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

B

C
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.
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