

## AP Physics 1- Dynamics Practice Problems (2019)

**FACT:** Inertia is the tendency of an object to resist a change in state of motion. A “change in state of motion” means a change in an object’s velocity, therefore inertia can also be defined as the tendency of an object to resist acceleration. Inertial mass is a measure of an object’s inertia. In other words, inertial mass is a measure of the tendency of an object to resist acceleration. The more mass something has, the more it resists acceleration. There is also gravitational mass, which is experimentally identical to inertial mass.

**FACT:** A force is often defined as a push or a pull on an object. A force is the ability to cause a change in state of motion of an object. Therefore, a force is what has the ability to cause an acceleration and mass is the measurement of how much an object resists that acceleration. Because force is *the ability* to cause a change in state of motion of an object, it doesn’t have to cause acceleration ( $\Sigma F_{\text{net}} = ma$ )

**FACT:** There are two types of forces. *Contact forces* are the result of two objects touching one another. Examples of contact forces are applied forces, drag force, friction force, force normal, spring force and tension. *Field forces* happen even when two interacting objects are *not touching* one another. Examples of Field forces are gravitational force, magnetic force and electric force.


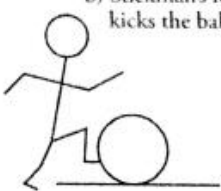




**Q1.** An object feels two forces; one of strength 8 N pulling to the left and one of 20 N pulling to the right. If the object’s mass is 4 kg, what is its acceleration?

**Q2.** A book whose mass is 2 kg rests on a table. Find the magnitude of the force exerted by the table on the book.

**Q3.** What is the mass (in both kg and pounds) of an object that weighs 500N? There are 2.2 lbs./1kg.

**FACT:** Free-body diagrams (FBD) are diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation. These diagrams will be used throughout our study of physics. The size of the arrow in a free-body diagram reflects the magnitude of the force. The direction of the arrow shows the direction that the force is acting. Each force arrow in the diagram is labeled to indicate the exact type of force.

**Q4.** Draw free-body diagrams (FBD) for the following six scenarios.

<p>a) A ball sits at rest.</p> 	<p>b) Stickman's foot kicks the ball.</p> 	<p>c) The ball rolls at a constant velocity across level ground.</p> 
<p>d) The ball rolls through a rough patch and slows down due to friction.</p> 	<p>e) The ball rolls up a ramp with friction.</p> 	<p>f) The ball rolls back down the ramp with friction.</p> 

**Q5.** A can of paint with a mass of 6 kg hangs from a rope. If the can is to be pulled up to the rooftop with an acceleration of  $1 \text{ m/s}^2$ , what must the tension in the rope be?

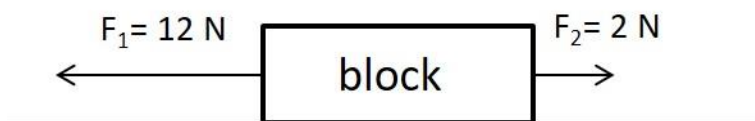
**Q6.** A bucket of water with a mass of 4 kg hangs from a rope. If the bucket is to be pulled up to the rooftop with a constant velocity of  $1 \text{ m/s}$ , what must the tension in the rope be?

**Q7.** How much tension must a rope have to lift a 50 N object with an acceleration of  $10 \text{ m/s}^2$ ?

**Q8.** A pair of fuzzy dice is hanging by a string from your rearview mirror. You speed up from a stoplight. During the acceleration, the dice do not move vertically; the string makes an angle of  $22^\circ$  with the vertical. The dice have a mass of 0.10 kg. Sum the forces in the x and y to determine the acceleration.

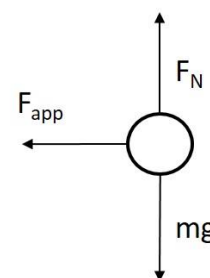
**Q9.** In the question above, how would the tension in the string change if the angle from the vertical increased?

**Q10.** Two forces,  $F_1$  and  $F_2$  are applied to a block on a frictionless, horizontal surface as shown below. If the magnitude of the block's acceleration is  $2.0 \text{ m/s}^2$ , what is the mass of the block?



**Q11.** A 0.15-kg baseball moving at 20 m/s is stopped by a catcher in 0.010 s. Find the average force to stop the ball.

**Q12.** A 25-N horizontal force northward and a 35-N horizontal force southward act concurrently on a 15-kg object on a frictionless surface. What is the magnitude of the object's acceleration?



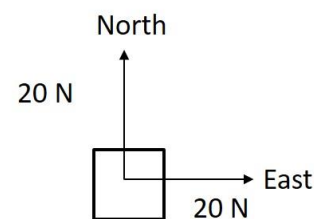
**Q13.** A cardboard box of mass  $m$  on a wooden floor is represented by the FBD to the right. A force is applied to the left. Given this information, derive two expressions that are accurate representations for the box.

**FACT:** With regards to Newton's 1<sup>st</sup> and 2<sup>nd</sup> laws, the two most common mistakes students make are underlined here: An object at rest will remain at rest and an object in motion will remain at a constant velocity unless acted upon by a net external force. Students will often say that an object in motion will remain in motion, which is not correct. Students will often leave off the "net external". ( $\Sigma F_{\text{net}} = ma$ )

**Q14.** You apply a force of 8.0 N horizontally to a 1 kg book that is at rest on a horizontal table. If the force of friction between the book and table is 4 N: a) What are the magnitudes of all the forces acting on the book? b) What is the acceleration of the book?

**Q15.** A 500 g cart is released from rest on a horizontal track and travels 75.0 cm in 1.75 seconds while experiencing an average, horizontal applied force of 0.5 N. What is the magnitude of the force of friction between the cart and the track?

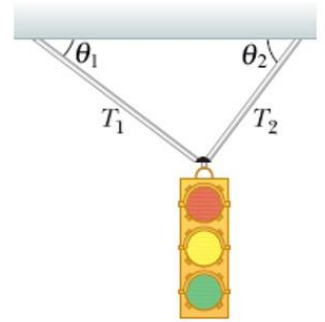
**Q16.** A 20-N force due north and a 20-N force due east act concurrently on an object, as shown in the diagram to the right. What additional force is needed to bring the object into a state of equilibrium?



**Q17.** A 1.0 N metal disk rests on an index card that is balanced on top of a glass. What is the net force acting on the disk?

**Q18.** A 15-kg wagon is pulled along a horizontal path to the right by a rope with a tension of 100 N. The rope is at an angle of 30 degrees above the horizontal. A frictional force of 20 N to the left acts simultaneously. (a). What is the acceleration of the wagon? (b). What would happen to the frictional force if the angle increased to 60 degrees above the horizontal?

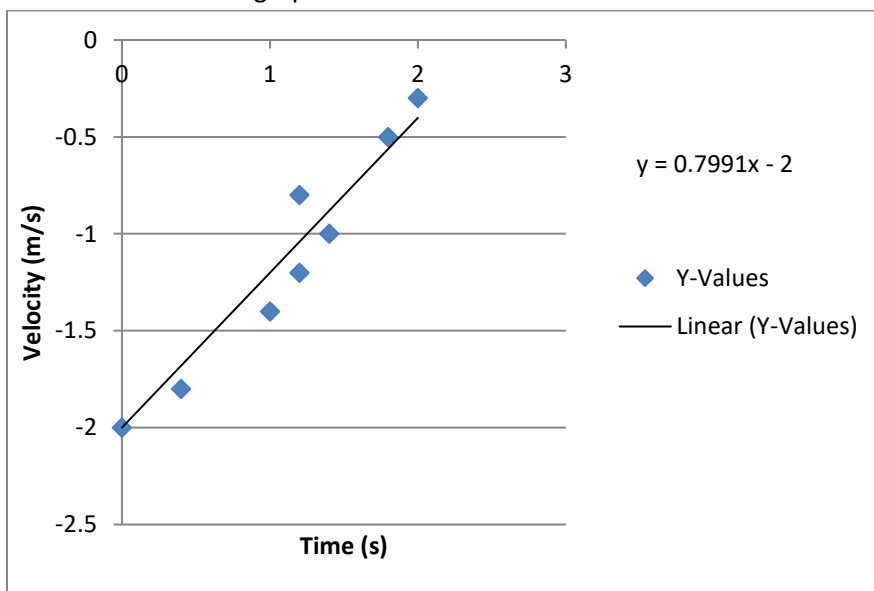
**FACT:** Tension force or the force of tension ( $T$  or  $F_T$ ) is the force transmitted through a rope, cable, string or wire pulled taut by forces acting on both ends. The tension force, like all forces, is a vector and has both magnitude and direction. The direction is always a pull in the direction of the rope and in opposite directions on opposite ends of the rope. The magnitude is equal in magnitude on both ends of the rope.



**Q19.** A traffic light is suspended by two cables as shown in the diagram. If cable 1 has a tension of 49 N and  $\theta_1 = 30^\circ$  and cable 2 has a tension force of 85 N and  $\theta_2 = 60^\circ$ , find the mass of the traffic light. What would the force of tension be on the cables if they were repositioned to hang vertically (i.e.,  $\theta_1$  and  $\theta_2 = 90^\circ$ )?

**Q20.** Three students are pulling on a bag of skittles. Each is pulling with a horizontal force. If student 1 pulls Eastward with 170 N, student 2 pulls Southward with 100 N and student 3 pulls with 200 N at an angle of  $20^\circ$  W of N, what is the net force caused by the three students on the bag of skittles?

**Q21.** You slide a 300 gram wooden block across the benchtop and record the velocity as a function of time. From these data you draw a best fit linear regression. The graph of its velocity as a function of time is shown below. (a).What is the magnitude of the force of friction between the block and the benchtop? (b). What other information could you determine from this graph?



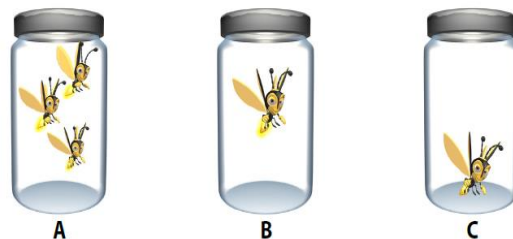
**FACT:** Newton's Third Law states that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs. For example, if someone throws a ball at my head, the force the ball exerts on my head is equal in magnitude and opposite in direction to the force my head exerts on the ball.

**Q22.** Draw a FBD for a book with mass (3 kg) resting on a table. Sum the forces to find force normal. Explain why the force of gravity and the force normal are **not** a Newton's Third Law Force Pair.

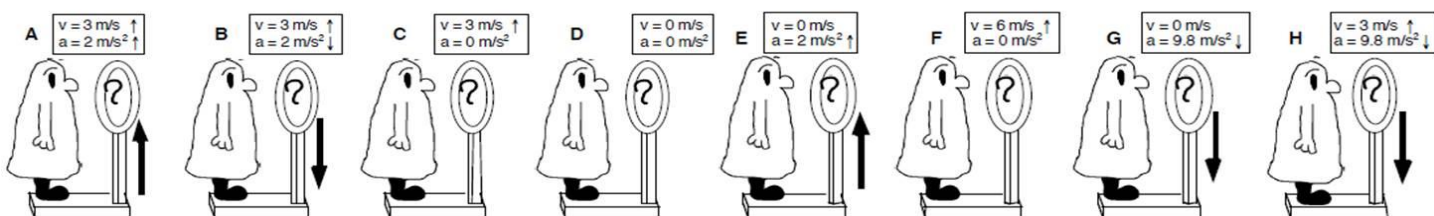
**Q23.** A man with a mass  $m$  stands on a scale in an elevator. If the scale reading is equal to  $mg$  when the elevator is at rest, what is the scale reading while the elevator is accelerating downwards with a magnitude of  $a_y$ ? Answer in terms of variables ( $m$ ,  $a_y$ ,  $g$ ).

**Q24.** A person stands on a scale in an elevator. If the scale reads 600 N when that person is riding upward at a constant velocity of 4 m/s, what is the scale reading when the elevator is at rest?

**Q25.** Identical fireflies are placed in closed jars in three different configurations as shown to the right. In configuration A, three fireflies are hovering inside the jar. In configuration B, one firefly is hovering inside the jar. In configuration C, one firefly is sitting at rest on the bottom of the jar. Each jar is placed upon a scale and measured. Rank the weight of each jar according to the scale reading from heaviest to lightest. If the jars have the same scale reading, rank them equally.



**Q26:** The figures below depict situations where a person is standing on a scale in eight identical elevators. Each person weighs 600 N when the elevators are stationary. Each elevator now moves (accelerates) according to the specified arrow that is drawn next to it. In all cases where the elevator is moving, it is moving upward. Rank the figures, from greatest to least, on the basis of the *scale weight* of each person as registered on each scale.



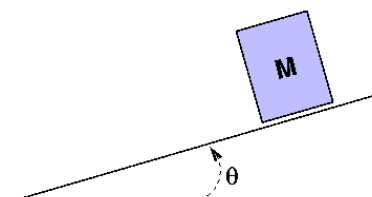
**Q27.** Four blocks of masses 20kg, 30kg, 40kg, and 50kg are stacked on top of one another in an elevator in order of decreasing mass with the lightest mass on the top of the stack. The elevator moves downward with an acceleration of 3.2 m/s<sup>2</sup>. Find the contact force between the 30kg and 40kg masses.

**FACT:** The friction force is the force exerted by a surface as an object moves across it or makes an effort to move across it. There are at least two types of friction force - kinetic and static friction. Friction results from the two surfaces being pressed together closely, causing intermolecular attractive forces between molecules of different surfaces. As such, friction depends upon the nature of the two surfaces and upon the degree to which they are pressed together. The maximum amount of friction force that a surface can exert upon an object can be calculated using the formula  $F_f = \mu F_N$ , where  $\mu$ , ( $\mu$ ) is the coefficient of friction, a proportionality constant that is specific to the two materials in contact and is dimensionless.

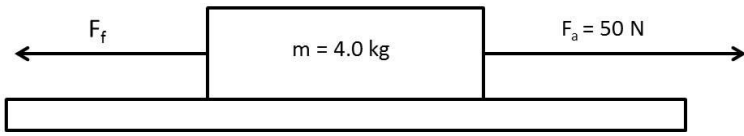
**Q28.** Calculate the coefficient of friction ( $\mu$ ) for the data graphed in question 21.

**FACT:** Kinetic friction is weaker than static friction, as it is easier to keep an object sliding once it is sliding than to start an object sliding in the first place (Newton's 1<sup>st</sup> law). Therefore, there are two types of  $\mu$ , denoted with subscripts. For a given pair of surfaces, it is true that  $\mu_k < \mu_s$ .

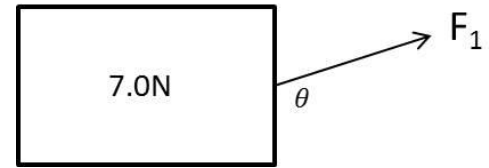
**Q29.** The diagram to the right shows a block sliding down a plane inclined at an angle  $\theta$  with the horizontal. As the angle  $\theta$  is increased, what can be concluded about the coefficient of kinetic friction between the bottom surface of the block and the surface of the incline? Answer semi-quantitatively.



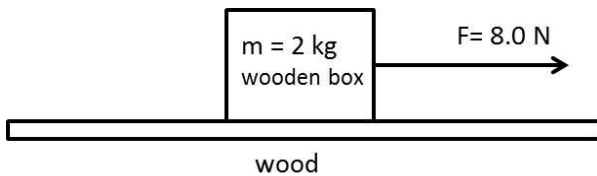
**Q30.** The diagram below shows a 4.0-kg object accelerating at 10 m/s<sup>2</sup> to the right on a rough horizontal surface. What is the magnitude of the frictional force ( $F_f$ ) acting on the object? Given these values, how much would the mass of the block need to be to experience no net force?



**Q31.** A 7.0 N block sits on a rough surface. It is being pulled by a force ( $F_1$ ) at an angle of  $\theta=30^\circ$  above the horizontal, as shown to the right. The block is initially moving to the right with a speed of 5 m/s. The coefficient of friction between the block and the surface is  $\mu=0.20$ . **a).** Is it possible for the block to be slowing down? If so, give a possible value of the magnitude of  $F_1$  that would allow the block to slow down. If not, explain why not with reference to Newton's second law. **b).** In order to double the block's initial speed to 10 m/s, how must the magnitude of the force  $F_1$  change?



**Q32.** A horizontal tension force of 8.0 N is used to pull a 20-N wooden box moving toward the right along a horizontal, wood surface, as shown. The coefficient of kinetic friction for wood on wood is  $\mu = 0.3$ .

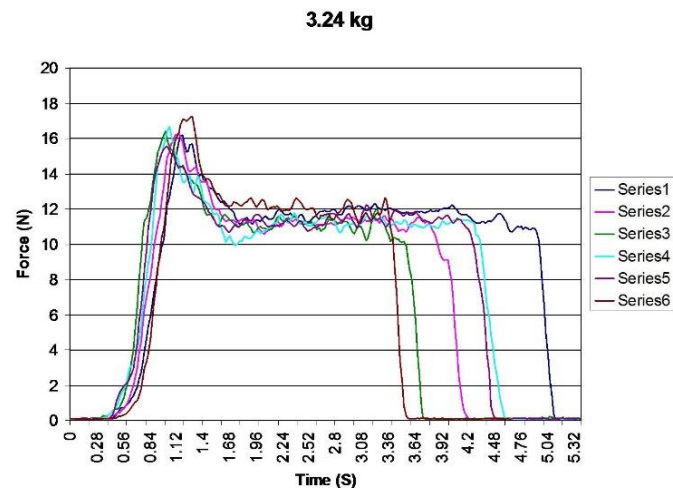


a). Calculate the magnitude of the frictional force on the box; b). Identify Newton's Third Law Force Pairs; c). Determine the magnitude of the force acting on the box; d). Calculate the magnitude of the acceleration of the box.

**Q33.** A 10-kg wooden box sits on a wood surface. The coefficient of static friction between the surfaces is 0.42. A horizontal force of 20 N is applied to the box. What is the force of friction on the box?

**Q34.** A crate of mass 100 kg rests on the floor ( $\mu_s = 0.4$ ) If a force of 250 N parallel to the floor is applied to the crate, will it move? If so, what is the coefficient for kinetic friction? If not, what is the magnitude of the force of static friction on the crate?

**Q35.** A group of PCHS Magnet students want to explore the relationship between the force of static and kinetic friction across a horizontal desktop. They decide to perform a drag test by dragging a 3.24-kg block using a force probe to collect data. The students decide to perform six trials to ensure the data can be replicated. Their graph of force as a function of time can be seen below. a). Calculate the approximate coefficient of static friction (max) and the coefficient of kinetic friction using the data graphed below. b). Explain why the coefficient of static friction is greater than the coefficient of kinetic friction

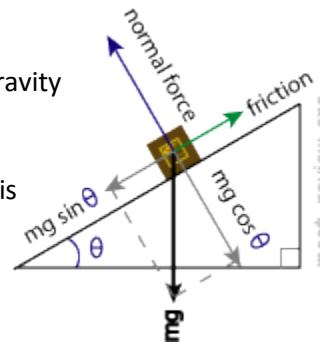


**Q35.** You apply a horizontal force of 3.0 N to a book with a mass of 0.8 kg. The values for the coefficients of friction between the book and the incline are  $\mu_s = 0.3$  and  $\mu_k = 0.25$ . (a) Does the book move? (b) What is the acceleration of the book?

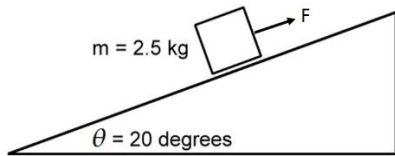
**Q36.** A 1200-kg car with anti-lock brakes driving on snow has an initial velocity of 15 m/s and slows to a stop in 5.0 seconds. Determine the coefficient of friction between the tires and the snow.

**FACT:** Previously, we resolved the vectors into components in the x and y directions, however, on an incline we usually resolve vectors into components which are in the  $\parallel$  (parallel) and  $\perp$  (perpendicular) directions. The  $\parallel$  direction is parallel to the incline and the  $\perp$  direction is perpendicular to the incline.

**FACT:** The component of gravity that is  $\perp$  to the incline is equal to  $mg \cos \theta$ . The component of gravity that is  $\parallel$  to the incline is equal to  $mg \sin \theta$ . Examine the diagram to the right.



**Q37.** A 2.5-kg mass is held at rest on a frictionless  $20^\circ$  incline by a force,  $F$  as shown below. What is the magnitude of  $F$ ? Given this calculated force, determine what angle of inclination would result in a net external force?



**Q38.** A 10-kg box that is initially at rest slides down a frictionless  $18^\circ$  ramp. Find the acceleration of the box, and the time it takes the box to slide 2 meters down the ramp.

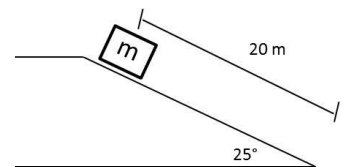
**Q39.** A block weighing 10 newtons is on a ramp inclined at  $30^\circ$  to the horizontal. A 3-newton force of friction acts on the block as it is pulled up the ramp at a constant velocity. The force applied to pull the box up the ramp acts parallel to the incline. Draw the FBD for this problem and determine the magnitude of the force applied.

**Q40.** A 10-kg box is released from rest and slides 20 meters down a  $40^\circ$  incline. A frictional force of 10 N acts on the object. Determine: a). the acceleration of the block down the plane; b). the time for the block to slide to the bottom of the plane.

**Q41.** A box of unknown mass is released from rest and slides 20 meters down a 10-meter high frictionless incline. Determine: a). the acceleration of the block down the plane; b). the time for the block to slide to the bottom of the plane.

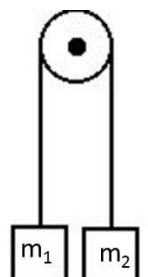
**Q42.** A 10-kg is released from rest and slides 20 meters down  $40^\circ$  incline with a coefficient of kinetic friction of 0.25. Determine: a). the acceleration of the block down the plane; b). the time for the block to slide to the bottom of the plane.

**Q43.** A 30-kg box is 20 m up a ramp sliding with an initial velocity of 3.0 m/s up the ramp. The plane makes a  $25^\circ$  incline from the horizontal and the surface has a coefficient of kinetic friction of  $\mu = 0.30$ . Determine: a). the acceleration of the block down the plane; b). the time for the block to slide to the bottom of the plane

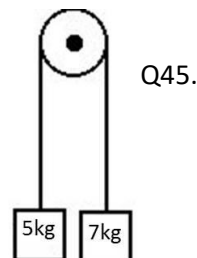


**FACT:** Pulleys, Atwood machines, and modified Atwood machines: An Atwood machine typically involves a pulley, a string, and system of masses. To solve these problems, recognize that the force transmitted by a string, known as tension, is constant throughout the string, and choose a consistent positive direction for the entire system to solve for acceleration.

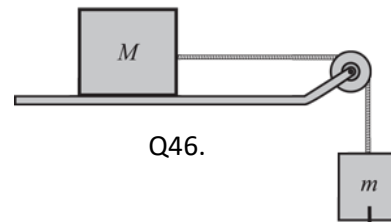
**Q44.** Two masses are hanging by a massless string from a frictionless pulley. If  $m_1$  is greater than  $m_2$ , derive an expression for the acceleration of the two masses when released from rest.



**Q45.** Two masses are hung from a frictionless pulley by a massless string as shown in the image to the right. How far will the 7-kg mass fall in 2 seconds if released from rest?

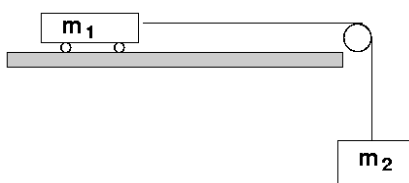


**Q46.** Two masses,  $M$  and  $m$ , are connected by a light string over a massless pulley as shown in the modified Atwood machine to the right. Assuming a frictionless surface, find the acceleration of  $m$ .

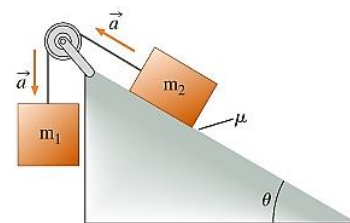


**FACT:** Since Atwood machine problems include a tension force, you may be asked to solve for  $F_T$ . Just remember to treat the entire machine as a system to solve for acceleration (choose positive direction) and then you can solve for any other variables.

**Q47.** In the diagram below, the mass of  $m_1$  is 2-kg and the mass of  $m_2$  is 10-kg. The wheels on the cart are jammed and do not roll, so the coefficient of kinetic friction between the cart and the rough surface is 0.5. Find the acceleration of the system.



**Q48.** In the diagram to the right, the mass of  $m_1$  is 8-kg and the mass of  $m_2$  is 2-kg. The coefficient of kinetic friction between the block and the incline is 0.2 and the plane rises  $25^\circ$  from the horizontal. Find the acceleration of the system and the force of tension in the string.



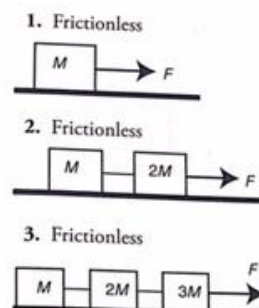
**Q49.** The following question has three parts (1-3). For each part, find the force of tension in the rope and the acceleration of the set of masses. Use the following variable definitions:  $F = 10 \text{ N}$ ,  $M = 1.0 \text{ kg}$ .

**Q50.** The following question has three parts (10-12). For each part, find the force of tension in the rope and the acceleration of the set of masses. Use the following variable definitions:  $F = 10 \text{ N}$ ,  $M = 1.0 \text{ kg}$ ,  $\mu = 0.2$ .

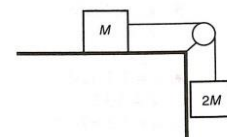
**FACT: Air Resistance:** As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. The actual amount of air resistance encountered by the object is dependent upon a variety of factors. To keep the topic simple, it can be said that the two most common factors that have a direct effect upon the amount of air resistance are the speed of the object and the cross-sectional area of the object. Increased speeds result in an increased amount of air resistance. Increased cross-sectional areas result in an increased amount of air resistance.

**FACT:** The drag forces on a free-fall object take a form similar to  $F_{\text{drag}} = bv$  or  $F_{\text{drag}} = cv^2$ , where  $b$  and  $c$  are constants. When an object reaches its maximum vertical velocity, known as terminal velocity ( $V_t$ ), the object falls at a constant velocity and is in equilibrium. It is unlikely you will encounter any mathematical problems dealing with air resistance on the AP Physics 1 exam; however, the concept might be assessed. I have also found that students are very curious about the concept of terminal velocity. For those curious about the complexity of the mathematics used to calculate the drag force, please view the following podcast:

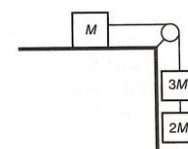
[https://www.youtube.com/watch?list=PLPyapQSxH6mY\\_hbPFnggb\\_Ru\\_gKos6mab&v=OukRTF6Bgcc](https://www.youtube.com/watch?list=PLPyapQSxH6mY_hbPFnggb_Ru_gKos6mab&v=OukRTF6Bgcc)



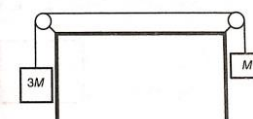
10. Coefficient of Friction  $\mu$



11. Coefficient of Friction  $\mu$



12. Frictionless

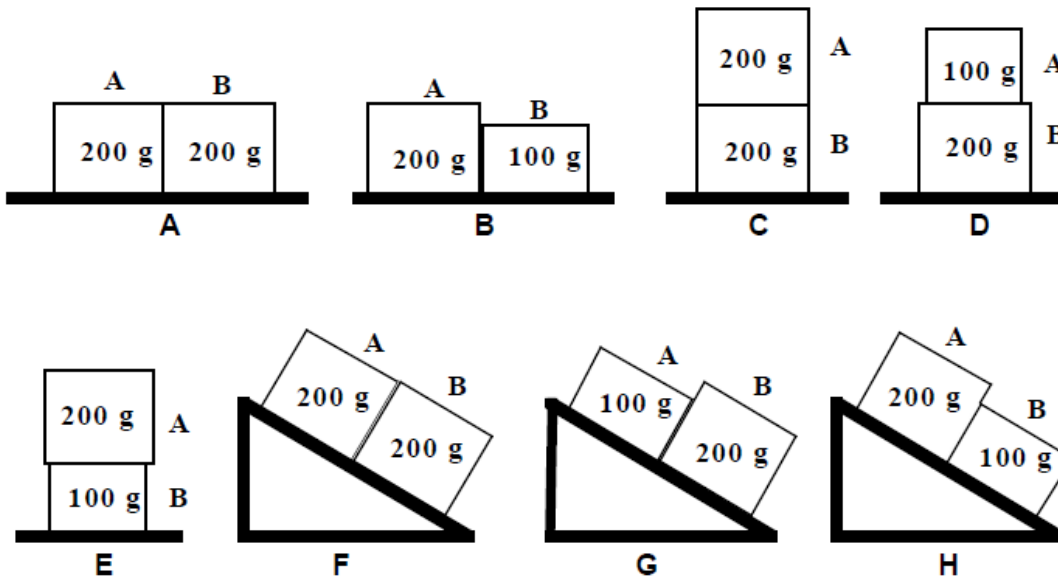
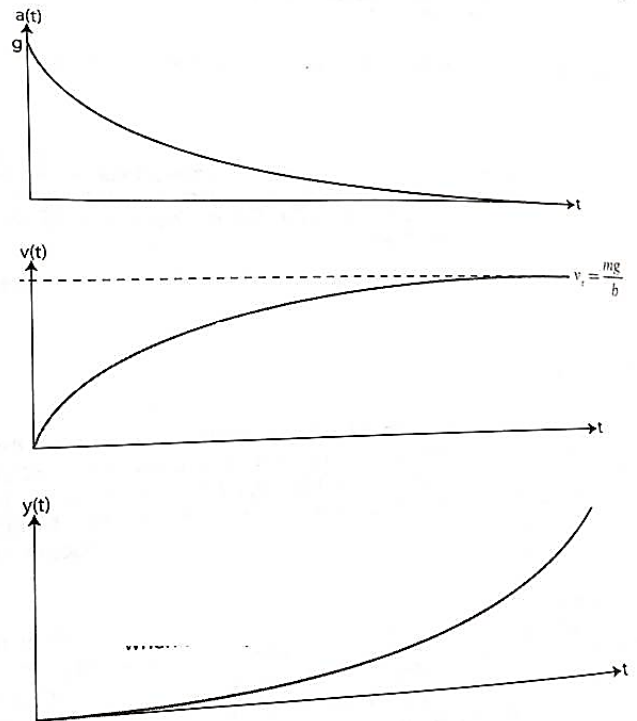




**Q51.** Examine motion-time graphs to the right for an object in free-fall. Write a sentence describing the motion for each graph.

**Q52.** Shown below are eight arrangements of two wooden blocks. There are two different mass blocks, either 100 g or 200 g. In all of the arrangements, the blocks are in contact, that is, they are touching each other. Also, in all of the arrangements the blocks are at rest, i.e., they are not moving. As you can see, one of the blocks given in each arrangement is labeled **A**, and the other is labeled **B**. The mass of each block is given in the figures.

Rank these arrangements from largest to smallest on the basis of the difference of the strengths (magnitudes) of the forces between the force **A** exerts on **B** and the force **B** exerts on **A**. In other words, the arrangement where the force **A** exerts on **B** minus the force **B** exerts on **A** is the largest will rank first. In the same way, the arrangement where the force **A** exerts on **B** minus the force **B** exerts on **A** is the smallest will rank last. Keep in mind that some of these values might be negative. If **B** is exerting a stronger force on **A** than **A** exerts on **B**, then the difference will be negative.



Largest 1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_ 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ Smallest

Or, all of these differences will be the same. \_\_\_\_\_