Solutions: AP Physics 1 Practice Exam 2, Section I (Multiple-Choice)

Questions 1–45: Single-Choice Items

1. A—The tension is the force of the string acting on the block. Newton’s third law says that since the string pulls on the block, the block pulls equally on the string. (The answer is NOT for force of friction: Newton’s third law force pairs can never act on the same object.)

2. B—Since the block has no acceleration, left forces equal right forces, and up forces equal down forces. The equation for a force of friction is \( F_f = \mu F_n \). Since the coefficient of friction \( \mu \) is less than 1, the friction force must be less than the normal force.

3. A—The energy gained or lost by a charge as it goes through a circuit element is voltage, and a voltmeter measures voltage. In this circuit loop, any energy gained by charges across the battery must equal the energy lost by the charges through the two resistors; this is known as Kirchoff’s loop rule.

4. D—“Charge that flows through each in a given time interval” is a complicated way of saying “current.” Current through series resistors must always be the same through each, so the 50 \( \Omega \) resistor and the 100 \( \Omega \) resistor should rank equally. Then simplify the circuit to two parallel branches. The left branch has an equivalent resistance of 150 \( \Omega \) and the right branch of 300 \( \Omega \). With the same voltage across each branch, the larger current goes through the path with smaller resistance by Ohm’s law.

5. C—Consider just the two series resistors, which have an equivalent resistance of 150 \( \Omega \) and are connected to the 9-V battery. The current through that branch of the circuit is

\[
\frac{9 \text{ V}}{150 \Omega} = 0.06 \text{ A.}
\]

Now consider just the 50 \( \Omega \) resistor. The voltage across it is \((0.06 \text{ A})(50 \Omega) = 3 \text{ V}\). As a sanity check, we know that for two resistors in series (which take the same current), \( V = IR \) says that the smaller resistor takes less voltage; 3 V across the 50 \( \Omega \) resistor leaves 6 V across the 100 \( \Omega \) resistor.

6. D—All experimental evidence in existence shows that the smallest unit of isolated charge is the electron charge \( e = 1.6 \times 10^{-19} \text{ C} \). The charge measured in A is equivalent to 4 fundamental charges; in B, 5 fundamental charges; and in C, 3 fundamental charges. But choice D would require an isolated charge of 1.5 \( e \), which is not possible.

7. D—The work done by the net force is the area under the graph. Since the cart only moved from position \( x = 0.5 \text{ m} \) to \( x = 1.5 \text{ m} \), area 1 is the work done by the net force. By the work-energy theorem, work done by the net force is the change in an object’s kinetic energy. (Yes, the mass must be known to determine the values of the initial and final kinetic energy; however, the question asks only for the change in kinetic energy.)

8. A—To evaluate the acceleration of the horse-cart system, you can only consider the forces applied by objects external to the system. This eliminates choices B and C, which discuss forces of the system on itself. Choice D is ridiculous because the horse remains on the ground. Choice A is correct: the ground pushes forward on the horse’s hooves because the horse’s hooves push backward on the ground.

9. B—The closed end of the pipe makes it impossible for the air particles right next to the end to vibrate at all, which is why a particle displacement node must exist there. It’s easiest, I think, just to remember that in a sound wave, pressure is at an antinode when particle displacement is at a node and vice versa. Or remember that the pressure must be equal to atmospheric pressure at the open end, which is exposed to the atmosphere, and greater inside because the air is compressed, not sucked out of the pipe.
10. C—The cart is in equilibrium, so the spring scale’s force is equal to the component of the cart’s weight that acts parallel to the plane. That component is $mg \sin \theta$. Thus, the graph of spring scale reading vs. $\theta$ should be a sine function, as in choice C. Choice B is wrong because that’s what a sine function looks like all the way to $180^\circ$; here, the angle of the incline only goes to $90^\circ$.

11. B—Newton’s second law for rotation says $\tau_{\text{net}} = I \alpha$, where $\alpha$ is the angular acceleration, or change in the wheel’s angular velocity per time. To find the wheel’s angular velocity, look at the slope of the angular position versus time graph. The slope changes after the torque is applied; so the change in the slope is the change in the angular velocity, which (when divided by the 0.10 s duration of the rocket firing) gives the angular acceleration.

12. B—Angular acceleration is the change in angular speed in each second. To find angular speed, take the slope of the angular position versus time graph shown. This slope is constant for two seconds, then it changes to another constant slope. Therefore, there is no angular acceleration during the time when the slope doesn’t change— with no change in angular speed, there’s no acceleration. The only change in angular speed comes at the moment the slope changes, so that’s the only time when there’s any angular acceleration.

13. D—The energy carried by a wave depends on the wave’s amplitude, meaning its height. The speed and pulse width or wavelength have no impact on the energy of a wave.

14. C—The magnitude of the electrostatic force depends on the product of the charges, regardless of sign. In state 2, the charges are both bigger than in state 1, giving a bigger electrostatic force in state 2. Without even doing the calculation, you can recognize that since Newton’s gravitational constant $G$ is orders of magnitude less than the coulomb’s law constant $k$, the electrostatic force will be much greater than the gravitational force between two objects in virtually any laboratory situation. The only time these forces become comparable is when objects the size of planets exert gravitational forces.

15. A—Charge is conserved, meaning that while negative charge can neutralize positive charge, the net charge of a system cannot change. The net charge of state 1 is zero; thus, the net charge of state 2 must also be zero, regardless of whether the balls touched or not. State 2 has a net charge of $-80 \mu C$, not zero; thus, the claim is not reasonable due to this violation of charge conservation.

16. C—You want the wavelength of the sound wave, not the wave on the guitar. Choices A and B both correctly determine the wavelength of a wave on a guitar string, but these are not the waves you are looking for. Choice D does discuss the sound wave in air, but when is the last time you visually “saw” a sound wave passing you in the air, let alone saw any peaks that you could practically measure with a meterstick? So do the experiment in choice C. Going from one resonance to the next adds half a wavelength to the standing wave in the pipe, regardless of whether the pipe is open or closed.

17. A—The initial momentum of the system is $(0.5 \text{ kg})(0.6 \text{ m/s}) + (0.5 \text{ kg})(0.8 \text{ m/s}) = 0.7 \text{ N·s}$. After cart B is stopped, the momentum of the system is just $(0.5 \text{ kg})(0.6 \text{ m/s}) = 0.3 \text{ N·s}$. So, the change in momentum is $0.4 \text{ N·s}$.

18. C—The graph represents the speed of cart A, the one that’s initially moving. So right before the collision, the vertical axis of the graph must be nonzero. Right after the collision, the vertical axis must quickly either decrease or perhaps become negative if the cart changed directions. That’s what happens in the tenth of a second or so after the time labeled C.

19. A—Conservation of momentum requires that the total momentum of the two-cart system be the same before and after the collision. You already know cart A’s speed and direction of motion before and after the collision by looking at the vertical axis of the graph; so the mass of cart A will give us cart A’s momentum before and after the collision. You know cart B has
no momentum before the collision. But you need both cart B’s mass AND its velocity after the collision to finish the momentum conservation calculation.

20. D—“Increase in the internal energy of the road-car system” is a fancy way of saying “work done by the car’s brakes to stop the car.” Without the brakes, the car would have gained \( mgh \) of mechanical energy in dropping the height \( h \), giving it a total mechanical energy of \( \frac{1}{2}mv^2 + mgh \). The brakes convert all of that mechanical energy to internal energy.

21. B—The equivalent resistance of the parallel resistors in circuit 1 is 12 k\( \Omega \); adding that to the 100 k\( \Omega \) resistor gives a total resistance in circuit 1 of 112 k\( \Omega \). Circuit 2’s parallel combination has an equivalent resistance of 23 k\( \Omega \), giving a total resistance in that circuit of 43 k\( \Omega \). By \( V = IR \) applied to both circuits in their entirety with the same total voltage, the circuit with smaller total resistance will produce the larger current. That’s circuit 2.

22. A—The motion after the push is finished is toward more positive \( x \), so it is in the positive direction. The puck is slowing down. When an object slows down, its acceleration and its net force are in the direction opposite the motion. (Choice C would be correct at a position at which the student were still pushing the puck, but at \( x = 1.0 \) m, the student had already let go, so the puck was slowing down.)

23. A—The net force on the cart-object system is 2.0 N. Dividing 2.0 N by the acceleration gives the mass of the entire cart-object system, not just the mass of the cart; so subtract the 0.2 kg mass of the object from the whole system mass to get the cart mass. This is actually inertial mass, because it uses the equation \( F_{net} = ma \); Newton’s second law defines inertial mass as resistance to acceleration.

24. D—All of the diagrams have the object’s weight correct. Any other force acting on the object must be provided by something in contact with that object. The only thing making contact with the object is the string, so add the force of the string on the object. That’s it. The force of the object on the string doesn’t go on this diagram, because this diagram only includes forces acting ON the object, not exerted by the object.

25. C—Positions 1 and 4 show minimum particle displacement, so these are nodes. The wavelength of a standing wave is measured node-to-node-to-node; that is, the wavelength is twice the distance between consecutive nodes.

26. A—The rod starts from rest, so its final angular momentum is the same as its change in angular momentum. Although the equation \( \omega = \frac{v}{r} \) is valid for a point object moving in a circle, it does not apply to a rotating rod; thus, choice B is wrong. Choice C gives the final angular momentum of the ball, which is not the same as the angular momentum change of the rod because the ball does NOT start from rest.

27. C—Choice C states the fundamental condition for angular momentum conservation, which is correct here. The ball does have angular momentum about the rod’s center of mass before and after the collision, because its line of motion does not go through the rod’s center of mass. Whether or not the collision is elastic has to do with conservation of mechanical energy, not angular or linear momentum.

28. C—Impulse is the area under a force-time graph. From \( t = 8 \) s to \( t = 10 \) s, the area is an approximate rectangle of 2 N times 2 s, giving 4 N\( \cdot \)s. Add an approximate triangle from \( t = 10 \) s to \( t = 11 \) s, which has the area \( \frac{1}{2}(2 \text{ N})(1 \text{ s}) = 1 \text{ N}\cdot\text{s} \). That gives a total of 5 N\( \cdot \)s.

29. D—The force of the engine on the rocket during this time is 2 N upward. The weight of the rocket is 1 N (that is, 0.1 kg times the gravitational field of 10 N/kg). So the net force is still upward during this time. Since the rocket was already moving upward, it will continue to move upward and speed up.

30. D—Impulse is change in momentum. The initial momentum was something like (0.5 kg)(1.6 m/s) = 0.8 N\( \cdot \)s to the right. The cart came to rest, changing its momentum by 0.8 N\( \cdot \)s, then
31. D—The gravitational acceleration is given by \( GM/d^2 \), where \( d \) is the Space Shuttle’s distance to Earth’s center. You don’t know values for \( G \) and \( M \), nor do you need to know them. You do know that at Earth’s surface, 6,400 km from the center, the gravitational acceleration is 9.8 m/s\(^2\). To calculate using this equation at the height of the Space Shuttle, the numerator remains the same; however, the denominator increases from \((6,400 \text{ km})^2\) to \((6,700 \text{ km})^2\), a difference of about 8%. (Try it in your calculator if you don’t believe me.) Thus, the gravitational acceleration will decrease by about 8%, giving choice D. (Yes, things seem “weightless” in the Space Shuttle. That’s not because \( g = 0 \) there, but because everything inside the shuttle, including the shuttle itself, is in free fall, accelerating at 8.9 m/s per second toward the center of Earth.)

32. B—The scale reading is less than the man’s weight; that means that the net force is downward. By Newton’s second law, the person’s acceleration is downward, too. Downward acceleration means either moving down and speeding up, or moving up and slowing down. Only choice B works.

33. C—The weight of the textbook is \( GMm/d^2 \), where \( M \) and \( m \) are the masses of Earth and the textbook. These don’t change on a mountain. The \( d \) term will change, because \( d \) represents the distance between the textbook and Earth’s center. But that will change the denominator of the weight equation from \((6,400 \text{ km})^2\) to \((6,406 \text{ km})^2\); in other words, not to the two digits expressed in the answers. No need to use the calculator. You can see that the choices require the weight to either stay the same, double, or be cut in half. The weight of the textbook remains 30 N.

34. C—In circular motion around a planet, the centripetal force is provided by gravity:

\[
\frac{mv^2}{d} = G \frac{Mm}{d^2}
\]

Solving for the radius of the satellite’s circular orbit, we get \( d = \frac{GM}{v^2} \). The numerator of this expression doesn’t change, because the mass of the planet \( M \) and Newton’s gravitation constant \( G \) don’t change. The satellite’s speed \( v \) is doubled. Since the \( v \) term is squared, that increases the denominator by a factor of 4. So the radius of orbit \( d \) is now \( \frac{1}{4} \) as much as before.

35. B—Consider the cart alone, which as a single object has no internal energy or potential energy. Thus, any work done on the cart will change the cart’s kinetic energy. The cart began with no kinetic energy at all. Earth increased the cart’s kinetic energy by 0.30 J, as stated in the problem; the spring decreased the cart’s kinetic energy by 0.20 J. A gain of 0.30 J and a loss of 0.20 J leaves 0.10 J of kinetic energy.

36. B—Conservation of linear momentum requires that the center of mass of the system continue to move to the right after the collision. The rotation will be about the combined rod-putty center of mass. To understand that, imagine if the putty were really heavy. Then after the collision, the rod would seem to rotate about the putty, because the center of mass of the rod-putty system would be essentially at the putty’s location. In this case, you don’t know whether the putty or the rod is more massive, but you do know that when the two objects stick together, they will rotate about wherever their combined center of mass is located.

37. D—No unbalanced forces act here other than the putty on the rod and the rod on the putty. (The weight of these objects is canceled by the normal force.) Thus, linear momentum is conserved. No torques act on the rod-putty system except those due to each other; thus, angular momentum is conserved. It’s essentially a fact of physics that in a collision between two objects, both linear and angular momentum must be conserved.
38. C—The net torque on the rod must be zero, because the rod doesn’t rotate. Therefore, whatever happens to Bob’s torque must also happen to Tom’s torque—these torques must cancel each other out. That eliminates choices A and B. The forces provided by Bob and Tom must add up to 500 N, the weight of the rod. Try doing two quick calculations: In the original case, Bob and Tom must each bear 250 N of weight and are each 2 m from the midpoint, for 500 N⋅m of torque each. Now put Tom farther from the midpoint—say, 3 m away. For the torques to balance, \( F_{\text{Bob}}(2 \text{ m}) = F_{\text{Tom}}(3 \text{ m}) \). The only way to satisfy this equation and get both forces to add up to 500 N is to use 300 N for \( F_{\text{Bob}} \) and 200 N for \( F_{\text{Tom}} \). Now, the torque provided by each is \( (300 \text{ N})(2 \text{ m}) = 600 \text{ N}⋅\text{m} \). The torque increased for both people.

39. A—The object is in equilibrium, so left forces equal right forces. Thus, the horizontal tensions must be the same in each rope. Rope A pulls at a steeper angle than rope B, but with the same amount of horizontal force as rope B. To get to that steeper angle, the vertical component of the tension in rope A must be larger than in rope B.

40. A—There’s no indication that energy must be conserved in collision I. However, momentum is always conserved in a collision. When block A bounces, its momentum has to change to zero and then change even more to go back the other way. Since block A changes momentum by more in collision I, block B must as well because conservation means that any momentum change by block A must be picked up by block B. Choices C and D are wrong because, among other things, they use conservation of momentum to draw conclusions about two separate collisions; momentum conservation means that total momentum remains the same before and after a single collision, not in all possible collisions.

41. B—The period of a mass-on-a-spring oscillator is \( T = 2\pi \sqrt{\frac{m}{k}} \). The important part here is that the mass term is in the numerator—a larger mass means a larger period. More mass oscillates on the spring in collision II, so collision II has a greater period. Frequency is the inverse of the period, so the period is smaller in collision II.

42. D—The fundamental will have a node at one edge, an antinode at the other, and no nodes in between. The next allowable harmonic will have the same end conditions as the fundamental plus one additional node. A string fixed at one end and free to move at the other can only produce standing waves whose frequency is an odd multiple of the fundamental. So 30 Hz is the next available frequency after the fundamental with one additional node.

43. D—Angular acceleration is net torque divided by rotational inertia, \( \alpha = \frac{T_{\text{net}}}{I} \). Imagine each object has total mass of 2 kg. Begin by comparing objects A and B: To find the net torque on object A, assume the entire 20 N weight is concentrated at the dot representing the rod’s center of mass. That’s located 10 cm from the pivot, giving a net torque of 200 N⋅cm. For object B, consider the torques provided by each block separately. The right block provides a torque of \((10 \text{ N})(30 \text{ cm}) = 300 \text{ N}⋅\text{cm} \) clockwise; the left block provides a torque of \((10 \text{ N})(10 \text{ cm}) = 100 \text{ N}⋅\text{cm} \) counterclockwise. That makes the net torque 200 N⋅cm, the same as for object A. But object B has more rotational inertia, since its 2 kg of mass are concentrated farther away from the pivot than object A’s mass. So the denominator of the angular acceleration equation is bigger for object B with the same numerator, which means \( A > B \).

Now consider object C. It experiences less net torque than A and B. Calculate \((10 \text{ N})(30 \text{ cm}) = 300 \text{ N}⋅\text{cm} \) clockwise, and \((10 \text{ N})(20 \text{ cm}) = 200 \text{ N}⋅\text{cm} \) counterclockwise for a net torque of 100 N⋅cm. And object C has the same mass distributed even farther from the pivot point than either of the other two objects, giving C an even bigger rotational inertia. In the angular acceleration equation, the numerator is fixed, so the term \( \frac{1}{I} \) is even bigger for C than for B or A, so \( A > B > C \).
acceleration equation, object C gives a smaller numerator and a bigger denominator than object B, meaning $C < B$. Put it all together to get $A > B > C$.

44. **B**—Since the source is still moving at constant speed, the wave fronts will be equally spaced. However, since the source is moving, it will have traveled a bit with the wave before emitting the next wave. Thus, the wave fronts will be closer together. As an alternative explanation, a stationary observer at the right of the page would hear a higher frequency by the Doppler effect, meaning that more waves should pass the observer in one second; that requires wave fronts to be closer together.

45. **D**—Consider the system consisting of the objects and Earth, with the location of the $3m$ mass being the zero of gravitational energy. The initial gravitational energy of the system is $mgL$. After the rotation, the final gravitational energy of the system is $3mgL$. That extra gravitational energy of $2mgL$ came from the work done on the system, meaning choice D. If you want instead to think of work on the objects as force times distance, remember that the force of Earth on the objects acts straight down, not along a circle. So the distance term to use here is just $L$, not $pL$.

Questions 46–50: Multiple-Correct Items (You must indicate both correct answers; no partial credit is awarded.)

46. **A and B**—Choice A uses the equation $F_{\text{net}} = ma$, which essentially defines inertial (as opposed to gravitational) mass. Choice B measures inertial mass, because it measures mass as resistance to the acceleration caused by the spring force. Choices C and D measure an object’s behavior in a gravitational field; by definition, that’s gravitational, not inertial, mass.

47. **C and D**—Though both speed divided by acceleration (as in choice A) and position divided by speed (as in choice B) give units of time, the time indicated has no relation to the period of the motion. The period is defined as the time for one complete cycle to happen. One complete cycle can be defined as the time for the object to get back to its extreme position, as in choice D, or it can be defined as the time between the occurrences of maximum velocity in the same direction, as in choice C.

48. **B and C**—Elastic means that mechanical energy is conserved in the collision, so the answer is not choice A, which describes a loss of mechanical energy. Mechanical energy conservation requires that carts bounce, so choice B is correct, but choice D is not. Linear momentum is conserved in all collisions, elastic or not elastic.

49. **A and C**—The relevant equation here is $R = \rho \frac{L}{A}$. The length of the wire is the variable $L$, so choice C is correct. The diameter measurement (choice A) can be used with the formula for the area of a circle to get $A$, the cross-sectional area of the wire.

50. **B and C**—Change in angular momentum is $\tau \Delta t$, which means the area under a torque-time graph; thus, choice C is correct. Since this graph is linear, the average torque multiplied by the maximum time is the same thing as the area under the graph, so choice B is also correct. While choice D describes a calculation of angular momentum, it does not correctly give the change in angular momentum, so you don’t know whether the object had an initial angular momentum or not.