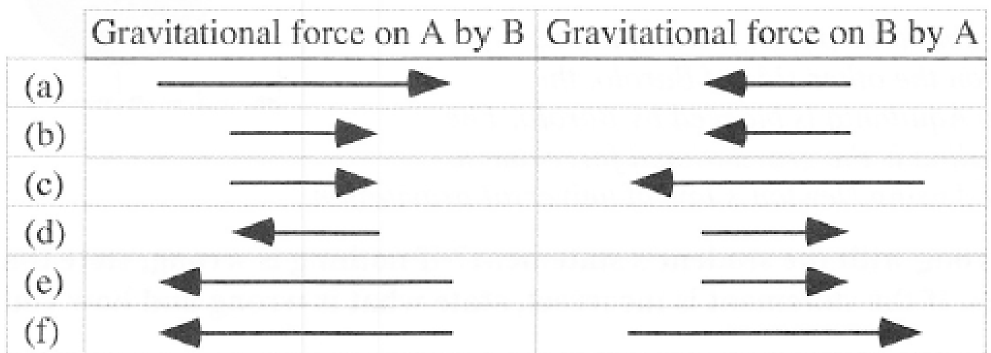
B3-QRT96: Two Objects—Gravitational Force on Each

Object A has twice the mass of Object B.

Identify the pair of force vectors (the arrows) that correctly compare the gravitational force exerted on A by B with the gravitational force exerted on B by A.

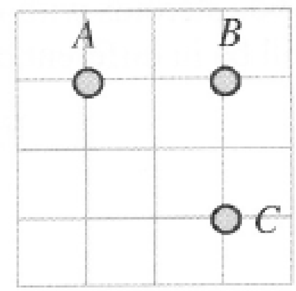


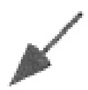
Explain your reasoning.

Answer; (b).
The forces must be attractive, because the gravitational force is always an attractive force. Newton's Third Law requires that the magnitude of the forces be the same.

B3-QRT94: THREE OBJECTS EXERTING GRAVITATIONAL FORCES—NET FORCE

Three objects each with a mass of M exert gravitational forces on each other. **Which of the arrows below shows the direction of the net force on mass B?**



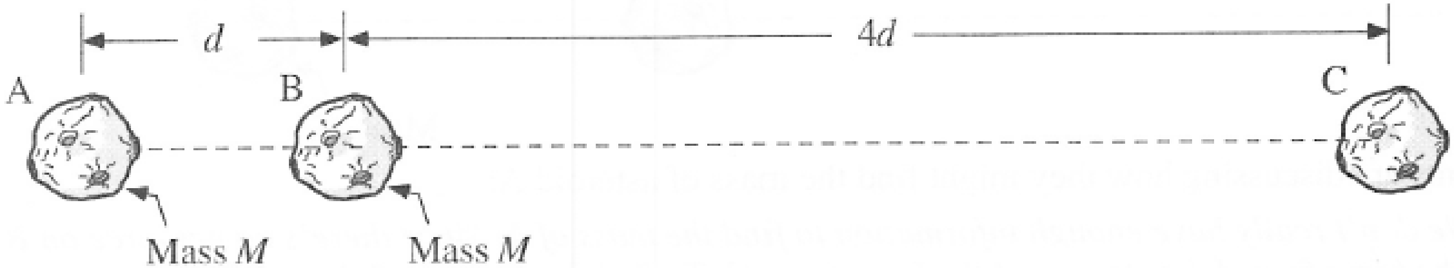
(i)  (ii)  (iii)  (iv)  (v) None of these

Explain your reasoning.

Answer (a) vector addition of the force on B by A (which is directed horizontally to the left) and the force on B by C (which is directed toward the bottom of the page or down) results in a force 45° down to the left.

B3-WWT95: Three Asteroids in a Line—Mass of Asteroid

At the instant shown, three asteroids are in a line, and the distance between B and C is 4 times as large as the distance between A and B. Asteroids A and B have the same mass. There is no net force on asteroid B due to the other two asteroids.



A student makes the following comment about the mass of asteroid C:

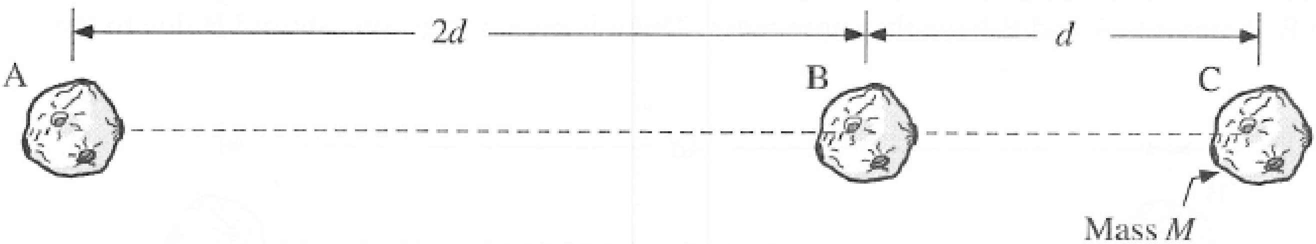
"Since C is four times as far from B as A is, it is only going to have one-quarter the effect on B. To get the forces on B to balance, you'd need the mass of C to be four times as large."

What, if anything, is wrong with the student's statement? If nothing is wrong, state that explicitly, and explain why it is correct. If the statement is incorrect, state what is wrong and how you would correct it.

Answer: The statement is incorrect.
The gravitational force on one asteroid by another is proportional to the product of the masses and inversely proportional to the square of the distance between the centers of mass. If asteroid C had the same mass as asteroid A, the force C exerts on B would only be one-sixteenth the magnitude of the force that A exerts on B. For the magnitude of the force that C exerts on B to be the same as the magnitude of the force that A exerts on B, the mass of C has to be sixteen times the mass of A. The two forces acting on B would then be equal in magnitude and opposite in direction, and the net force on B would be zero.

B3-SCT93: THREE ASTEROIDS IN A LINE—CALCULATION OF MASS

At the instant shown, three asteroids are in a line, and the distance between A and B is twice the distance between B and C. Asteroid C has mass M. There is no net force on asteroid B due to the other asteroids.



Three students are discussing how they might find the mass of asteroid A:

Ari: *"We don't really have enough information to find the mass of A. Since there's no net force on B, the force from A has to cancel the force from C. To find the force on B from C, we'd use Newton's law of universal gravitation. But since the force is proportional to the product of the masses, we'd need to know both masses."*

Bira: *"I don't think we really need the mass of B. Asteroid A is twice as far away as C, so if it also has a mass M it will exert half as much force as C does. Since it has to exert the same force for the net force on B to be zero, it has to have twice the mass."*

Cole: *"It's true that A pulls on B to the left, and C pulls on B to the right. But you can't just use Newton's law of universal gravitation, because that only allows you to calculate the force between two masses. Here there are three masses, and asteroid A is exerting some of its force on B and some on C."*

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

Ari _____ **Bira** _____ **Cole** _____ None of them_____

Explain your reasoning.

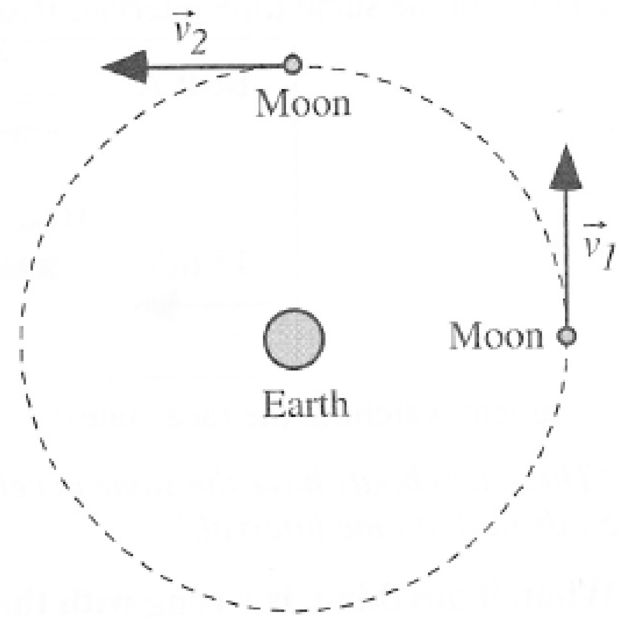
Answer: None of the students are correct, but Bira comes close.
The force on B due to each of the other asteroids is proportional to the mass of B, as Ari states. However, if the mass of B were to increase by some factor, the force acting on it from each of the other asteroids would increase by that same factor, and the net force on it would still be zero. Bira's reasoning is correct except that the force due to each asteroid is proportional to the inverse square of the distance. Since asteroid A is twice as far away from B as C is, it would only exert one-quarter the force if it had mass M. Asteroid A must have a mass 4M in order for the net force on B to be zero. Cole is correct that the universal law of gravitation only allows you to calculate the force between two masses, but once you have used this law to calculate the force between each pair of masses, the force on any individual mass is just the vector s

B2-QRT05: VELOCITY AND POSITION OF THE MOON—VELOCITY CHANGE DIRECTION

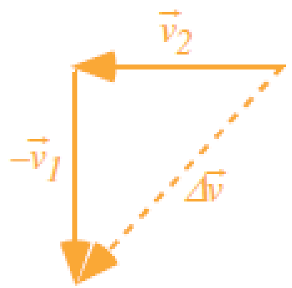
The position and velocity of the moon are shown at two times, about seven days apart.

Find the direction of the change in velocity of the moon in this time interval. If the change in velocity is zero, state that explicitly.

Explain your reasoning.

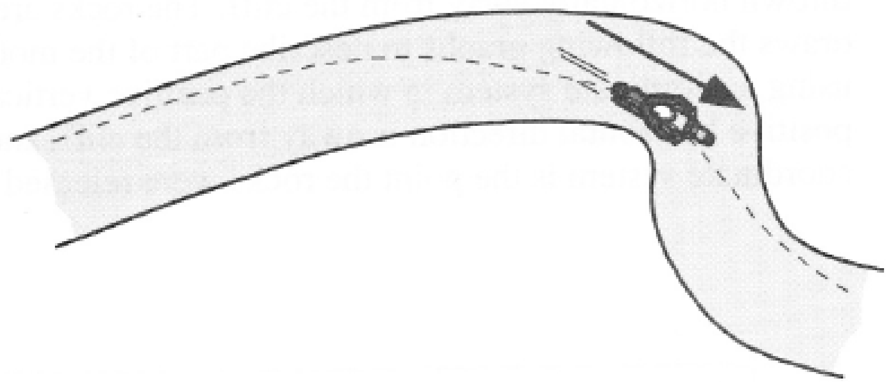


Answer: The change in velocity is found by subtracting the earlier velocity from the later velocity. The direction of the change in velocity is down and to the left.



B2-SCT06: MOTORCYCLE ON ROAD COURSE—ACCELERATION

A motorcycle is slowing down as it travels through a bend in a road. The path of the motorcycle is the dashed line shown in the bird's-eye view. The arrow represents the motorcycle's velocity at the instant shown. Three physics students make the following contentions about the acceleration of the motorcycle:



Alexi: *"The motorcycle's acceleration is in the opposite direction to the velocity since it is slowing down."*

Bindi: *"No, the acceleration will have two components, one opposite the velocity and the other toward the center of the curve."*

Carlos: *"I don't think the motorcycle has an acceleration, since it is braking."*

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

Alexi _____ Bindi _____ Carlos _____ None of them_____

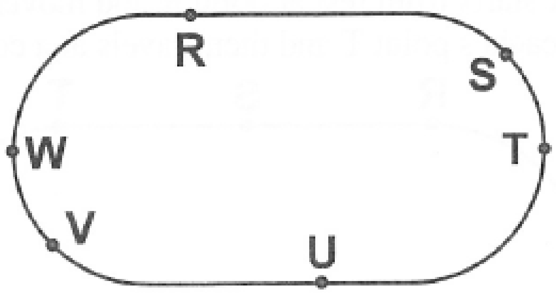
Explain your reasoning.

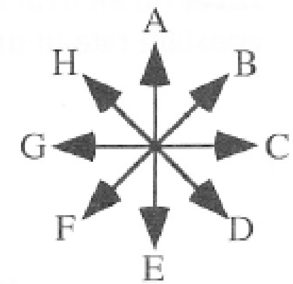
Answer: Bindi is correct. Both the rate of motion and the direction of motion are changing. Since the motorcycle is slowing down, it will have an acceleration component in the direction opposite its motion, and since it is turning it will have an acceleration component perpendicular to the direction of motion toward the center of curvature.

B2-QRT26: Constant Speed Car on Oval Track—Acceleration and Velocity Directions

A car travels clockwise at a constant speed around an oval track.

In the table below, indicate the direction of the velocity and acceleration of the car for the labeled points. Use the direction labels in the rosette at the far right: **J** for no direction, **K** for into the page, **L** for out of the page, or **M** if none of these are correct.





Point on track	Velocity direction	Acceleration direction
R		
S		
T		
U		
V		
W		

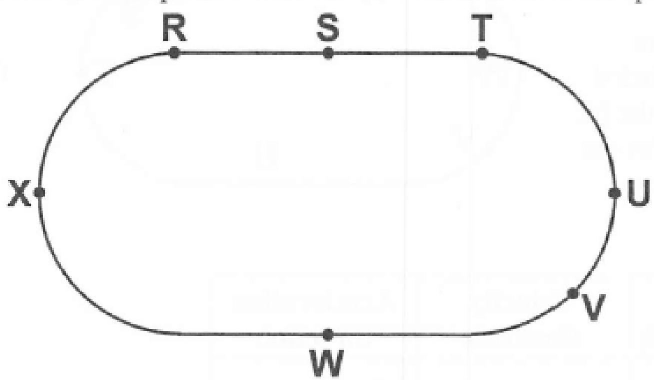
Explain your reasoning.

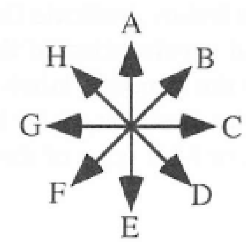
Answer: The velocity of the car is tangent to the path at each point in the direction of motion. The car's velocity points to the right at point R and the speed is constant so the acceleration is zero. At S the velocity is directed toward D, but its direction is changing so the acceleration is directed toward F. The situation is similar at T with the velocity directed toward E and the acceleration, which has to be perpendicular to the velocity since only the direction is changing, is directed toward G. For point U the velocity is tangent to the track the acceleration is zero. For point V the velocity is tangent to the track pointing toward H, and the acceleration is perpendicular to this, pointing toward B. At point W the velocity is directed toward A and the acceleration is directed toward C.

Point on track	Velocity direction	Acceleration direction
R	C	J
S	D	F
T	E	G
U	G	J
V	H	B
W	A	C

B2-QRT27: Car on Oval Track—Direction of the Acceleration and Velocity

A car on an oval track starts from rest at point R and moves clockwise around the track. It increases its speed at a constant rate until it reaches point T and then travels at a constant speed until it returns to point R.





In the table below, give the direction of the velocity and acceleration of the car at the indicated points. Use the direction labels in the rosette to the right of the racetrack drawing: **J** for no direction, **K** for into page, **L** for out of page, or **M** if none of these are correct.

Point on track	Velocity direction	Acceleration direction
S		
U		
V		
W		
X		

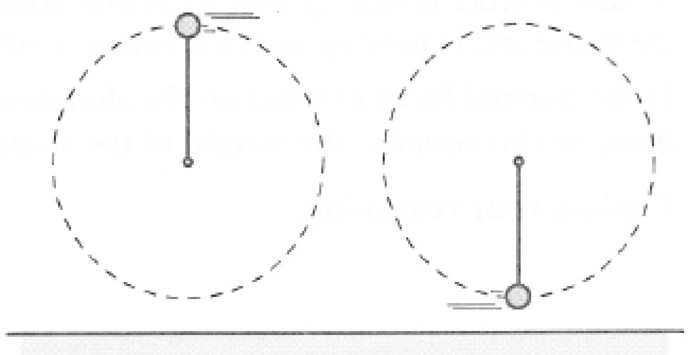
Explain your reasoning.

The car's velocity points to the right between points R and T, and since the speed is increasing the acceleration also points to the right. From point T to the bottom of the semicircle it is moving at a constant speed in a circle, so there is only a centripetal acceleration pointing to the inside of the track and perpendicular to the velocity. For point U the velocity is tangent to the track and points down, and the acceleration is to the left. For point V the velocity is tangent to the track pointing down and to the left, and the acceleration is perpendicular to this, pointing up and to the left. At point W the velocity is to the left but since the car is not speeding up, slowing down, or changing directions there is no acceleration. Finally, at point X the velocity is tangent to the track pointing up, and the acceleration is centripetal only, pointing to the right.

Point on track	Velocity direction	Acceleration direction
S	*C*	*C*
U	*E*	*G*
V	*F*	*H*
W	*G*	*J*
X	*A*	*C*

B3-SCT100: Ball Whirled in Vertical Circle—Net Force on Ball

A ball with a weight of 2 N is attached to the end of a cord of length 2 m. The ball is whirled in a vertical circle counterclockwise. The tension in the cord at the top of the circle is 7 N, and at the bottom it is 15 N. (The speed of the ball is not the same at these points.)



(a) Three students discuss the net force on the ball at the top.

Angelica: *"The net force on the ball at the top position is 7 N since the net force is the same as the tension."*

Bo: *"The net force on the ball at the top position is 9 N. Both the tension and the weight are acting downward so you have to add them."*

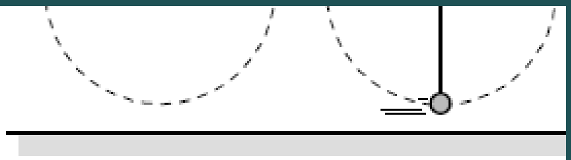
Charles: *"No, you are both wrong. You need to figure out the centripetal force (mv^2/r) and include it in the net force."*

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

Angelica _____ Bo _____ Charles _____ None of them _____

Explain your reasoning.

(a) Three students discuss the net force on the ball at the top.



Angelica: "The net force on the ball at the top position is 7 N since the net force is the same as the tension."

Bo: "The net force on the ball at the top position is 9 N. Both the tension and the weight are acting downward so you have to add them."

Charles: "No, you are both wrong. You need to figure out the centripetal force (mv^2/r) and include it in the net force."

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

Angelica _____ Bo _____ *Charles* _____ None of them _____

Explain your reasoning.

Answer: Bo is correct, as can be seen by drawing a free-body diagram for the ball.
The tension acts downward at the top (the cord cannot push on the ball!) and the weight is also downward, toward the center of the earth. So the net force at the top is the vector sum of these to forces acting in the same direction and has a magnitude of 9 N.

(b) Now the students discuss the net force on the ball at the bottom.

Angelica: *"The net force on the ball at the bottom position is 15 N since the net force is the same as the tension."*

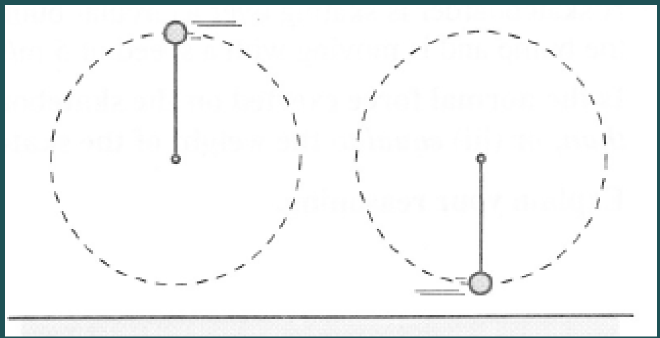
Bo: *"The net force on the ball at the bottom position is 17 N, since you need to add the weight of 2 N to the tension of 15 N."*

Charles: *"The net force on the ball at the bottom position is 13 N. I agree that you need to take into account both the weight and the tension, but they are in different directions so they will subtract."*

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

Angelica _____ Bo _____ Charles _____ None of them _____

Explain your reasoning.



(b) Now the students discuss the net force on the ball at the bottom.

Angelica: "The net force on the ball at the bottom position is 15 N since the net force is the same as the tension."

Bo: "The net force on the ball at the bottom position is 17 N, since you need to add the weight of 2 N to the tension of 15 N."

Charles: "The net force on the ball at the bottom position is 13 N. I agree that you need to take into account both the weight and the tension, but they are in different directions so they will subtract."

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

Angelica _____ Bo _____ *Charles* _____ None of them _____

Explain your reasoning.

Answer: Charles is correct, as can be seen by drawing a free-body diagram for the ball.
The tension is upward and the weight is still downward, and the vector sum of these two forces must point toward the center of the circle. The magnitude of the net force is the vector sum of these two oppositely directed forces and has a magnitude equal to 15 N minus 2 N or 13 N.

B3-CT101: SKATEBOARDER ON CIRCULAR BUMP—WEIGHT AND NORMAL FORCE

A skateboarder is skating over a circular bump. At the instant shown, she is at the top of the bump and is moving with a speed of 5 m/s.

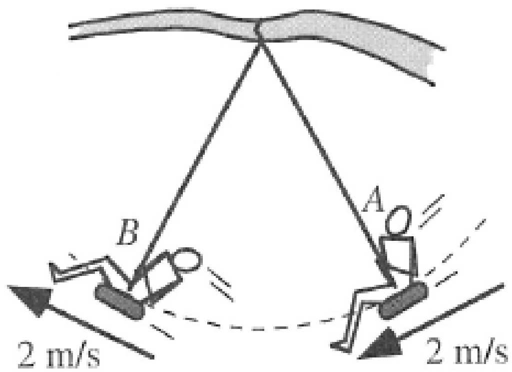
Is the normal force exerted on the skateboarder by the bump (i) *greater than,* (ii) *less than,* or (iii) *equal to* the weight of the skateboarder? ______

Explain your reasoning.

Answr: The normal force is less than the weight.
Since the skateboarder is moving along a circular path, there is an acceleration toward the center of the circle, or downward. Therefore the net force must point down, and the weight must be greater than the normal force.

B3-SCT102: CHILD ON A SWING—TENSION

A child is swinging back and forth on a tire swing that is attached to a tree branch by a single rope. Shown are two positions during a swing from right to left. Three students are discussing the tension in the rope at the bottom of the swing.



Alia: *"At the bottom of the swing, she will be moving exactly horizontally. Since she is not moving vertically at that instant, the vertical forces cancel. The tension in the rope at that instant equals the weight."*

Brian: *"Just looking at the velocity vectors, the change in velocity points upward between A and B. So that is the direction of the acceleration, and also of the net force. To get a net force pointing upward, the tension would have to be greater than the weight."*

Clara: *"But there aren't just two forces acting on her at the bottom of the swing. Since she's moving in a circle, there's also the centripetal force, which acts toward the center of the circle. Since both the tension and the centripetal force point upward, and the weight points downward, to get zero net force the tension actually has to be less than the weight. The tension plus the centripetal force equals the weight."*

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

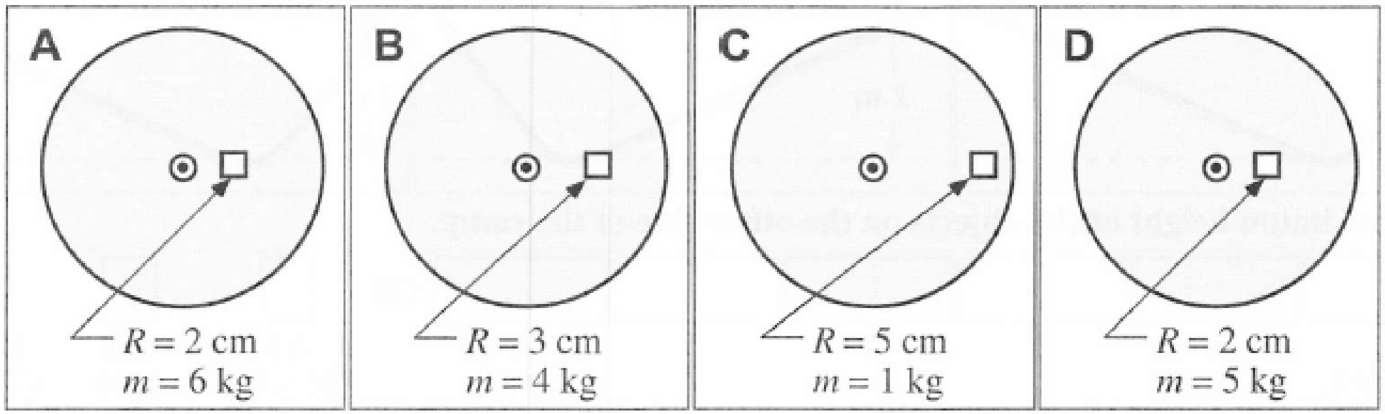
Alia _____ Brian _____ Clara _____ None of them_____

Explain your reasoning.

Answr: Brian is correct.
The average acceleration must be in the direction of the change in velocity from A to B, which is upward. So the net force points upward, and therefore the tension must be greater than the weight. Clara is treating the centripetal force as if it were a separate force, when in this case the force acting toward the center is the tension.

B6-RT32: Blocks on Rotating Disc—Horizontal Frictional Force

A block is placed on a rotating disc and moves in a circular path. The discs have the same rotation rate in each case, but the masses of the blocks and their distance from the center varies.



Rank the magnitude of the frictional force on blocks by the discs.

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

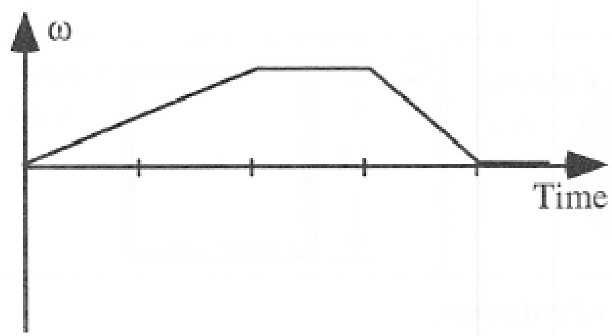
Explain your reasoning.

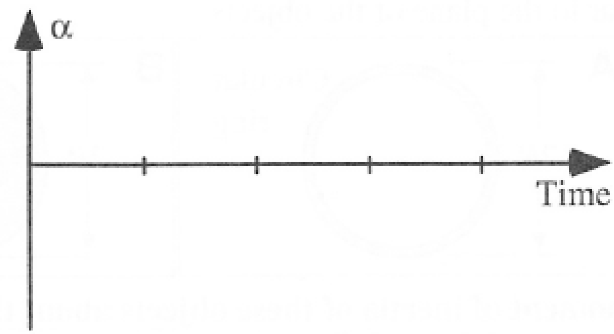
Answer: A = B > D > C.

The blocks are being held on the discs by the frictional force which in this case is acting as the centripetal force. Centripetal forces are calculated by mass times velocity squared divided by the radius. The linear velocity is the radius times the angular velocity, so the forces are proportional to the product of the mass and the radius.

B6-CRT02: ANGULAR VELOCITY-TIME GRAPH—ANGULAR ACCELERATION-TIME GRAPH

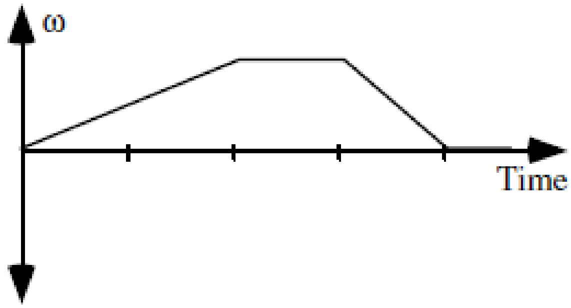
Sketch an angular acceleration versus time graph given the angular velocity versus time graph shown for the same time interval.

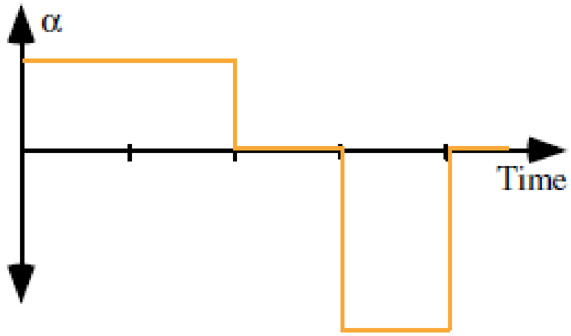




Explain your reasoning.

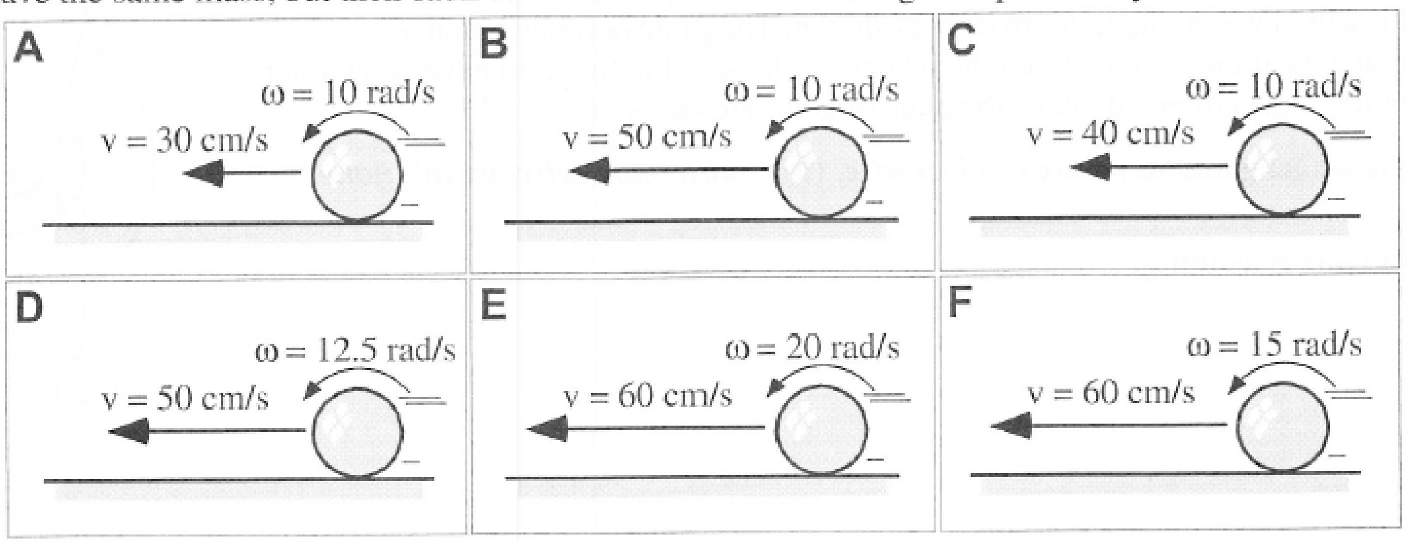
Answer: The slope of the line in the angular velocity graph tell us the angular acceleration. The first segment has a positive slope for two time units, then a zero slope for one time unit, a negative slope for one time unit, and finally a zero slope at zero velocity. The positive slope has a smaller magnitude than the negative slope, so the acceleration-time graph should look like the following:





B6-RT06: Spheres Rolling—Radius

The figures below show hollow spheres (not drawn to scale) that are rolling at a constant rate without slipping. The spheres all have the same mass, but their radii as well as their linear and angular speeds vary.



Rank the radius of the spheres.

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

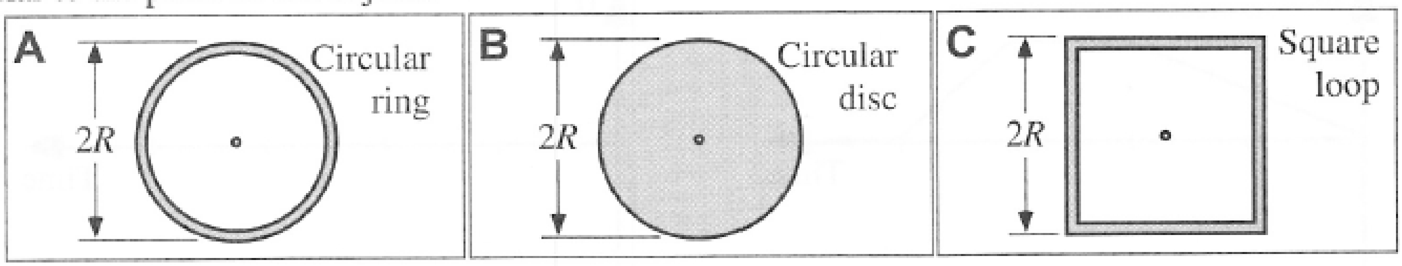
Explain your reasoning.

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

Ranked on v/ω since $v = \omega R$ when objects roll without slipping.

B6-RT04: Flat Objects—Moment of Inertia Perpendicular to Surface

Three flat objects (circular ring, circular disc, and square loop) have the same mass M and the same outer dimension (circular objects have diameters of $2R$ and the square loop has sides of $2R$). The small circle at the center of each figure represents the axis of rotation for these objects. This axis of rotation passes through the center of mass and is perpendicular to the plane of the objects.



Rank the moment of inertia of these objects about this axis of rotation.

1 Greatest	2	3 Least	OR	All the same	Cannot determine

Explain your reasoning.

Answer: C > A > B.

Based on the distribution of mass. Mass farther from axis contributes more to the moment of inertia than mass closer to the axis. For the circular ring, all of the mass is at a distance R from the axis of rotation; and for the square loop almost all of the mass is at a distance that is greater than R. All of the mass of the disc is at a distance R or less.

B6-CT17: SPECIAL ROD—MOMENT OF INERTIA

A rod is made of three segments of equal length with different masses. The total mass of the rod is $6m$.

Will the moment of inertia of the rod be (i) *greater* about the left end, (ii) *greater* about the right end, or (iii) *the same* about both ends? _____

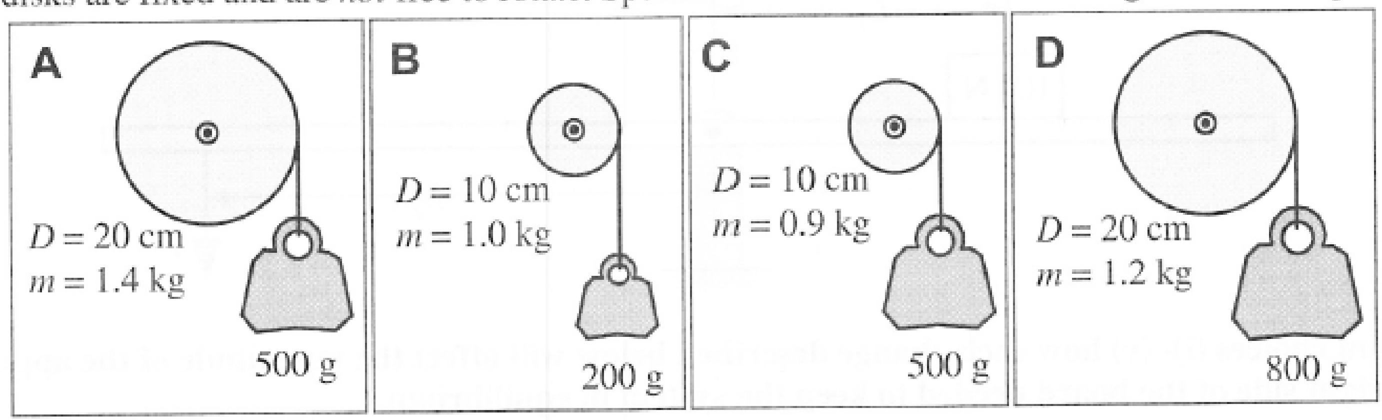
Explain your reasoning.

Answer: (i) The moment of inertia will be greater about the left end.

The moment of inertia is a measure of how difficult it is to change the rate of rotation of an object. When mass is close to the axis of rotation, it is not as difficult to speed up or slow down in rotation. The moment of inertia is greatest when more mass is further from the axis of rotation.

B6-RT21: Hanging Weights on Fixed Disks—Torque

Vertically oriented circular disks have strings wrapped around them. The other ends of the strings are attached to hanging masses. The diameters of the disks, the masses of the disks, and the masses of the hanging masses are given. The disks are fixed and are *not* free to rotate. Specific values of the variables are given in the figures.



Rank the magnitudes of the torques exerted by the strings about the center of the disks.

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

Explain your reasoning.

Answer: D > A > C > B.

The torque will be the product of the tension in the string, which will be equal to the magnitude of the hanging weight since the systems remain at rest, times the radius of the disk, which is half of the diameter given in each figure.