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Science education methods involving the use of vector arrows in gravitational and Coriolis force problems

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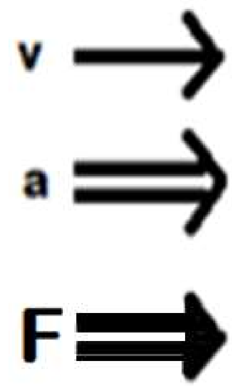
Abstract/Summary:

- Introductory science students often confuse concepts of acceleration and velocity. It can be helpful to remind students that the acceleration of gravity is constant and that "the force of gravity never turns off".
- Newton's second law states force is equal to mass (which is not a vector) times acceleration.
- The Coriolis force, which affects meteorological high and low formation and their advection direction, can also be troubling to students because, while gravity has an identifiable consistently present object as its source of force (e.g. planet Earth), the Coriolis force is due to the geometry (which is non-Euclidian and rotating) on Earth or other planet.
- Dimensional analysis can assist students with the mathematics, but also suggested here is something as simple as using different types of vector arrows for velocity (single-shafted arrow) and **acceleration (double-shafted arrow)** to highlight the differences between these concepts. A **thick double-shafted arrow is suggested to designate force** in preparing diagrams for solving.
- The double shaft also can serve to remind advanced students of the second derivative nature of acceleration and force.
- The alternative use of different colored arrows is also possible but has downside in that color selection is not universal. Also- the use of color might not be practical as when writing in pen. It is suggested that the use of different colors could be reserved for distinguishing different components in the system, but not to differentiate between velocity, acceleration and force which are different types of vectors.

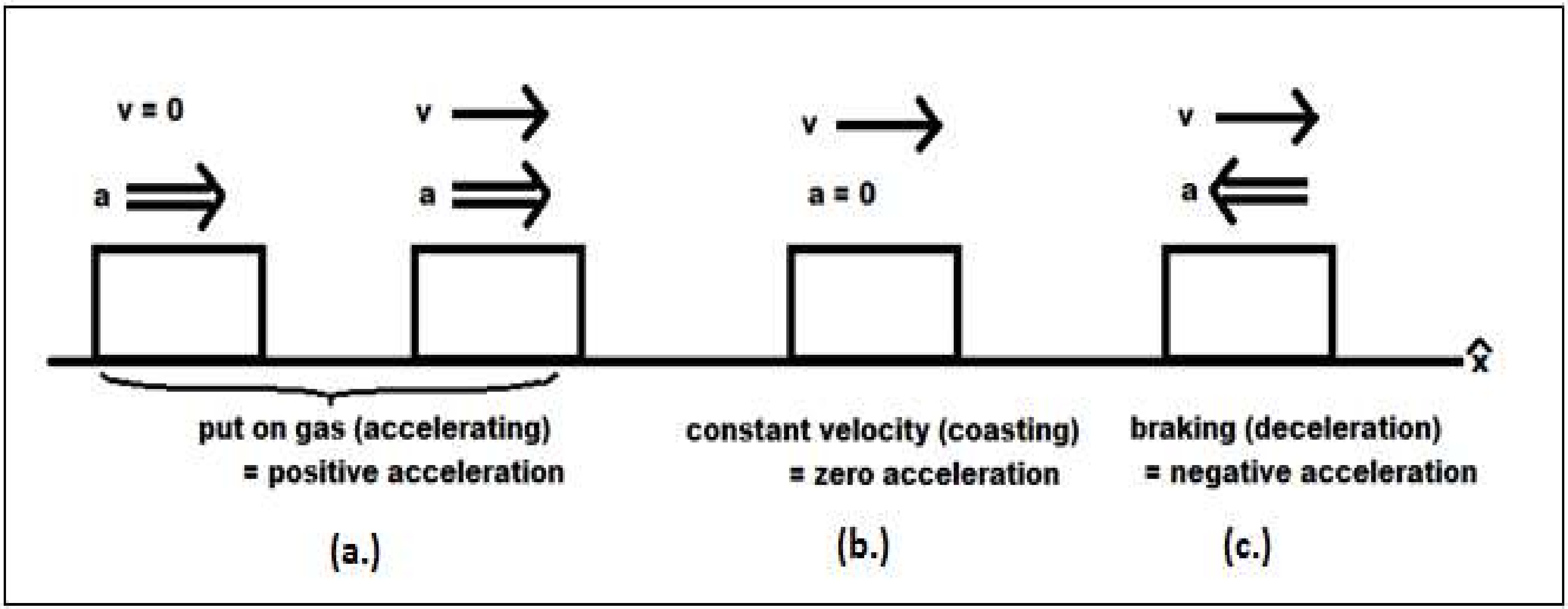
The concepts of acceleration and velocity is often a source of confusion for introductory students

To help students:

- velocity (thin single-shafted arrow)
- acceleration (thin double-shafted arrow)
- force (thick double-shafted arrow)

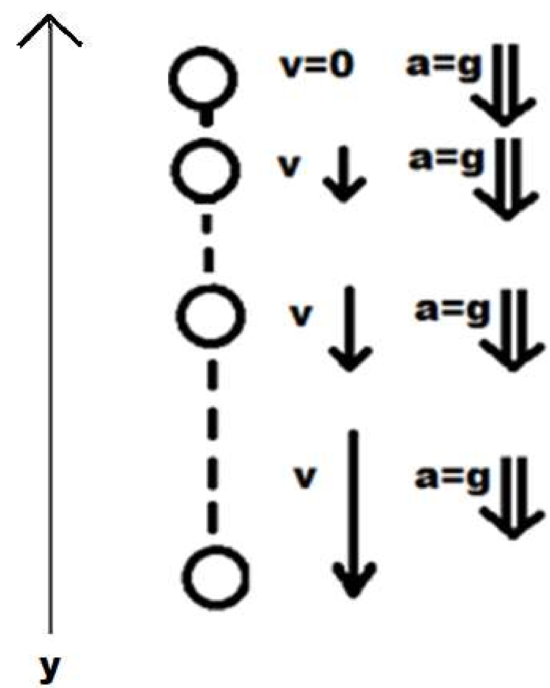


EXAMPLE: Car starting, then moving in the x-direction
(a.) speeding up, then
(b.) travelling at constant velocity, and finally
(c.) braking to decelerate,
where velocity (v) and acceleration (a).



Velocity and acceleration with arrows for a <u>dropped object</u>

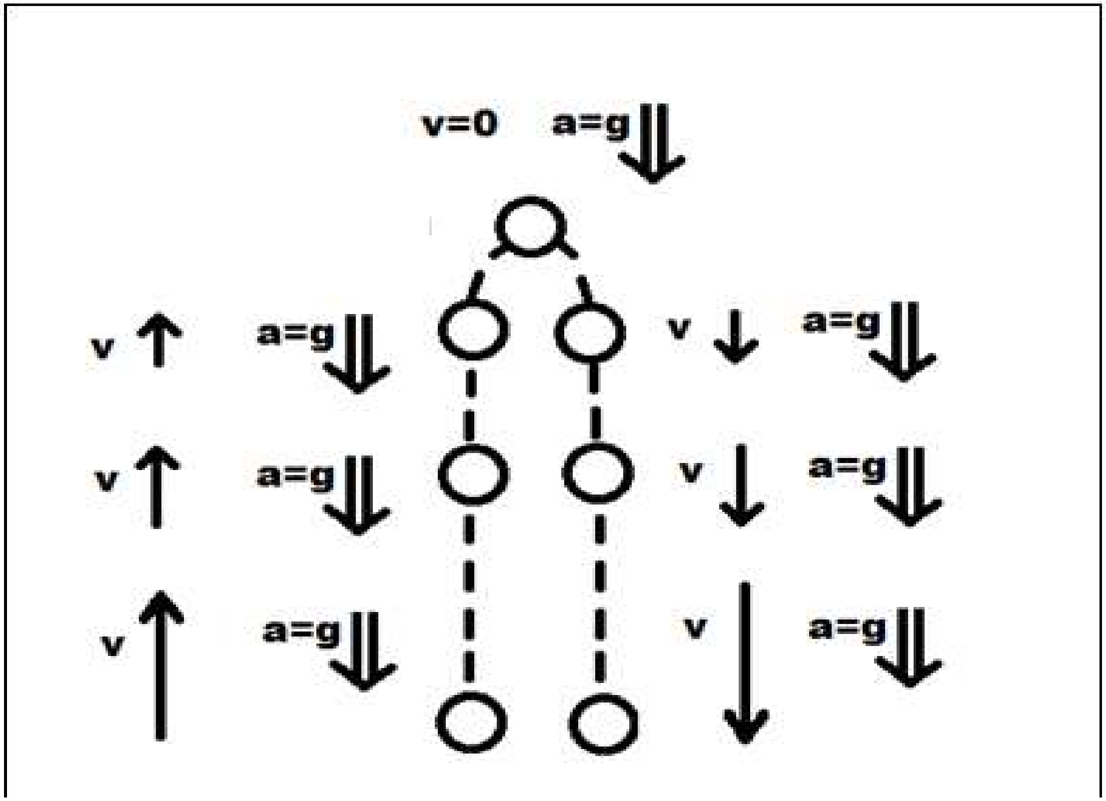
- *<u>Velocity is changing</u> (depict as **single-shafted arrow** that is increasing in length as object falls)*
- *<u>Acceleration of gravity is constant</u> (depict as **double-shafted arrow** that has constant length as object falls)*



ANOTHER EXAMPLE:

Ball thrown upward (after leaves hand) is in free-fall

At the topmost height, velocity is zero but acceleration is not - "gravity does not turn off"!



1. On earth, a ball tossed vertically upward rises. Assuming air resistance is negligible, during this time of ascent the acceleration of the ball is (CHOOSE ALL THAT APPLY)

(A.) in the direction of motion.

(B.) opposite its velocity.

(C.) directed upward.

(D.) directed downward.

(E.) equal to 9.8 m/s^2 in the negative y-direction.

(F.) zero.

2. At the top of the flight, before it descends, for the ball tossed in the previous question there will be

(A.) zero velocity.

(B.) zero acceleration.

(C.) both of the above.

(D.) none of the above.

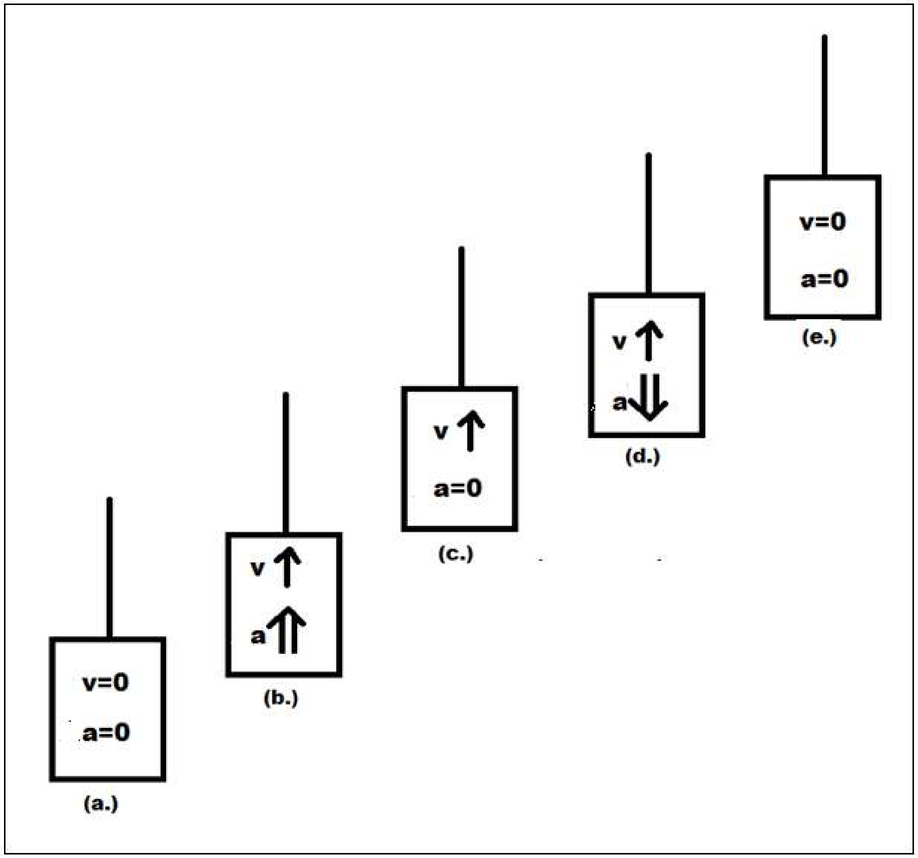
3. If you drop an object, it will accelerate downward. If you instead throw it downwards, its acceleration (in the absence of air resistance) will be ________ than when you drop it.

(A.) less

(B.) <u>same</u>

(C.) greater

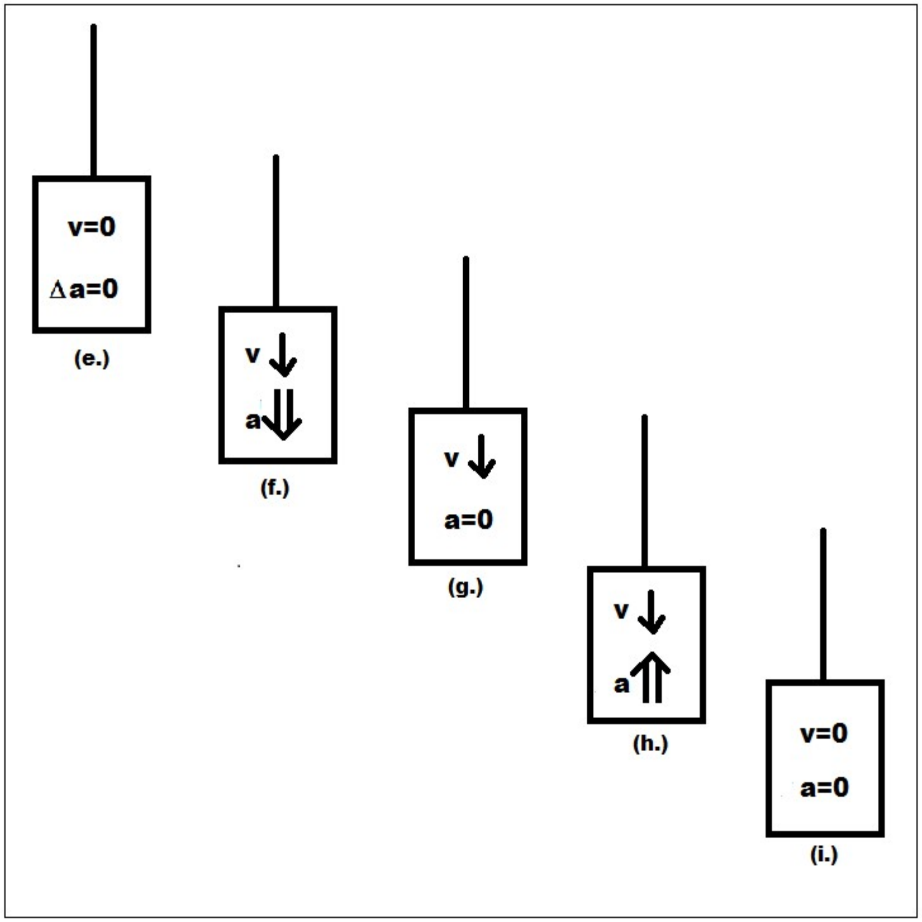
An elevator stopped and then as it goes up (in consecutive snap-shot-like frames).



- *The net acceleration is indicated by the double-shafted arrows.*
- *On board the elevator in (b.) the floor feels like it rises up beneath us and we feel heavier with our scale reading at that time is larger than when at rest.*
- *In (d.) one feels floor drops out and almost floating for an instant, with the scale reading slightly less at that point.*

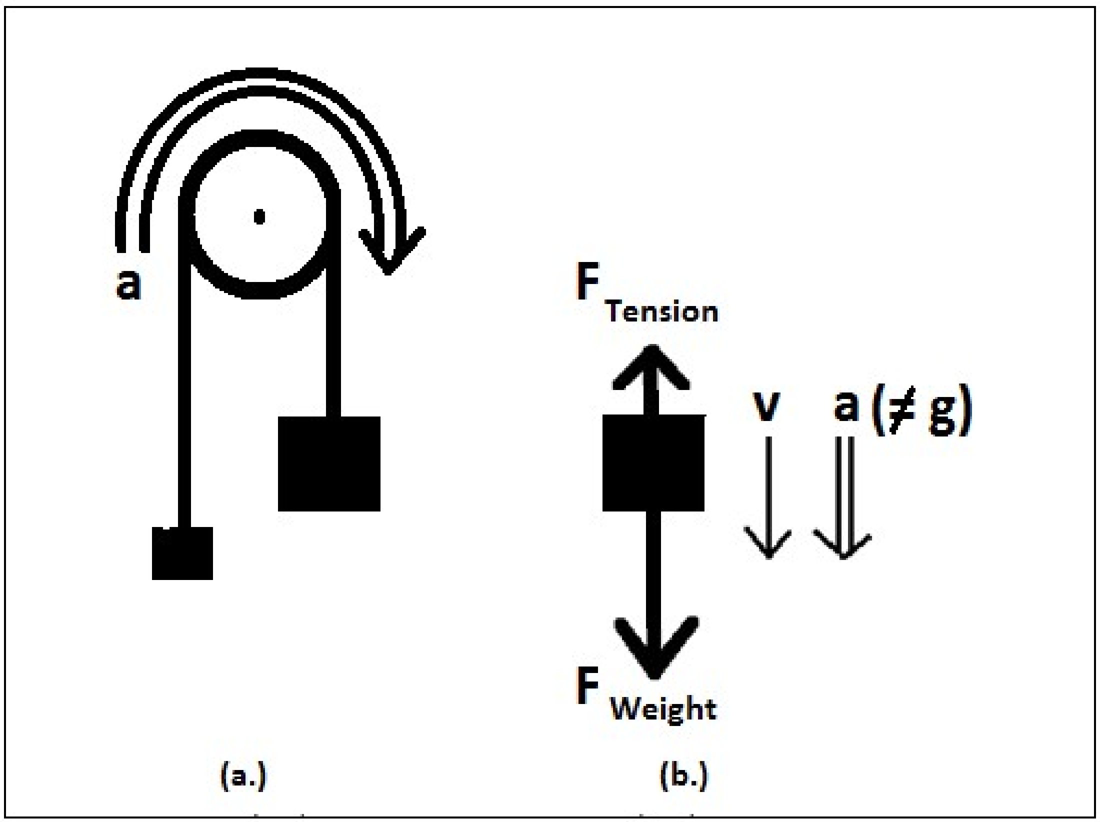
Elevator at the top of the elevator shaft now descends.

- *The net acceleration is again indicated by the double-shafted arrows.*
- *On board the elevator in (f.) the floor feels like it drops beneath one and one feels lighter, the scale reading less than when at rest.*
- *As stopping in (h.) one feels heavier for an instant and the scale reads slightly more at that point.*



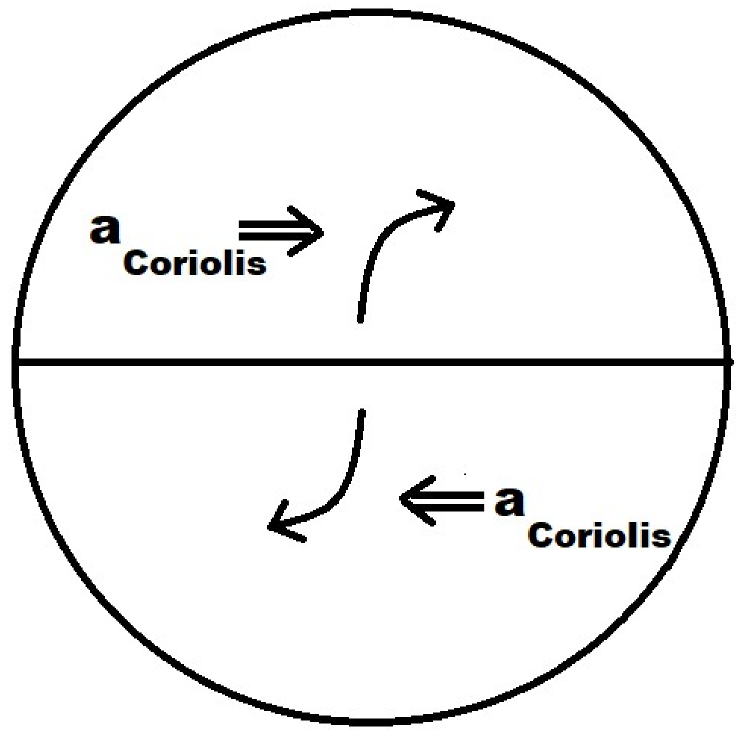
<u>Atwood's Machine</u>

(a.) real-life diagram, with the acceleration noted,
(b.) free-body diagram for the larger of the weights



Coriolis Effect – acceleration (hence force)

- Due to the rotation of earth (or other planet) and varies with latitude.
- Acts on objects (particles of air) to change direction of advection (wind)
- In Northern Hemisphere from path directly north deflected toward east (causing prevailing WEST WIND)
- Opposite in Southern Hemisphere
- **Depicting with <u>double-shafted arrow</u> highlights Coriolis effect as acceleration (and not as position or velocity)!**



Using different types of arrows
for velocity, acceleration and forces is suggested (on the board especially, but also in text books)

but

NOT using color distinction between vector-types because there is no consistent color coding AND students do not usually take notes or write in colors when using pen.

CONCLUSIONS:

In the application of vectors involving acceleration:

- can be helpful to remind students that forces such as Gravity or Coriolis effect do not suddenly disappear: "gravity never turns off" as is true for other forces too!
- acceleration vector needs to be indicated if it is non-zero.
- indicate acceleration using **double-shafted arrows**
- to distinguish from velocity depicted using single-shafted arrows.

THANK YOU! tabormorris@georgian.edu