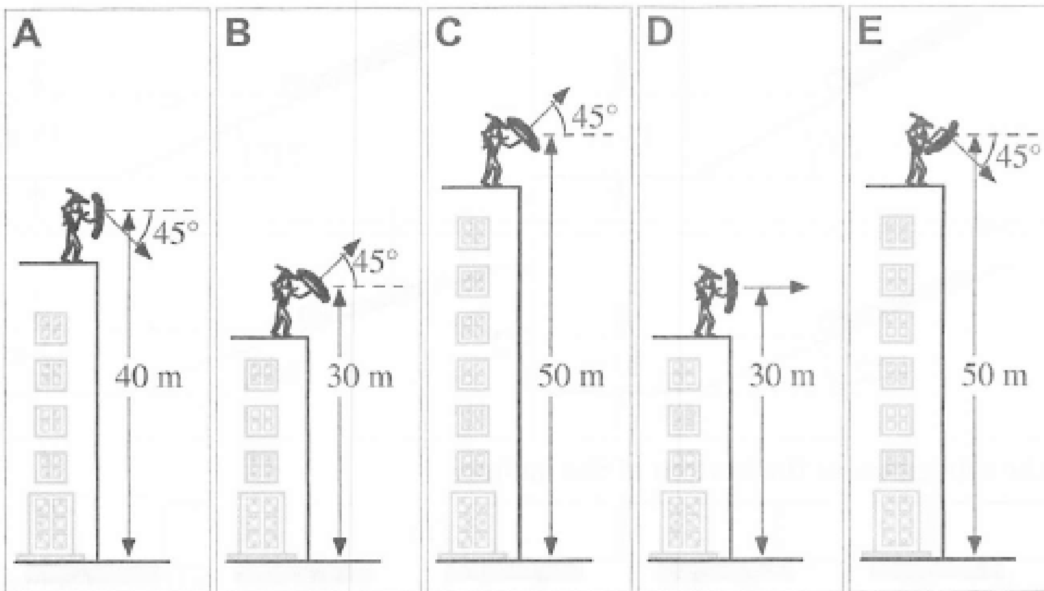
Explain your reasoning.

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-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

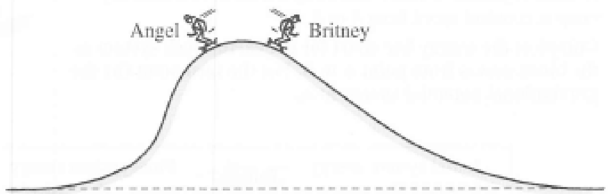
Explain your reasoning.

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-CT28: SKATEBOARDERS ON A HILL—TIME, SPEED, KINETIC ENERGY, AND WORK

Starting from rest, Angel and Britney skateboard down a hill as shown. Angel rides down the steep side while Britney rides down the shallow side. Angel has more mass than Britney. Assume that friction and air resistance are negligible.



(a) Is the speed at the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

(b) Is the time it takes to get to the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

(c) Is the work done by the gravitational force on the skateboarder (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

(d) Is the work done by the normal force on the skateboarder (i) *greater* for Angel, (ii) greater for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

(e) Is the kinetic energy at the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

(a) Is the speed at the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

Answer-(iii) Same for both. Both skateboarders lose the same amount of height as they travel down the hill, and their change in potential energy (strictly speaking, the change in potential energy of the skateboarder-earth system) is equal to their gains in kinetic energy. Both kinetic and potential energy terms are proportional to the mass, so it doesn't matter that the skateboarders have different masses.

(b) Is the time it takes to get to the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

Answer-(ii) Greater for Britney. Both start from rest, and Angel, who will have the greater acceleration, also has a shorter path.

(c) Is the work done by the gravitational force on the skateboarder (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

Answer-(i) Greater for Angel. If the two skateboarders had the same mass, then the work done by the gravitational force would be the same for both. (Work depends only on displacement in direction of force, and the vertical displacement is the same for the two skateboarders). But since the gravitational force is proportional to the mass, this force is greater on Angel, and more work will be done on her by the gravitational force.

(d) Is the work done by the normal force on the skateboarder (i) *greater* for Angel, (ii) greater for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

Answer-(iii) Same for both. The displacement for each skateboarder at all points on the hill is parallel to the surface of the hill, and the normal force at all points is perpendicular to the hill, so the angle between the normal force and the displacement is 90°. Since work depends on the dot product of the force and displacement vectors, the work done by the normal force is zero for both skater

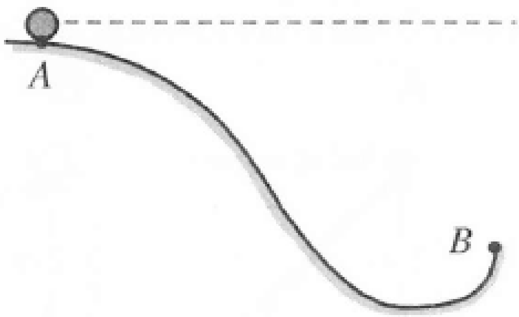
(e) Is the kinetic energy at the bottom of the hill (i) *greater* for Angel, (ii) *greater* for Britney, or (iii) *the same* for both skateboarders? _____

Explain your reasoning.

Answer: (i) Greater for Angel. They have the same speed, but Angel has a larger mass.

B6-QRT29: SOLID SPHERE ROLLING ALONG A TRACK—LOCATION AT HIGHEST POINT

A solid sphere rolls without slipping along a track shaped as shown at right. It starts from rest at point *A* and is moving vertically when it leaves the track at point *B*.

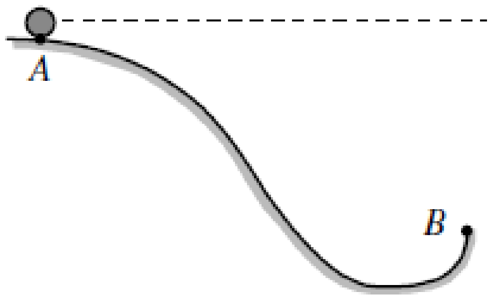


At its highest point while in the air, will the sphere be (a) *above*, (b) *below*, or (c) *at the same height as* point *A*? _____

Explain your reasoning.

B6-QRT29: Solid Sphere Rolling Along a Track—Location at Highest Point

A solid sphere rolls without slipping along a track shaped as shown at right. It starts from rest at point *A* and is moving vertically when it leaves the track at point *B*.



At its highest point while in the air, will the sphere be (a) *above*, (b) *below*, or (c) *at the same height as* point *A*? _____

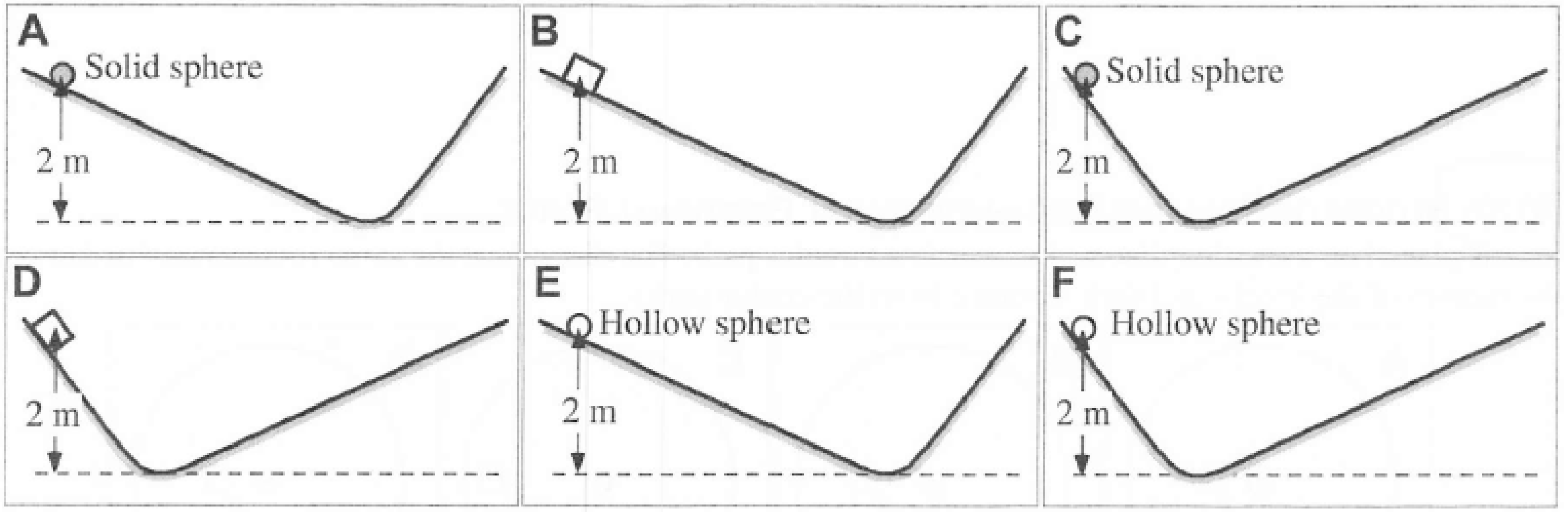
Explain your reasoning.

Answer: It will be below point A.

The initial potential energy will be converted into both rotational kinetic energy and translational kinetic energy at point B. After the ball is launched, it will still be spinning. Once it is in the air there is no external torque acting on it so it will continue to rotate at the angular velocity with which it was launched. At the top of its trajectory, it will still have rotational kinetic energy, so the final gravitational potential energy will be less than the initial.

B6-RT30: Moving down a Ramp—Maximum Height on the Other Side of a Ramp

In each case, a 1-kg object is released from rest on a ramp at a height of 2 m from the bottom. All of the spheres roll without slipping, and the blocks slide without friction.



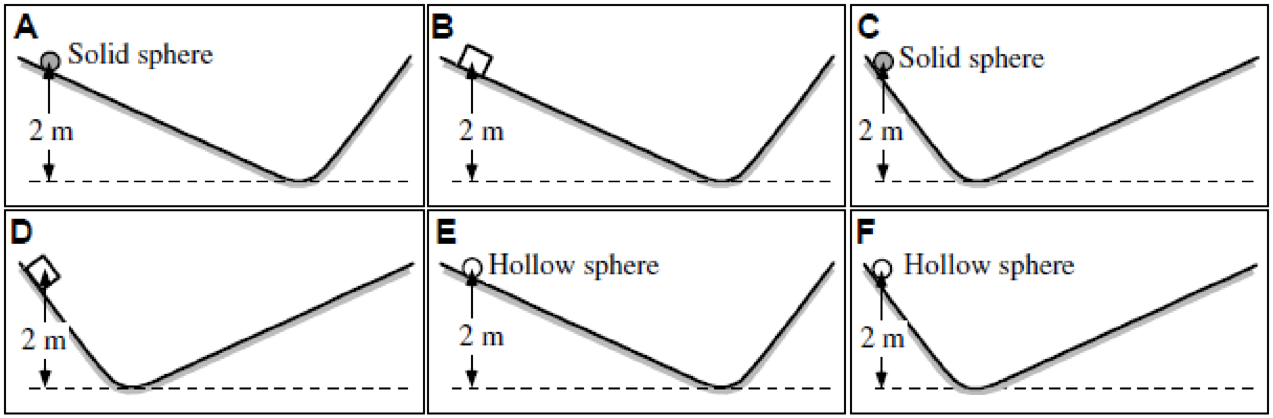
Rank the maximum height of the objects on the other side of the ramp.

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

Explain your reasoning.

B6-RT30: Moving down a Ramp—Maximum Height on the Other Side of a Ramp

In each case, a 1-kg object is released from rest on a ramp at a height of 2 m from the bottom. All of the spheres roll without slipping, and the blocks slide without friction.



Rank the maximum height of the objects on the other side of the ramp.

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

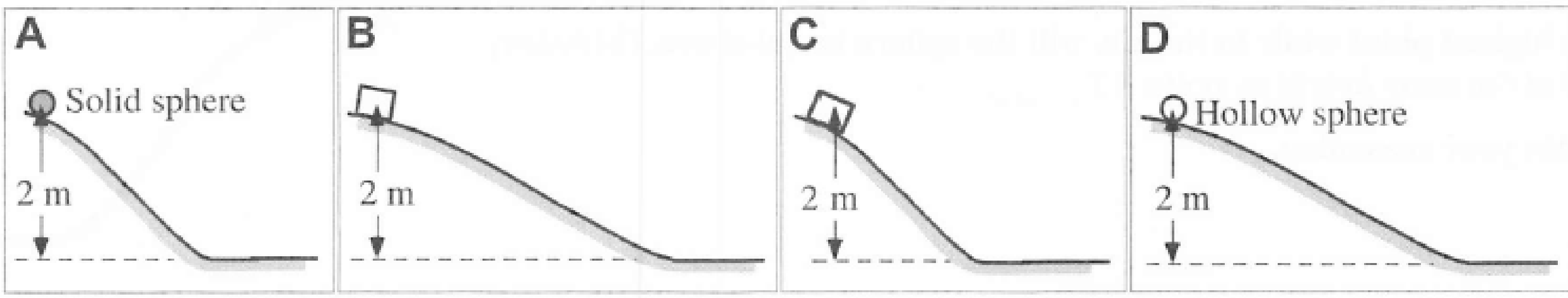
Explain your reasoning.

Answer: All the same.

None of the objects lose energy as they travel, so they will all have the same potential energy on the other side. All objects will come to rest on the other side at a height of 2 meters.

B6-RT31: OBJECTS MOVING DOWN RAMPS—SPEED AT BOTTOM

In each case, a 1-kg object is released from rest on a ramp at a height of 2 m from the bottom. All of the spheres roll without slipping, and the blocks slide without friction. The ramps are identical in Cases A and C. The ramps in Cases B and D are identical and are not as steep as the others.



Rank the speed of the objects when they reach the horizontal surface at the bottom of the ramp.

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

Explain your reasoning.

Answer: B = C > A > D.

Since all of the masses are the same a large translational speed corresponds to a large translational kinetic energy. At the bottom of the ramp all of the objects have converted all of their initial potential energy into kinetic energy. However the spheres will have converted some of the potential energy into rotational kinetic energy as well as translational kinetic energy, whereas all of the initial potential energy of the blocks will have been converted into translational kinetic energy. Since the height of the objects initially is all the same, all of the initial energies are the same. The shape of the ramp does not matter. Since a hollow sphere has agreater moment of inertia than a solid sphere, the hollow spheres will have a greater fraction of their energy as rotational energy when they are rolling without slipping.