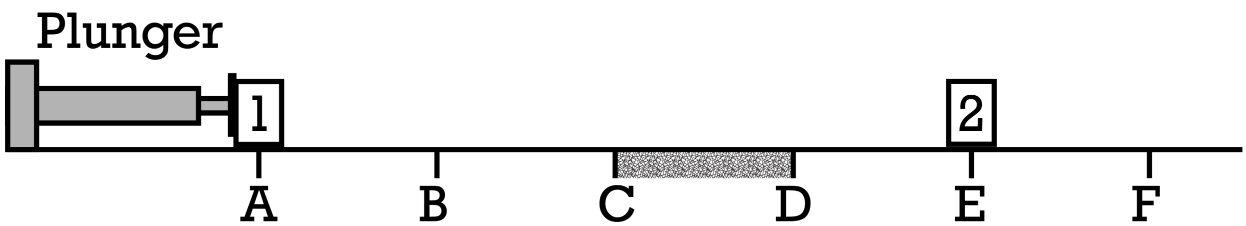
Flipping Physics Lecture Notes:

2019 #1 Free Response Question - AP Physics 1 - Exam Solution
http://www.flippingphysics.com/ap1-2019-frq1.html

This Short Answer question also works as a part of the AP Physics C: Mechanics curriculum.



Identical blocks 1 and 2 are placed on a horizontal surface at points A and E, respectively, as shown. The surface is frictionless except for the region between points C and D, where the surface is rough. Beginning at time t_A , block 1 is pushed with a constant horizontal force from point A to point B by a mechanical plunger. Upon reaching point B, block 1 loses contact with the plunger and continues moving to the right along the horizontal surface toward block 2. Block 1 collides with and sticks to block 2 at point E, after which the two-block system continues moving across the surface, eventually passing point F.

(a) On the axes below, sketch the speed of the center of mass of the two-block system as a function of time, from time t_A until the blocks pass point F at time t_F . The times at which block 1 reaches points A through F are indicated on the time axis.

A to B: Block 1 experiences a constant, positive, net external force caused by the plunger which, according to Newton's Second Law, causes a constant, positive acceleration.

B to C: Block 1 experiences zero net eternal force, because there is no friction, and therefore moves at a constant velocity.

*C to D: Block 1 experiences a constant, **negative**, net external force cause by surface friction, which causes a constant, **negative** acceleration.*

D to E: Block 1 experiences zero net eternal force, because there is no friction, and therefore moves at a constant velocity.

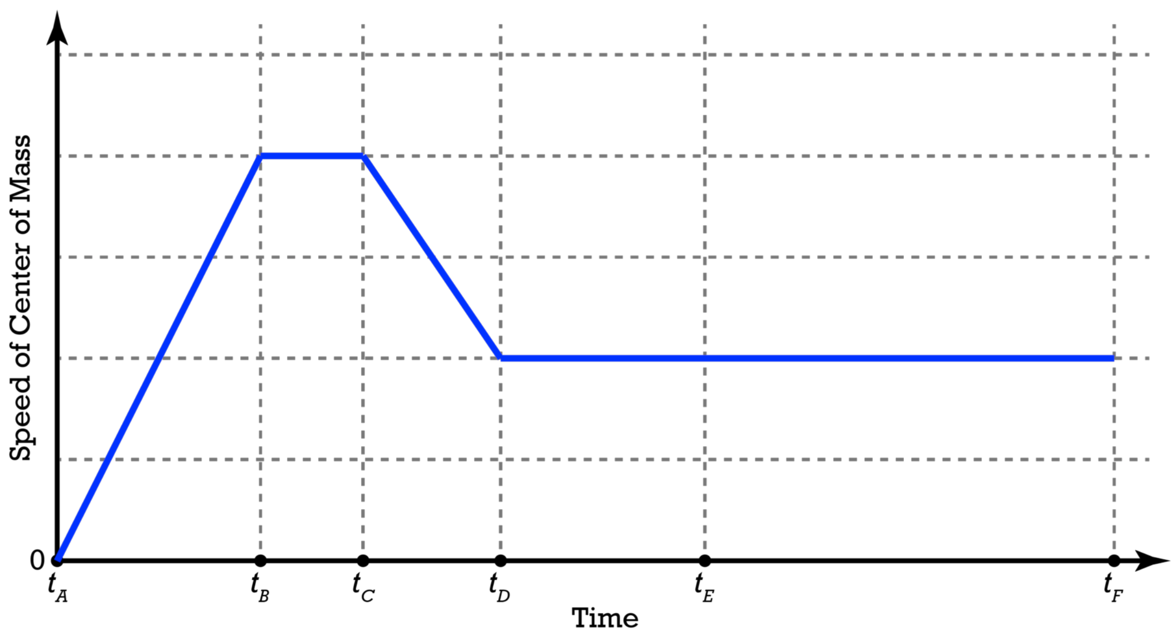
At E: Block 1 collides with block 2, linear momentum is conserved, and, because blocks 1 and 2 have identical mass, the speed of block 1 is cut in half, because the mass is doubled, and the momentum of the system stays constant. However, this collision is irrelevant because the question asks about the speed of the CENTER OF MASS OF THE TWO-BLOCK SYSTEM as a function of time. So, let's try again.

A to B: Block 1 experiences a constant, positive, net external force caused by the plunger which, according to Newton's Second Law, causes a constant, positive acceleration. Block 2 is at rest. The average of those two is a constant, positive acceleration. Yes, the magnitude of the acceleration of the center of mass of both blocks is half of what it is for just block 1, however, there is no y-axis scale given in the problem, so that does not really matter for this question. Draw a line with a constant, positive slope from t_A to t_B .

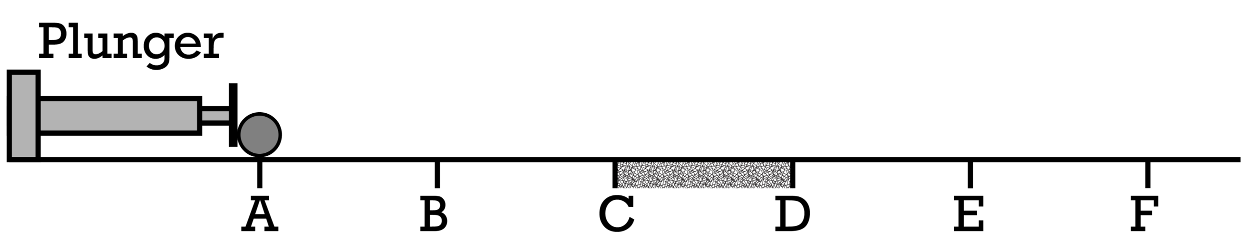
B to C: Block 1 experiences zero net eternal force and therefore moves at a constant velocity. Block 2 is at rest. The average of those two is a constant velocity. From t_B to t_C , starting where the previous line ended, draw a horizontal line.

*C to D: Block 1 experiences a constant, **negative**, net external force cause by surface friction, which causes a constant, **negative** acceleration. Block 2 is at rest. The average of those two is a constant, **negative** acceleration. From t_C to t_D , starting where the previous line ended, draw a line with a constant, **negative** slope. We know the line must not reach zero speed because the block is still moving to the right after t_D .*

*D to **F**: Block 1 experiences zero net eternal force and therefore moves at a constant velocity. Block 2 is at rest. The average of those two is a constant velocity. Yes, at E there is a collision between blocks 1 and 2, however, the net external force on the two-block system is still zero, so the center of mass of the two-block system still moves at a constant velocity! From t_D to t_F , draw a horizontal line which starts where the line from t_C to t_D ends.*



Note about grading: Part (a) is worth 5 out of 7 points for this problem. That’s right, drawing lines correctly on this graph is worth 5 out of 7 points. No explanation necessary. Please draw carefully. And do not write out your explanation if you are not asked to. Also, realize you only lose one point for incorrectly showing a decrease in velocity at t_E .



(b) The plunger is returned to its original position, and both blocks are removed. A uniform solid sphere is placed at point A, as shown. The sphere is pushed by the plunger from point A to point B with a constant horizontal force that is directed toward the sphere’s center of mass. The sphere loses contact with the plunger at point B and continues moving across the horizontal surface toward point E.

In which interval(s), if any, does the sphere's angular momentum about its center of mass change? Check all that apply.

____ A to B ____ B to C _X_ C to D ____ D to E _____ None

Briefly explain your reasoning.

Angular momentum is conserved when the net torque acting on an object equals zero. Let's look at all the forces acting on the sphere and if they cause a net torque on the sphere.

Force Normal acts on the sphere from A to E. The force normal is directed toward the center of mass of the sphere and therefore will not cause zero torque on the sphere.

Force of Gravity acts on the sphere from A to E. The force of gravity acts on the center of mass of the sphere and therefore will cause zero torque on the sphere.

Force Applied by the plunger acts on the sphere from A to B. The force applied is directed toward the center of mass of the sphere and therefore will cause zero torque on the sphere.

Force of Friction by the rough surface acts on the sphere from C to D. The force of friction does not act on the center of mass of the sphere and is not directed toward the center of mass of the sphere and therefore ***will cause torque on the sphere.***

Therefore, the only interval where a net torque is acting on the sphere is from C to D. That net torque is caused by the friction force acting on the sphere.

Note about grading: My explanation is a bit excessive. My goal is for you to truly understand all the physics here, which is a bit different than simply answering the question. You really only need to say change in angular momentum is caused by net torque and that the force of friction from C to D is the only force which causes a net torque and explain why.