AP Physics C – Dynamics, Complete Answers

1. The setting of plates, silverware, glasses, etc. has inertia, the tendency of matter to maintain a state of motion. The initial state is at rest relative to Earth, so when the tablecloth moves rapidly out from underneath it is only natural that the setting remains at rest. The tablecloth's rapid motion ensures that whatever force it exerts on the setting has very little time to cause change in state of motion.
2. In the absence of force an object must follow a linear path. By the 1st Law, without force the object's velocity must remain constant, which means it must move in only one direction. This is only possible along a linear path.
3. An object does <u>not</u> always <u>move</u> in the direction of the net force, however it must always <u>accelerate</u> in the direction of the net force, by the 2nd Law. An object that is already <u>moving</u> in a particular direction can continue to move in that direction due to its inertia, even as it accelerates in a different direction. Example – a ball thrown upward continues to move upward, in the opposite direction of gravity and air resistance. The net force and acceleration are both downward at the same time the movement is upward.
4. To start the cart moving the force exerted is opposite friction but also must be great enough to cause a certain amount of acceleration. The loaded cart has large mass and inertia so the force to cause the initial acceleration may be fairly large because force is proportional to mass and acceleration by the 2nd Law. However, once the cart is moving, if it is not being accelerated, the only reason any force at all must be applied is because of friction. The cart has inertia and will continue to move on its own by the 1st Law. To keep the cart moving at a constant velocity the force exerted only has to be as great as friction, which will be relatively small for a cart with decent wheels.
5. In principle, it does not require greater and greater force for an object to move at greater and greater speeds. By the 2nd Law <u>any</u> amount of force (no matter how small) will cause an object to continue to accelerate for as long as the force acts. Therefore, a very small force that acts for a very long time can in principle accelerate an object to however great a speed is desired. (In practice, however, in an earthly setting, there is always friction and air resistance. Air resistance in particular will increase as speed increases. This is why for an object like a car it <u>may</u> require greater force to move at greater speeds.)
6. a. By the 1st Law the person's body will continue to move forward at the car's original speed while the car stops.

   b. As the person moves between seat and dash the person is essentially in freefall and would mainly accelerate downward at g in the direction of the net force of gravity. The person wound not actually accelerate forward into the dash, rather the dash accelerates into the person.

   c. The previous statements are using the Earth as an <u>inertial</u> frame of reference, which is a requirement for proper application of Newton's Laws. In the frame of reference of the car the person does in fact have a forward acceleration while moving between seat and dash. However this is due only to the acceleration of the frame of reference as the car slows down.

   d. The frame of the car is accelerating and makes it a noninertial frame of reference. The observed acceleration forward of the person into the dash does not have an apparent force as a cause – there is no interaction with any other object causing it to happen, which is a violation of the 3rd Law. An acceleration without any force is also obviously a violation of the 1st and 2nd Laws.

7. a. The impact of the car ramming the truck is a force causing the body of the truck to accelerate forward. The person's head is not directly affected by this force and has inertia and the tendency to remain at rest – relative to the cab of the truck the head appears to snap backward, but in reality it is the window of the cab that "snaps forward" and impacts the head, which is somewhat stationary relative to Earth.
   b. If the truck is already in motion the effect will be essentially exactly the same as described above, but now it is a matter of a sudden increase in the forward speed of the truck and the head's tendency to remain moving at the previous speed of the truck.
8. 5600 N
9. a. 5.10 m/s^2
   b. 4.50 m/s^2, 9.60 m/s
   c. 4.52 s
   d. 7.75 s
10. 1.4 kg
11. a. 2.7 m/s^2, up
    b. 3.6 m/s^2, down
12. $F = W\left(1 + \dfrac{a}{g}\right)$
13. 6.1 kN, upward
14. a. 50.7 m/s^2, 37.1°
    b. 66.9 m/s^2, 270.0°
15. a. thru d.
16. $28\underline{0}$ N, westward
17. a. Action-reaction pairs: Earth attracts apple downward and apple attracts Earth upward; apple pushes hand downward, hand pushes apple upward.
    b. 4.49×10^{-25} m
    c. 267 N, downward
18. The net force on any particular object need not be zero by Newton's Laws – to say so is to misinterpret the laws. Suppose all of the forces acting on the particular object do not add up to zero and the object accelerates by the 2nd Law – this is fine and consistent with the 3rd Law, so long as each force acting on the object is paired with an equal and opposite force acting on other objects. Because the equal and opposite forces of the 3rd Law are always affecting other objects there is never an occasion when any two forces acting on a particular object have to be equal and opposite. There are times when two forces acting on a particular object may be equal and opposite, but it is not a requirement of Newton's Laws of Motion.
19. a. 53.5 N, up
    b. 53.5 N, down
20. 24.5 N, 30.0° and 42.4 N, 120.0°
21. a. 358 N in each
    b. 277 N and 301 N
22. $\tan\theta = a/g$
23. a. 27.4 N, up
    b. 123 N, down
    c. 905 N, down

24. a. 1311 N
    b. 1328 N
    c. 1346 N
25. a. 343 N ea. foot, 225 N ea. joint
    b. 413 N ea. foot, 271 N ea. joint
    c. 291 N ea. foot, 191 N ea. joint
26. $T = F\dfrac{m_2}{m_1 + m_2}$
27. a. 372 g
    b. 4.76 N
28. a. 49$\underline{0}$ N, down
    b. 245 N
    c. 0.700 m/s^2, up
29. 11 m/s^2, up (6 kg)
    5.8 m/s^2, up (8 kg)
    8.4 m/s^2, up (pulley)
30. a. 8.9 kN
    b. 3.9 kN
31. a. 1.0 m/s^2, back
    b. 2.9 kN
32. 0.69 m/s^2, 180° (smaller boy)
    the larger boy does not move
33. a. 18$\underline{0}$ N, right
    b. 41 kg
34. a. $F = \dfrac{\mu mg}{\mu \sin\theta + \cos\theta}$
    b. $\theta = \arctan \mu$
    c. 4.5 m/s^2, 0°
35. 0.92 m/s^2
36. a. 5.9 m/s^2, forward
    b. 3.5 m/s
37. a. 12 s
    b. Air resistance depends on how air interacts with the exterior surface of an object and is proportional to cross-sectional area, speed squared, and coefficient of drag (a factor related to the shape). None of these properties change when the number of people in the car is different. Also, the mechanical workings of the car should be the same, so the “internal friction is the same. The only thing significantly different then is the rolling resistance, which increases due to greater normal force on the car.
38. a. 3.02 m/s
    b. 2.84 m, 2.75 m/s, 0.428 m/s^2, down
39. a. 17.6 m/s^2 down
    b. 1.20 s, 8.66 m
    c. 32.7 m

40. a. $\tau = \frac{v_t}{g}$
b. $\approx 4.6\tau$
c. The object with greater mass must have a greater cross-sectional area and/or a less aerodynamic shape, such that it has greater air resistance at a particular speed than the object with less mass. If two different mass have the same terminal velocity, then the air resistance in that scenario is proportionally greater for the object with greater mass. This proportionality would hold at any speed as the objects accelerate toward terminal velocity and therefore the behavior of the two objects would be identical due to equal acceleration at any point in the motion.
41. a. $a = g(\sin\theta - \mu\cos\theta)$
b. The more massive kid coasting down a hill will have proportionally greater forces of gravity and friction, which is why the resulting acceleration is expected to be the same as the less massive kid. However, air resistance will not be greater in proportion to mass. The mass of a person would be roughly proportional to volume, but the increase in cross-sectional area would not be the same and this area is the main difference causing greater air resistance on the bigger person. The increase in area for the bigger person relative to the smaller person will be less than the ratio of the masses and therefore the air resistance on the larger person has a smaller effect in relative terms. As an illustrative example suppose the diameter of one rubber ball is twice that of another made of the same material. The volume and mass will be eight times greater but the cross-sectional area will only be four times greater. The heavier ball will fall through the air faster having eight times as much gravity as the smaller ball, but only four times as much air resistance as the smaller ball. If the smaller ball is accelerating at $0.5g$ downward with air resistance half its weight, the larger ball at the same speed would have air resistance one fourth its weight and accelerate at $0.75g$ (the air resistance is four times half the weight of the smaller ball but the weight is eight times that of the smaller ball).
42. 2.4 s
43. a. $\mu_s = \tan\theta$
b. 45°
44. a. 0.301 kg
b. 1.54 m/s^2
45. big block: 1.75 m/s^2 330.0°
small block: 1.75 m/s^2 150.0°
46. a. -720 N $< F$ (up slope) < 4600 N
b. 5200 N