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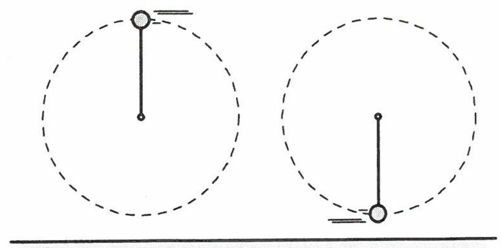
#1 **B3-SCT100: BALL WHIRLED IN VERTICAL CIRCLE—NET FORCE ON BALL**

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.

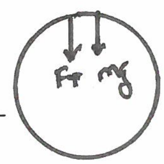
Angelica: "The net force on the ball at the top position is 7 N since the net force is the same as the tension."

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?

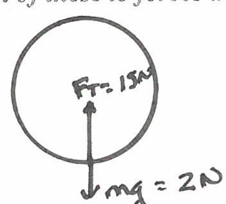
Angelica ____ Bo __X__ *Charles* ____ None of them ____



$F_{Net} = F_T + mg$
$= 7N + 2N$
$= 9N$

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?

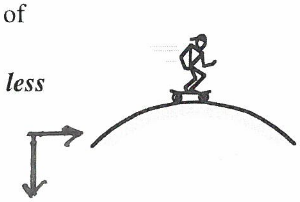
Angelica ____ Bo ____ *Charles* __X__ None of them ____

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.

#2 **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.

$\Sigma F_{Net} = -F_N + mg = F_c$

$mg = F_c + F_N$

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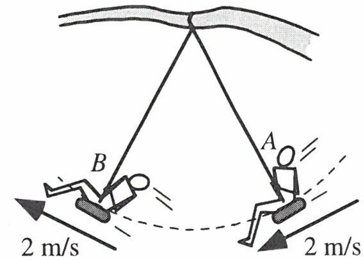
#3

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.



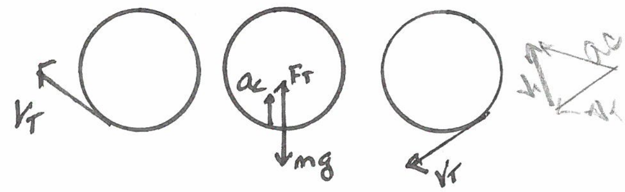
Alia: "At the bottom of the swing, she will be moving exactly horizontally. Since she is not moving vertically at that instant, the vertical forces cancel. The tension in the rope at that instant equals the weight."

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* __X__ *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.

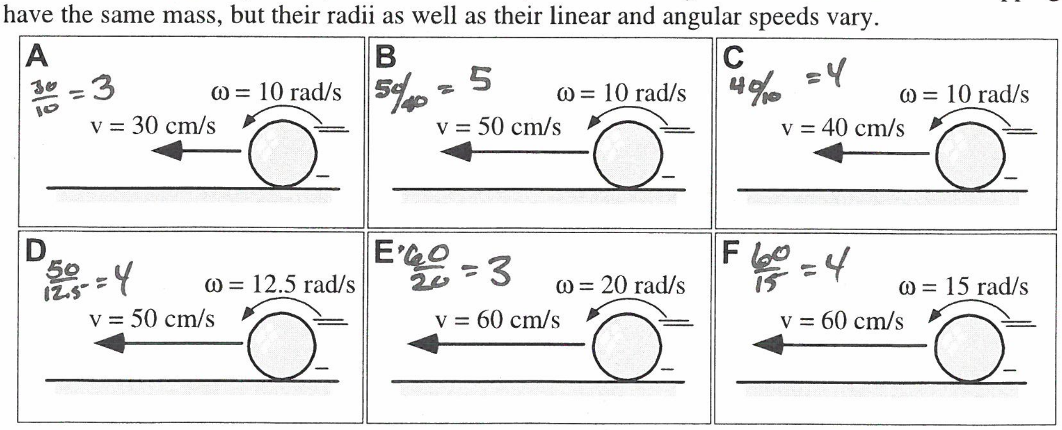
#4

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.

$V_T = r\omega$

$r = \frac{V_T}{\omega}$



Rank the radius of the spheres.

B >	C =	D =	F >	A =	E	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 = ωR when objects roll without slipping.

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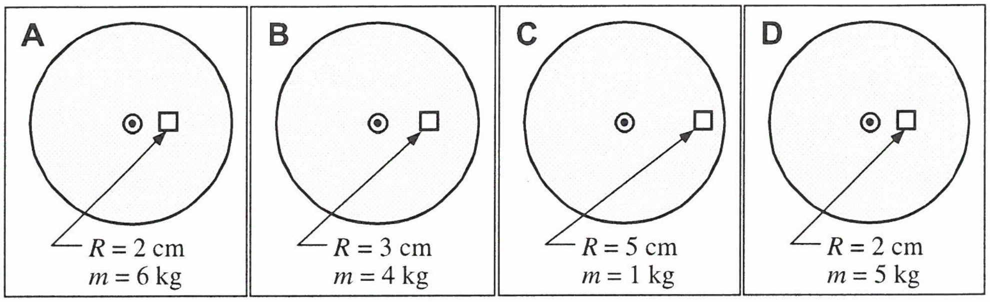
#5 **B6-RT32: Blocks on Rotating Disc—Horizontal Frictional Force**

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.

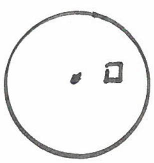
A =	B >	D >	C	OR	☐	☐	☐
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

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.

radius changes, not on outer edge so it is not V_T



$\Sigma F_{net} = F_c$

$F_{net} = F_f$

$F_c = \frac{V_T^2 m}{r}$

$F_f = \frac{V_T^2 m}{r}$ $\quad V_T = \omega r$

$= \frac{\omega^2 r^2 m}{r}$

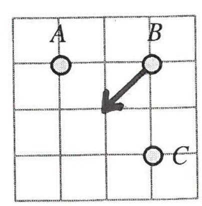
$F_f = \omega^2 r m$ $\quad \omega^2$ = constant ∴ (1)

$F_f = r \cdot m$

A	B	C	D
2×6 = 12	3×4 = 12	5×1 = 5	2×5 = 10

#6 **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.

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#7

B3-QRT96: Two Objects—Gravitational Force on Each

Object A has twice the mass of Object B.

$2m$	m
○ A	● 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.

	Gravitational force on A by B	Gravitational force on B by A
(a)	⟶	←
(b)	→	←
(c)	→	⟵
(d)	←	→
(e)	⟵	→
(f)	⟵	⟶

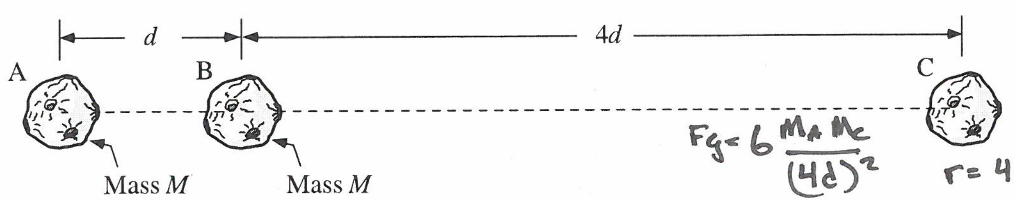
Explain your reasoning.

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.

#8

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.



$F_g = G\frac{M_A M_C}{(4d)^2}$ $r = 4d$

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

$F_g = G\frac{M_A M_C}{16d}$

"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."

$M_C = 1/16$

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.

For M_C to have same F_g as M_A on M_B, M_C ∴ needs to be 16x more mass

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.

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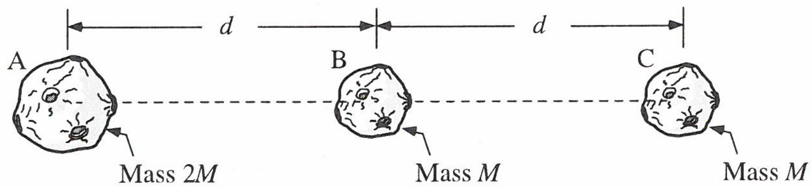
#9 **B3-RT97: THREE ASTEROIDS IN A LINE—NET FORCE**

At the instant shown, three asteroids are in a line, and the distance between A and B is the same as the distance between B and C. Asteroids B and C have the same mass, while asteroid A has twice the mass.



Rank the magnitude of the net force on each asteroid due to the other two asteroids.

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

Explain your reasoning.

Answer: A > C > B.
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 we let the force on B by C have magnitude F then the force on A by B will have magnitude 2F since A has twice the mass. The force on A by C will have magnitude one-half F because the distance is doubled and mass is doubled. Free-body diagrams for the three asteroids are shown below. In terms of F, the magnitude of the net force on A is 2.5F; on B it is F; and on C it is 1.5F.

B3-WWT92: Two Asteroids—Gravitational Force on Each

Two asteroids with masses of m and $3m$ exert gravitational forces on each other. A student contends that the forces will be in different directions and of different magnitudes as shown below.

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

Answer: The forces are attractive so the directions should be reversed and the forces should be equal as required by Newton's Third Law.

B3-CT99: Astronaut near a Moon—Gravitational Force

In both cases shown at right, an astronaut is a distance x from a moon. The two cases are identical except that in Case A there is a large planet directly between the astronaut and the moon.

Is the gravitational force on the astronaut by the moon (i) *greater* in Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

Answer: The same in both cases.
The gravitational force between two objects is the same whether there is mass between the objects or not. Newton's Law of Universal Gravitation will give the force on the astronaut due to the moon in both cases.