Descartes's Laws of Motion

Philosophy 168
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The first law of motion

- “Each and every thing, in so far as it can, always continues in its same state” (Part II, Article 37).
- There are two states relevant to motion: the state of motion and the state of rest.
- So, each thing always continues to move when it is moving and to be at rest when it is at rest.
- This natural tendency to preserve the present state can be overcome by “external causes.”

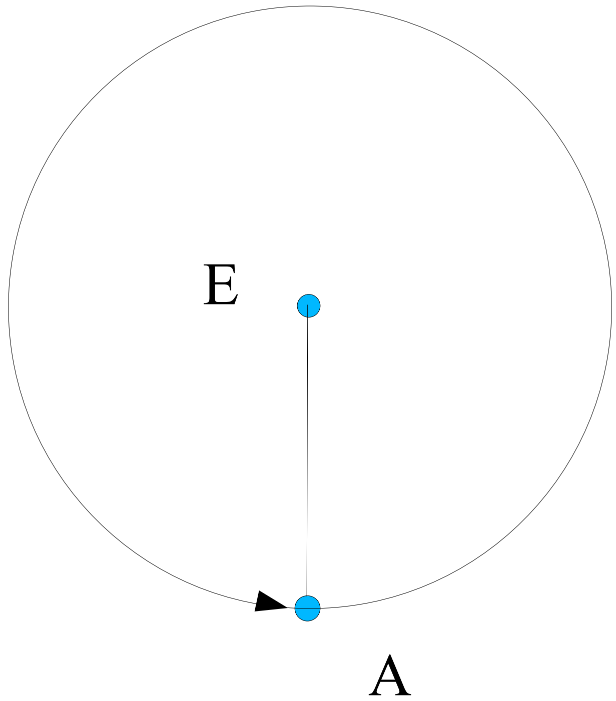
The second law of motion

- “All motion is in itself rectilinear” (Part II, Article 39).
- The natural tendency of a body to move in a straight line can be overcome by external causes.
- At any point in time, a body will continue to move along the straight line in which it has been moving.
- Question: under what conditions will a body move in a circle?

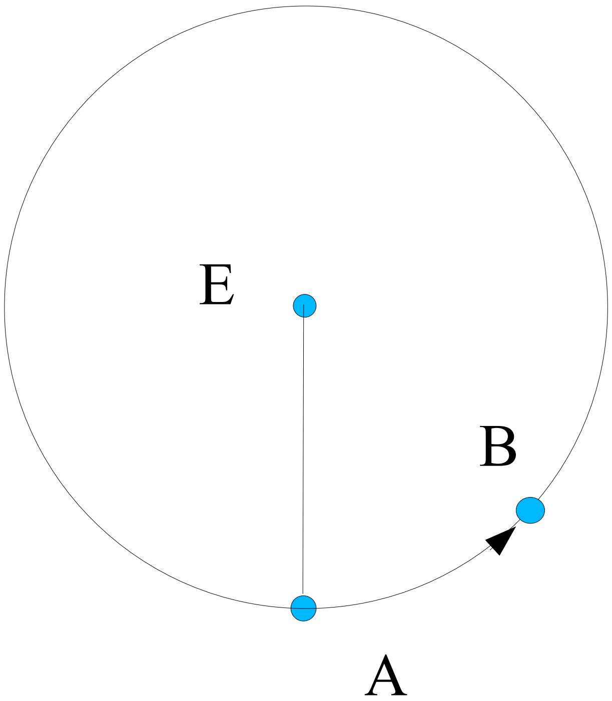
The sling example

- A stone can be swung in a circle by a sling.
- The hand swinging the sling describes a circular motion.
- The sling itself provides a physical connection which allows the duplication of its motion by the stone.

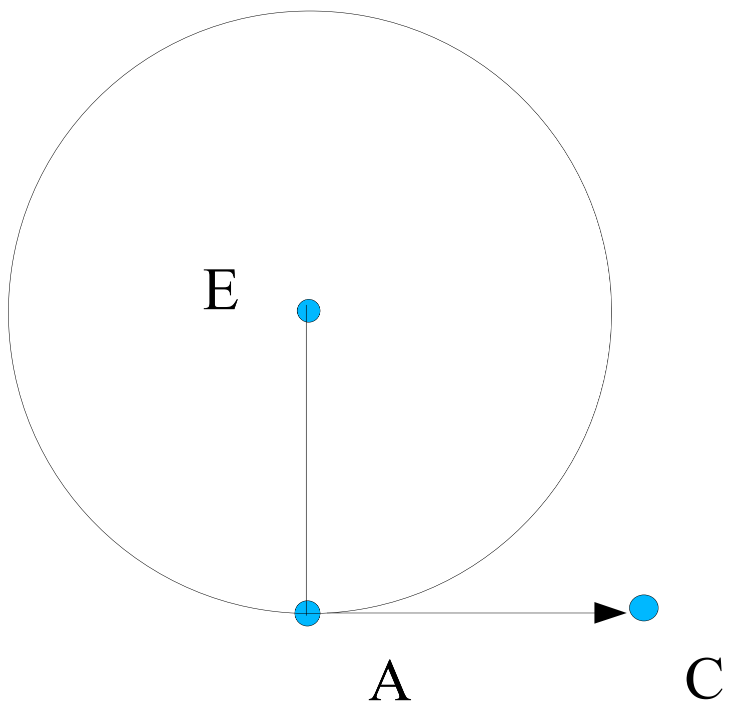
Stone revolving in sling



Stone continues in sling



Stone released at A



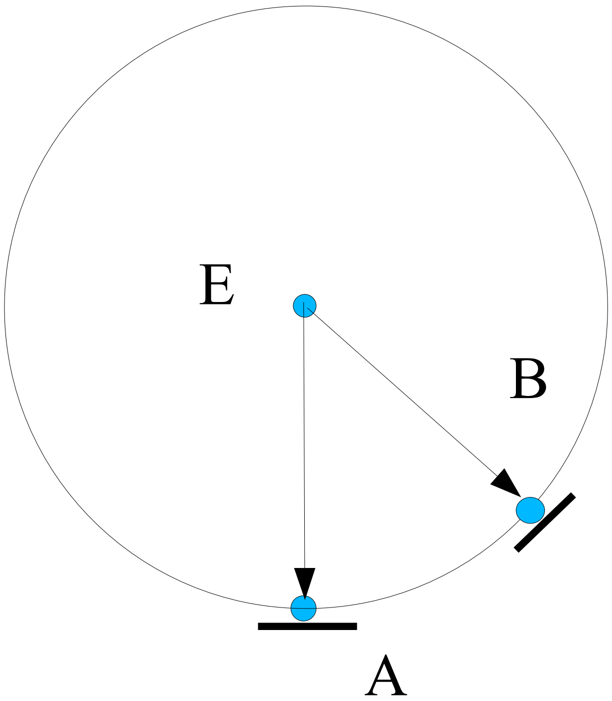
Analysis

- The motion from A to B and from A to C must be explained.
- Descartes states in the rest of Article 39 that “at the instant it is at point A, it is inclined to move along the tangent of the circle toward C.”
- There is no inclination to move circularly at point A, despite the fact that it arrived at A along a curved path.
  - This is a consequence of the second law.

Two Questions

- What is the cause of the stone's circular motion when it moves from A to B?
- Why is the stone inclined to move specifically toward C, and not in some other direction, when it is released?
- The explanation for circular motion has two components.
  - The stone is inclined to move outward from E
  - This inclination is constrained by the sling

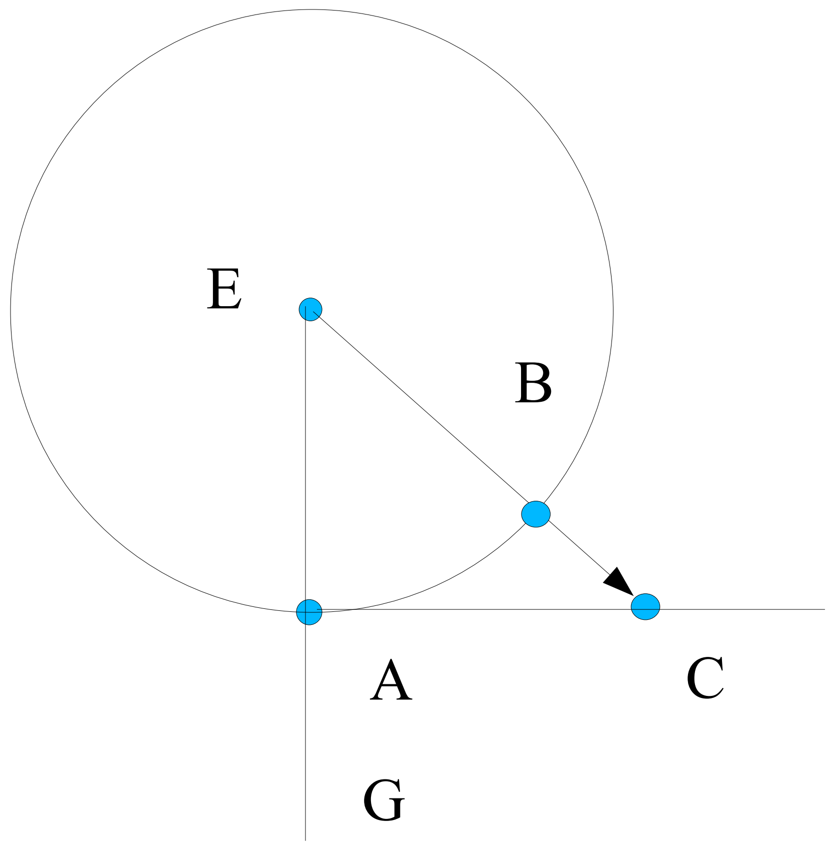
Radial motion constrained



Linear Motion Explained

- What happens when the constraint is removed?
- The radial motion outward from E continues.
- Thus the stone moves farther away from E at each moment after its release.

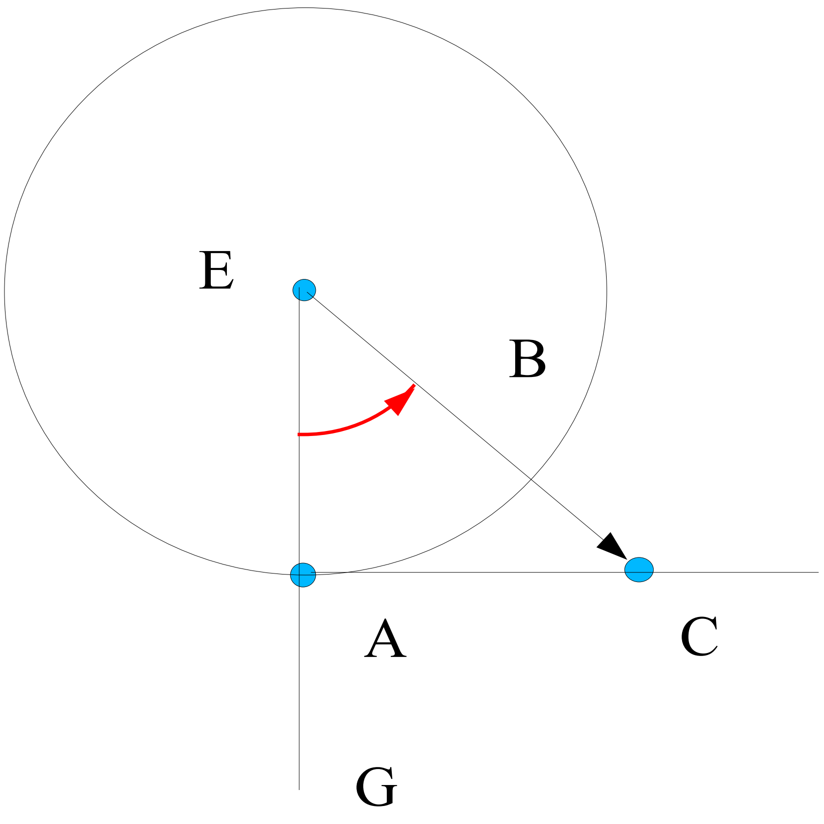
Radial motion unconstrained



Query

- Why does the continuation of the radial motion describe the straight line AC?
- Why does it not instead continue its radial motion along the line EA toward G?
- An obvious answer is that this result is contradicted by experience.
- The only theoretical answer is that the radial axis itself moves in a circular direction.
- But there is no more attachment to the sling!

A circular component of motion



A further issue

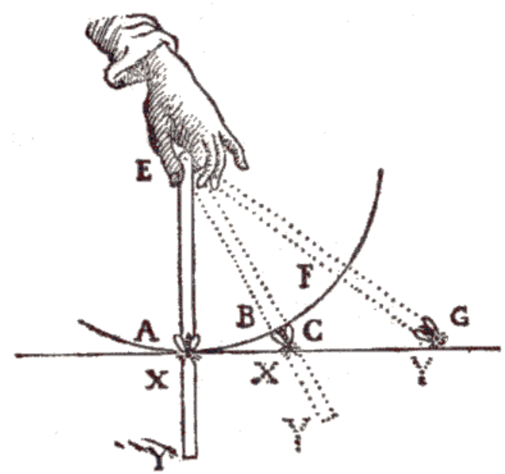
- Experience shows that the stone moves along the tangent AC.
- For this to occur, the motion would have to increase, so that the stone arrives at C in the time it would have arrived at B if constrained.
- Descartes claims that the striving to recede from E increases in force. “In addition to retaining its original force it will acquire a new force from its new striving to recede from E” (Part III, Art. 59).

Ad hoc explanation?

- What reason is there to think that the force would increase?
- Why must it increase at the rate which would yield exactly the path AC?
- If the only answer is that it must increase if the model is to explain what is observed, then this is an *ad hoc* component of the explanation.
- Descartes tried to motivate the claim independently.

Striving

- Descartes claimed that the striving away from the center of a body in circular motion increases with the distance from the center.
- Descartes imagines an ant on a rotating rod, reaching point A from end E.

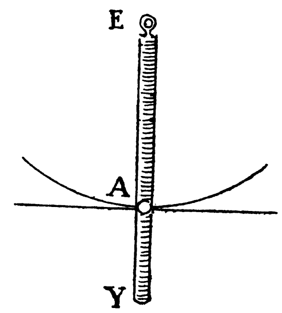


The striving of the ant

- If unrestrained, the ant would arrive at point Y on the rod by the time the rod got to point B.
- The reason is that Descartes assumes that the motion of the rod is exactly what would be needed to get the ant to point Y.
- If the rod rotated at a uniform speed, the ant would have to speed up to get to Y.
- Descartes claims that striving "increases as it has its effect" (Part III, Art. 59).

Accelerated striving

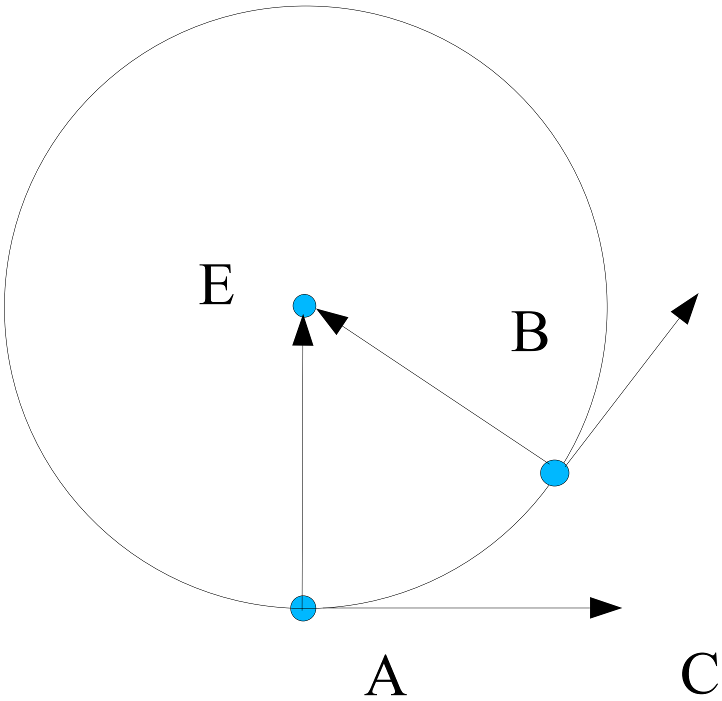
- Descartes introduces experimental evidence that the striving increases.
- Consider a globe A enclosed in a tube and located at point E.
- As the tube rotates, A moves toward the other end and speeds up as it goes.



Newtonian Analysis

- The stone naturally moves in a straight line tangent to the circle.
- The hand is pulling the stone toward it, exerting centripetal force, which makes the path circular.
- When the centripetal force is removed, the stone will move along the tangent.
- The Cartesian radial force, centrifugal force, is an equal and opposite reaction to centripetal force, acting only on the hand.

Two rectilinear forces



Comparison

- Newton’s account requires only rectilinear forces, with no covert appeal to circular motion.
- The tangential path of the unreleased ball does not require explanation for Newton.
- Both explanations appeal to forces, but Descartes’s physics has no place for the “strivings” he postulates.

The third law of motion

- “If a body collides with another body that is stronger than itself, it loses none of its motion.”
- “If it collides with a weaker body, it loses a quantity of motion equal to that which it imparts to the other body” (Part II, Article 40).
- What are the properties “stronger” and “weaker?”
- What is the quantity of motion?
- Details are spelled out in seven rules of collision.

Proof of first part

- Motion considered in itself is a mode of a body.
- Its determination (direction) can be changed with no change in the motion.
- Motion (in itself) “continues to exist so long as it is not destroyed by an external cause.”
- If a body in motion strikes a hard body “which it is quite incapable of pushing,” the other body does not remove its motion, but only changes its determination (French version, Article 41).

Resistance

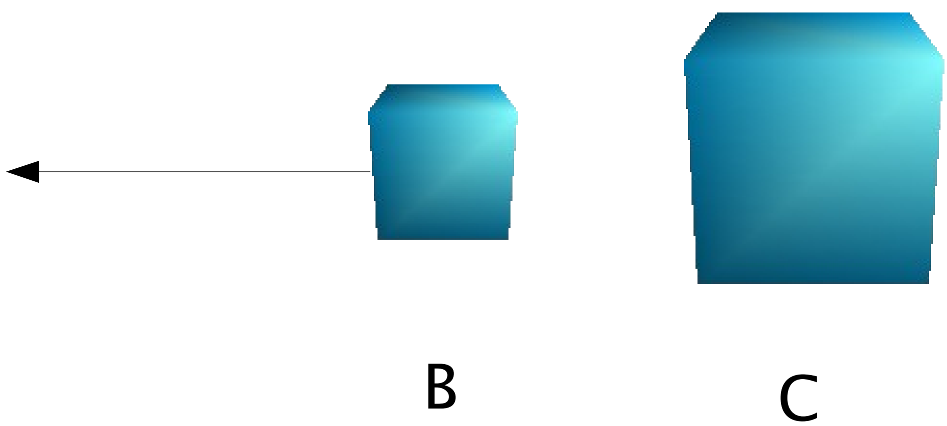
- The power to resist change from motion to rest or from rest to motion is based on the tendency of things to remain in their present state (law one).
- A body's power of resisting change in speed and direction depends on:
  - Its size
  - The size of its surface relative to other bodies
  - The speed of the motion
  - The mode of collision
  - The degree of opposition

Idealizations

- The two colliding bodies are perfectly solid.
  - The rules would be difficult if a tennis ball collided with a pillow, for example.
- No surrounding bodies would aid or impede their movement.
  - Generally, the surrounding bodies do make a difference in how the bodies would move (Article 53).
  - Overcoming the problem requires an examination of the nature of solid and fluid bodies.

Weaker moving B hits stronger stationary C

The result of the collision



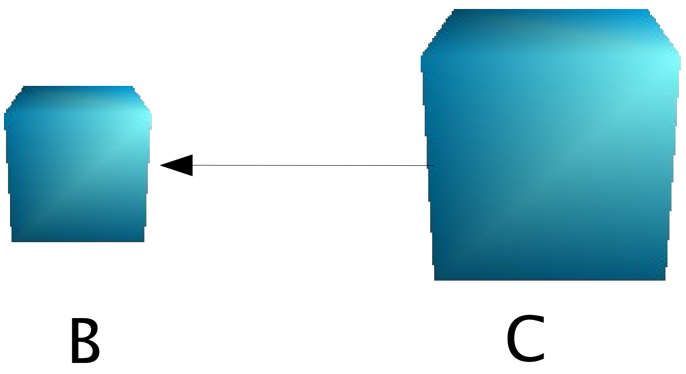
Why does C not move?

- The size of C gives it too much resistance to a change from its state of rest.
- No amount of motion can overcome the advantage in size.
- In fact, Descartes claims that the resistance increases with the speed of the colliding body B!
- An analogy: body C is heavier than body B at the other end of a balance. Only a body heavier than C could tip the scales toward it.

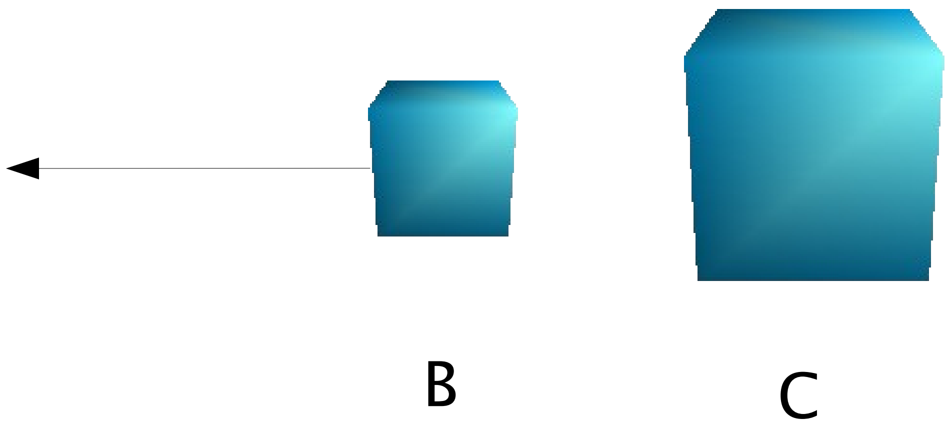
Relativity

- If motion and rest are not taken to be absolute modes of bodies (Article 29), then a problem arises.
- Body C could be said to be in motion, while body B is considered at rest.
- In that case, C's motion ends, while B begins to move.
- This contradicts rule 5, which says that when a larger body strikes a smaller one, it continues to move and sweeps the other in front of it.

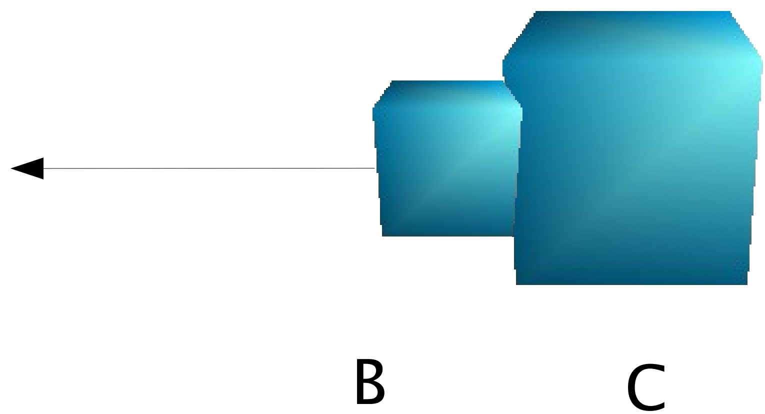
C considered as moving



The result of the collision: C stops



Expected result by rule 5: C pushes B forward



The demise of the third law

- Christian Huygens showed in 1667 that the third law is false.
  - The problem was that the direction of motion, as well as speed and mass, is a factor in the consequences of collision.
- He also showed that the final six rules of collision are false.
- He did, however, use the first rule of collision as an axiom in his own system.
  - Two bodies with equal size and speed will rebound with no loss of speed.

Acknowledgments

I have benefitted greatly in the preparation of these slides from two books:

V. R. Miller and R. P. Miller's translation of the *Principles* (D. Reidel, 1983) for translations of passages not in Cottingham et. al. and for the very helpful footnotes.

Stephen Gaukroger, *Descartes' System of Natural Philosophy* (Cambridge University Press, 2002)