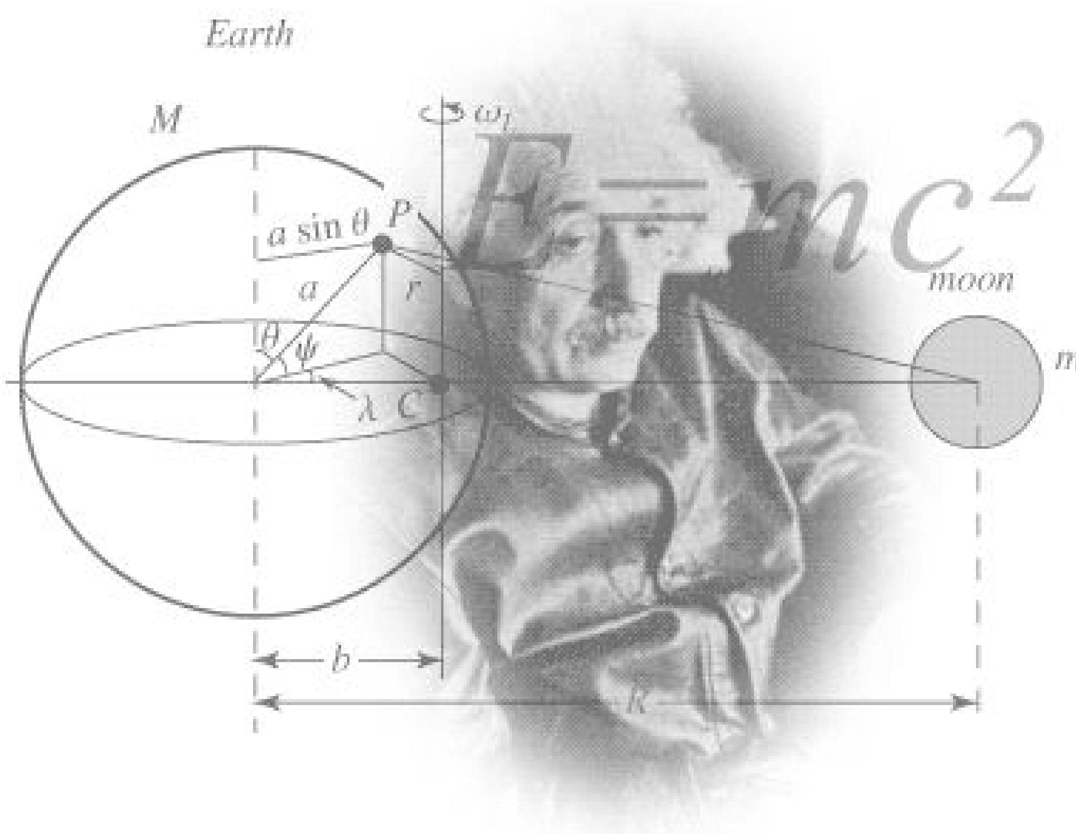
AP Physics 1 – Practice Workbook – Book 1

Mechanics, Waves and Sound, Electrostatics and DC Circuits



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IMPORTANT:

This book is a compilation of all the problems published by College Board in AP Physics B and AP Physics C that **were** appropriate for the AP B level as well as problems from AAPT's Physics Bowl and U.S. Physics Team Qualifying Exams organized by topic.

DISCLAIMER

The Multiple Choice Questions in this workbook have been compiled and modified from previous AP Physics B and C examinations and Physics Bowl exams. They are **not** meant to be representative of the new AP Physics courses.

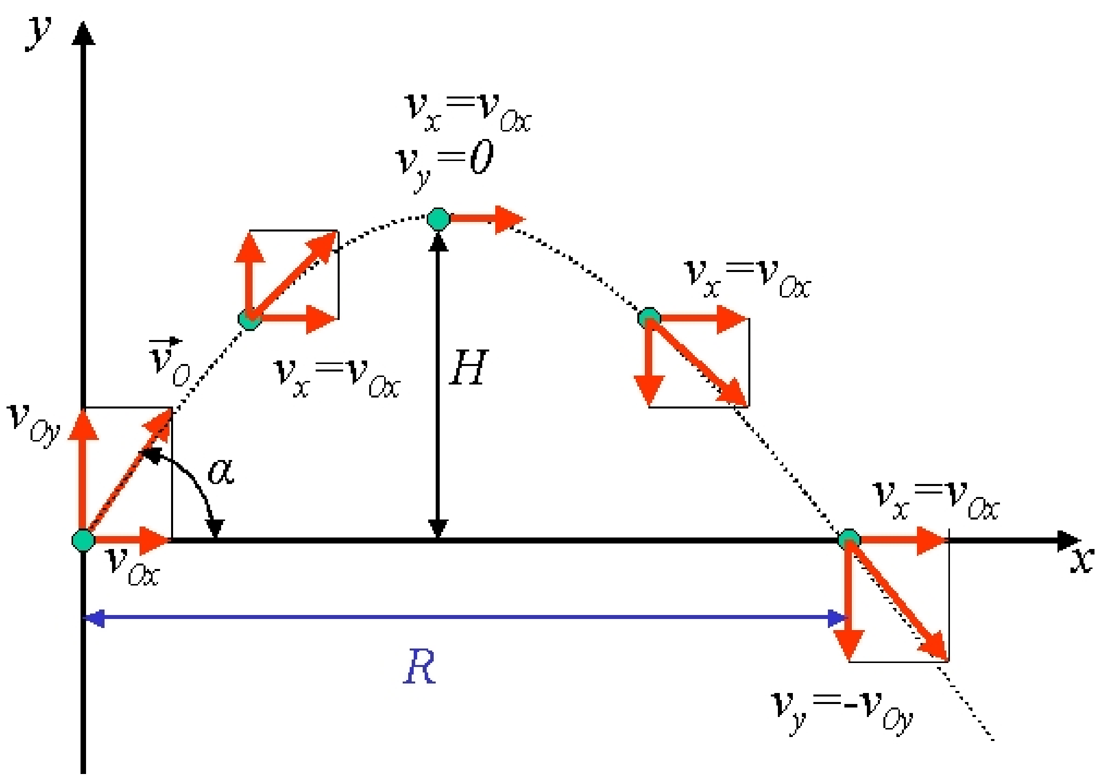
The Free-Response Questions have not been edited and might not represent the topics covered nor the style of questions in the new exams.

The answers as presented are not the only method to solving many of these problems and physics teachers may present slightly different methods and/or different symbols and variables in each topic, but the underlying physics concepts are the same and we ask you read the solutions with an open mind and use these differences to expand your problem solving skills.

Finally, we *are* fallible and if you find any typographical errors, formatting errors or anything that strikes you as unclear or unreadable, please let us know so we can make the necessary announcements and corrections.

Chapter 1

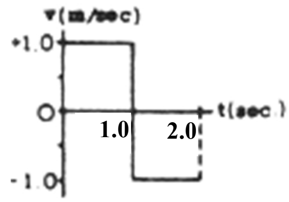
Kinematics



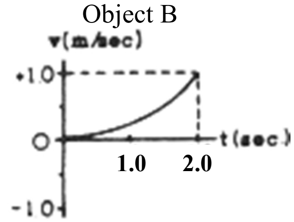
AP Physics Multiple Choice Practice – Kinematics

Questions 1 – 3 relate to two objects that start at x = 0 at t = 0 and move in one dimension independently of one another. Graphs, of the velocity of each object versus time are shown below

Object A



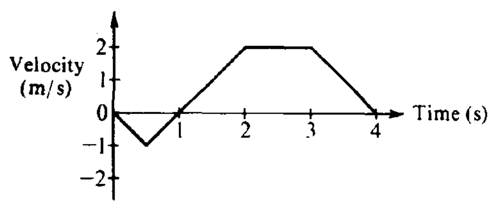
Object B



1. Which object is farthest from the origin at t = 2 seconds.
(A) A (B) B (C) they are in the same location at t = 2 seconds (D) They are the same distance from the origin, but in opposite directions

2. Which object moves with constant non-zero acceleration?
(A) A (B) B (C) both A and B (D) neither A nor B

3. Which object is in its initial position at t = 2 seconds?
(A) A (B) B (C) both A and B (D) neither A nor B

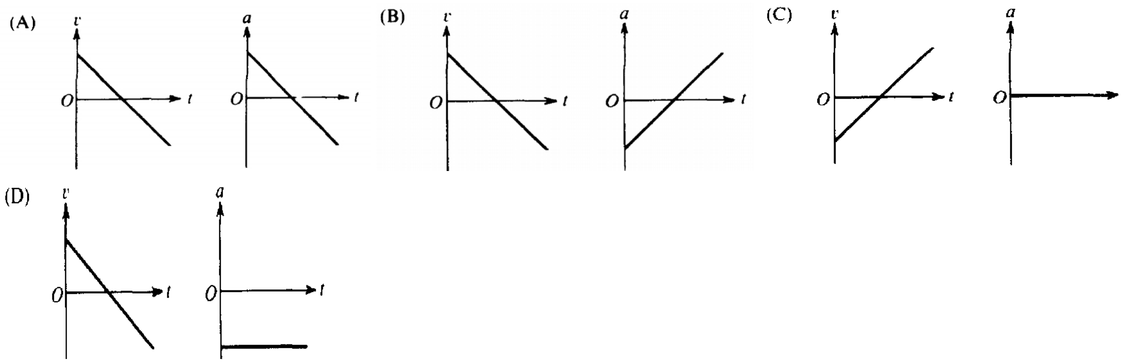


4. The graph above shows the velocity versus time for an object moving in a straight line. At what time after t = 0 does the object again pass through its initial position?
(A) 1 s (B) Between 1 and 2 s (C) 2 s (D) Between 2 and 3 s

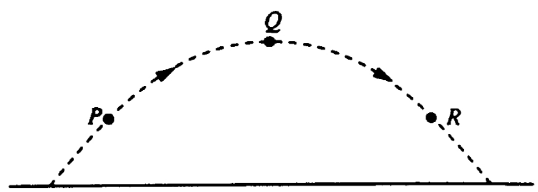
5. A body moving in the positive x direction passes the origin at time t = 0. Between t = 0 and t = 1 second, the body has a constant speed of 24 meters per second. At t = 1 second, the body is given a constant acceleration of 6 meters per second squared in the negative x direction. The position x of the body at t = 11 seconds is
(A) + 99m (B) + 36m (C) – 36 m (E) – 99 m

6. A diver initially moving horizontally with speed v dives off the edge of a vertical cliff and lands in the water a distance *d* from the base of the cliff. How far from the base of the cliff would the diver have landed if the diver initially had been moving horizontally with speed 2v?
(A) *d* (B) $\sqrt{2d}$ (C) *2d* (D) *4d*

7. A projectile is fired with initial velocity v_o at an angle θ_0 with the horizontal and follows the trajectory shown above. Which of the following pairs of graphs best represents the vertical components of the velocity and acceleration, v and a, respectively, of the projectile as functions of time t?



Questions 8-9

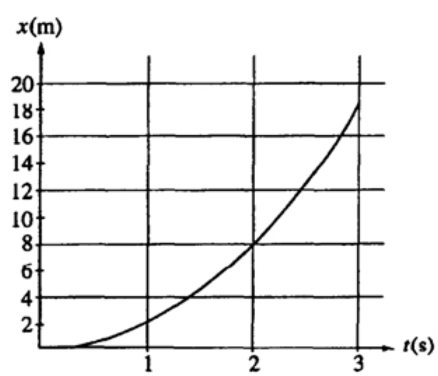


A ball is thrown and follows the parabolic path shown above. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground.

8. How do the speeds of the ball at the three points compare?
(A) $v_P < v_Q < v_R$ (B) $v_R < v_Q < v_P$ (C) $v_Q < v_R < v_P$ (D) $v_Q < v_P = v_R$

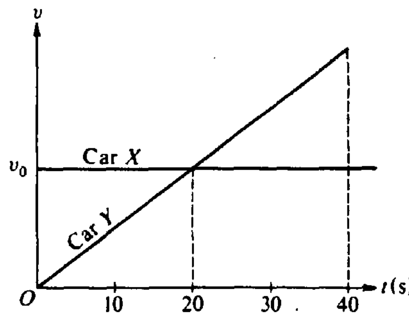
9. Which of the following diagrams best shows the direction of the acceleration of the ball at point P?

(A) ↗ (B) → (C) ↘ (D) ↓



10. The graph above represents position x versus time t for an object being acted on by a constant force. The average speed during the interval between 1 s and 2 s is most nearly
(A) 2 m/s (B) 4 m/s (C) 5 m/s (D) 6 m/s

Questions 11 – 12

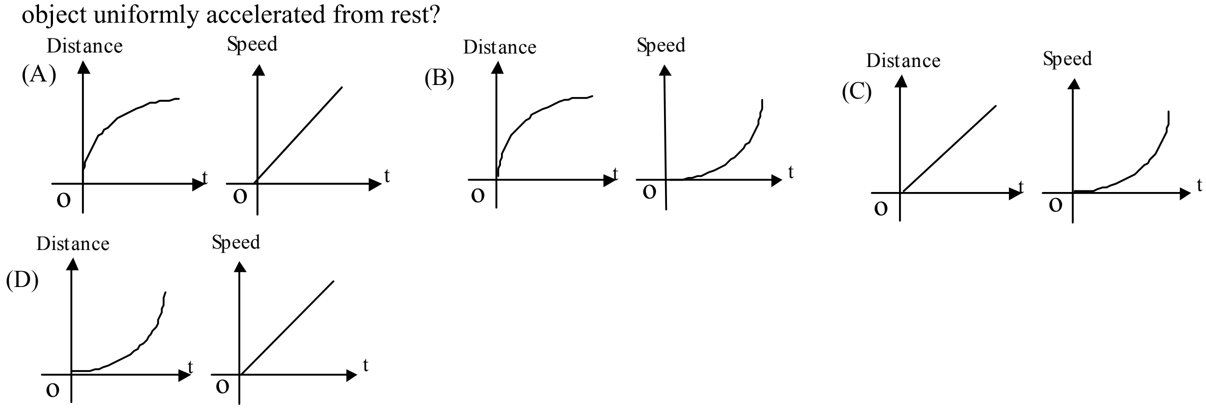


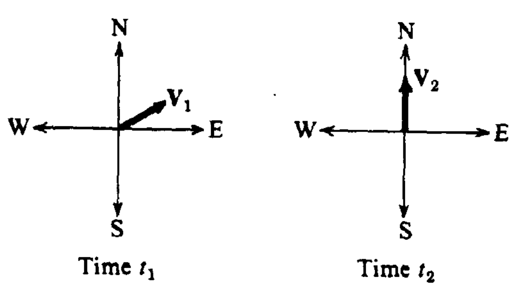
At time t = 0, car X traveling with speed v_0 passes car Y which is just starting to move. Both cars then travel on two parallel lanes of the same straight road. The graphs of speed v versus time t for both cars are shown above.

11. Which of the following is true at time t = 20 seconds?
(A) Car Y is behind car X. (B) Car Y is passing car X. (C) Car Y is in front of car X.
(D) Car X is accelerating faster than car Y.

12. From time t = 0 to time t = 40 seconds, the areas under both curves are equal. Therefore, which of the following is true at time t = 40 seconds?
(A) Car Y is behind car X. (B) Car Y is passing car X. (C) Car Y is in front of car X.
(d) Car X is accelerating faster than car Y.

13. Which of the following pairs of graphs shows the distance traveled versus time and the speed versus time for an object uniformly accelerated from rest?

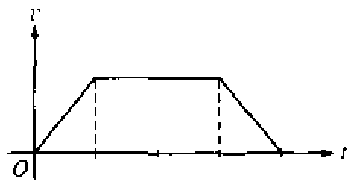




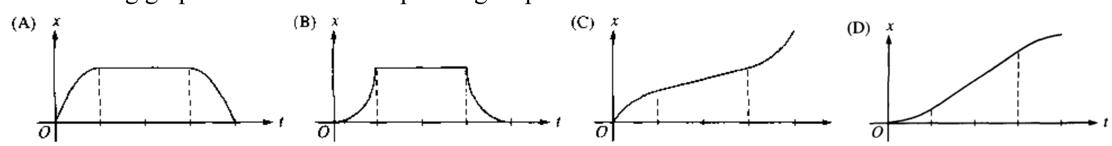
14. Vectors $\mathbf{V_1}$ and $\mathbf{V_2}$ shown above have equal magnitudes. The vectors represent the velocities of an object at times t_1, and t_2, respectively. The average acceleration of the object between time t_1 and t_2 was
(A) directed north (B) directed west (C) directed north of east (D) directed north of west

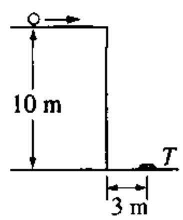
15. The velocity of a projectile at launch has a horizontal component v_h and a vertical component v_v. Air resistance is negligible. When the projectile is at the highest point of its trajectory, which of the following shows the vertical and horizontal components of its velocity and the vertical component of its acceleration?

	Vertical Velocity	Horizontal Velocity	Vertical Acceleration
(A)	v_v	v_h	0
(B)	0	v_h	0
(C)	0	0	g
(D)	0	v_h	g



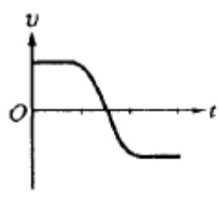
16. The graph above shows the velocity *v* as a function of time *t* for an object moving in a straight line. Which of the following graphs shows the corresponding displacement *x* as a function of time *t* for the same time interval?



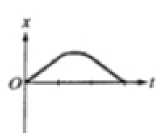
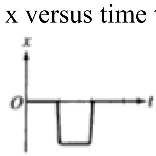
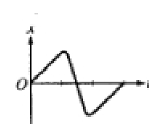


17. A target *T* lies flat on the ground 3 m from the side of a building that is 10 m tall, as shown above. A student rolls a ball off the horizontal roof of the building in the direction of the target. Air resistance is negligible. The horizontal speed with which the ball must leave the roof if it is to strike the target is most nearly

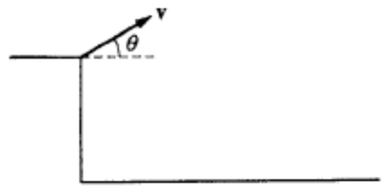
(A) 3/10 m/s (B) $\sqrt{2}$ m/s (C) $\frac{3}{\sqrt{2}}$ m/s (D) 3 m/s



18. The graph above shows velocity v versus time t for an object in linear motion. Which of the following is a possible graph of position x versus time t for this object?

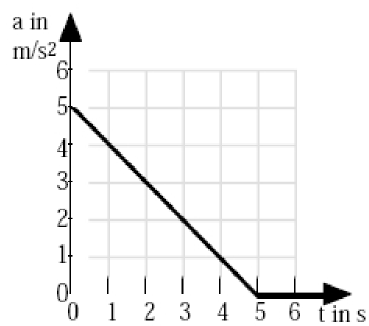
(A)  (B)  (C)  (D) 

19. A student is testing the kinematic equations for uniformly accelerated motion by measuring the time it takes for light-weight plastic balls to fall to the floor from a height of 3 m in the lab. The student predicts the time to fall using g as 9.80 m/s^2 but finds the measured time to be 35% greater. Which of the following is the most likely cause of the large percent error?
(A) The acceleration due to gravity is 70% greater than 9.80 m/s^2 at this location.
(B) The acceleration due to gravity is 70% less than 9.80 m/s^2 at this location.
(C) Air resistance increases the downward acceleration.
(D) The acceleration of the plastic balls is not uniform.



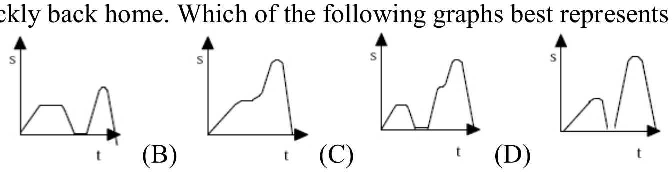
Note: Figure not drawn to scale.

20. An object is thrown with velocity **v** from the edge of a cliff above level ground. Neglect air resistance. In order for the object to travel a maximum horizontal distance from the cliff before hitting the ground, the throw should be at an angle θ with respect to the horizontal of
(A) greater than 60° above the horizontal
(B) greater than 45° but less than 60° above the horizontal
(C) greater than zero but less than 45° above the horizontal
(D) greater than zero but less than 45° below the horizontal



21. Starting from rest at time t = 0, a car moves in a straight line with an acceleration given by the accompanying graph. What is the speed of the car at t = 3 s?
(A) 1.0 m/s (B) 2.0 m/s (C) 6.0 m/s (D) 10.5 m/s

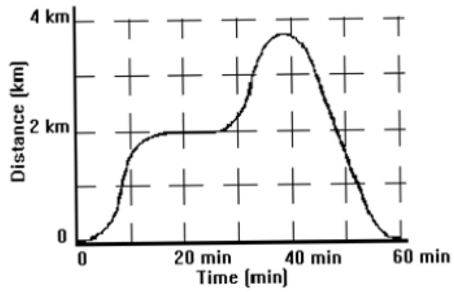
22. A child left her home and started walking at a constant velocity. After a time she stopped for a while and then continued on with a velocity greater than she originally had. All of a sudden she turned around and walked very quickly back home. Which of the following graphs best represents the distance versus time graph for her walk?



(A) (B) (C) (D)

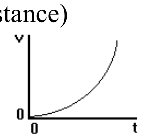
23. A whiffle ball is tossed straight up, reaches a highest point, and falls back down. Air resistance is not negligible. Which of the following statements are true?
I. The ball's speed is zero at the highest point.
II. The ball's acceleration is zero at the highest point.
III. The ball takes a longer time to travel up to the highest point than to fall back down.

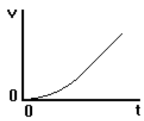
(A) I only (B) II only (C) I & II only (D) I & III only

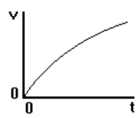


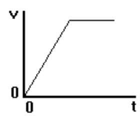
24. Above is a graph of the distance vs. time for car moving along a road. According the graph, at which of the following times would the automobile have been accelerating positively?
(A) 0, 20, 38, & 60 min. (B) 5, 12, 29, & 35 min. (C) 5, 29, & 57 min. (D) 12, 35, & 41 min.

25. A large beach ball is dropped from the ceiling of a school gymnasium to the floor about 10 meters below. Which of the following graphs would best represent its velocity as a function of time? (do not neglect air resistance)

(A) 

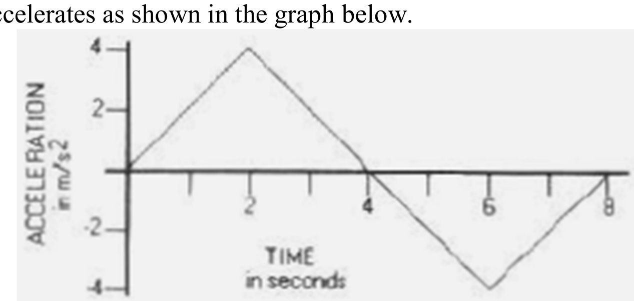
(B) 

(C) 

(D 

Questions 26-27

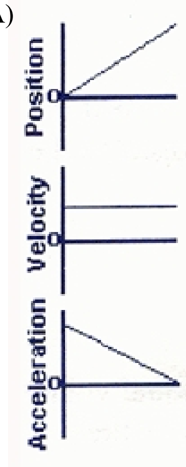
A car starts from rest and accelerates as shown in the graph below.

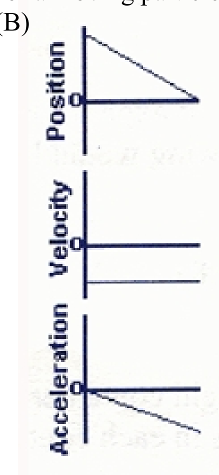


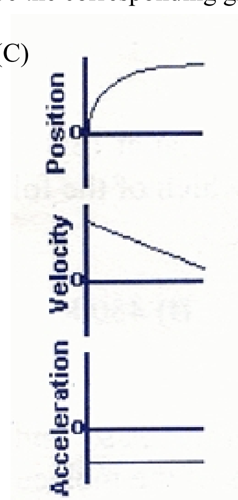
26. At what time would the car be moving with the greatest velocity?
(B) 2 seconds (C) 4 seconds (D) 6 seconds (E) 8 seconds

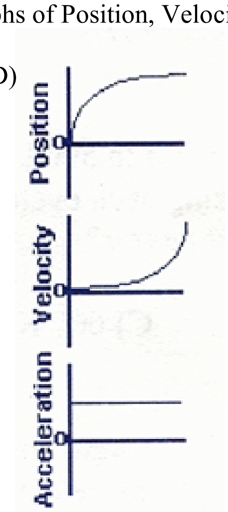
27. At what time would the car be farthest from its original starting position?
(A) 2 seconds (B) 4 seconds (C) 6 seconds (D) 8 seconds

28. Which of the following sets of graphs might be the corresponding graphs of Position, Velocity, and Acceleration vs. Time for a moving particle?

(A)


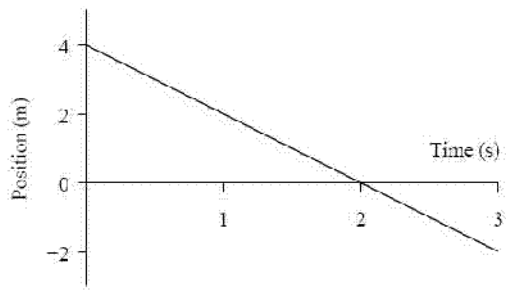
(B)


(C)


(D)


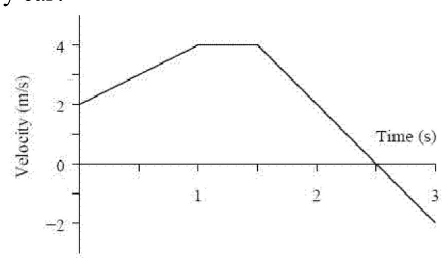
29. An object is thrown with a fixed initial speed v_0 at various angles α relative to the horizon. At some constant height h above the launch point the speed v of the object is measured as a function of the initial angle α. Which of the following best describes the dependence of v on α? (Assume that the height h is achieved, and assume that there is no air resistance.)
(A) v will increase monotonically with α.
(B) v will increase to some critical value v_{max} and then decrease.
(C) v will remain constant, independent of α.
(D) v will decrease to some critical value v_{min} and then increase.

30. The position vs. time graph for an object moving in a straight line is shown below. What is the instantaneous velocity at $t = 2$ s?



(A) – 2 m/s (B) ½ m/s (C) 0 m/s (D) 2 m/s

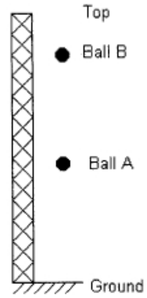
31. Shown below is the velocity vs. time graph for a toy car moving along a straight line. What is the maximum displacement from start for the toy car?



(A) 5 m (B) 6.5 m (C) 7 m (D) 7.5 m

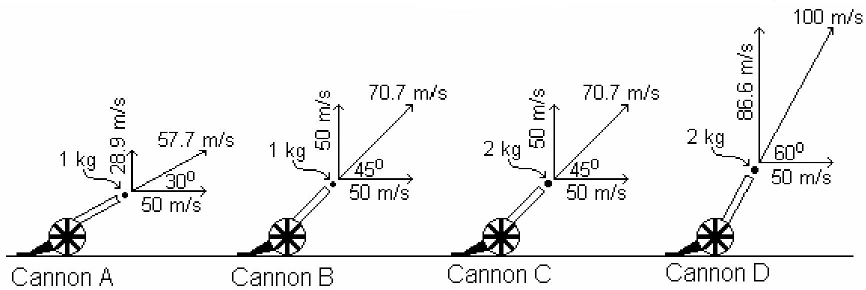
32. An object is released from rest and falls a distance h during the first second of time. How far will it fall during the next second of time?
(A) h (B) $2h$ (C) $3h$ (D) $4h$

33. Two identical bowling balls A and B are each dropped from rest from the top of a tall tower as shown in the diagram below. Ball A is dropped 1.0 s before ball B is dropped but both balls fall for some time before ball A strikes the ground. Air resistance can be considered negligible during the fall. After ball B is dropped but before ball A strikes the ground, which of the following is true?



(A) The distance between the two balls decreases.
(B) The velocity of ball A increases with respect to ball (B)
(C) The velocity of ball A decreases with respect to ball (B)
(D) The distance between the two balls increases.

34. The diagram below shows four cannons firing shells with different masses at different angles of elevation. The horizontal component of the shell's velocity is the same in all four cases. In which case will the shell have the greatest range if air resistance is neglected?



(A) cannon A (B) cannon B only (C) cannon C only (D) cannon D

35. Starting from rest, object 1 falls freely for 4.0 seconds, and object 2 falls freely for 8.0 seconds. Compared to object 1, object 2 falls:
(A) half as far (B) twice as far (C) three times as far (D) four times as far

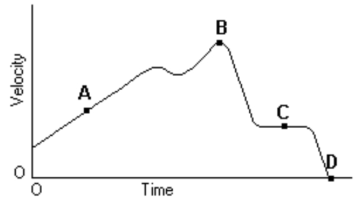
36. A car starts from rest and uniformly accelerates to a final speed of 20.0 m/s in a time of 15.0 s. How far does the car travel during this time?
(A) 150 m (B) 300 m (C) 450 m (D) 600 m

37. An arrow is aimed horizontally, directly at the center of a target 20 m away. The arrow hits 0.050 m below the center of the target. Neglecting air resistance, what was the initial speed of the arrow?
(A) 20 m/s (B) 40 m/s (C) 100 m/s (D) 200 m/s

38. A rocket near the surface of the earth is accelerating vertically upward at 10 m/s^2. The rocket releases an instrument package. Immediately after release the acceleration of the instrument package is:
(A) 20 m/s^2 up (B) 10 m/s^2 up (C) 0 (D) 10 m/s^2 down

39. A ball which is dropped from the top of a building strikes the ground with a speed of 30 m/s. Assume air resistance can be ignored. The height of the building is approximately:
(A) 15 m (B) 30 m (C) 45 m (D) 75 m

40. In the absence of air resistance, if an object were to fall freely near the surface of the Moon,
(A) its acceleration would gradually decrease until the object moves with a terminal velocity.
(B) the acceleration is constant.
(C) it will fall with a constant speed.
(D) the acceleration is zero

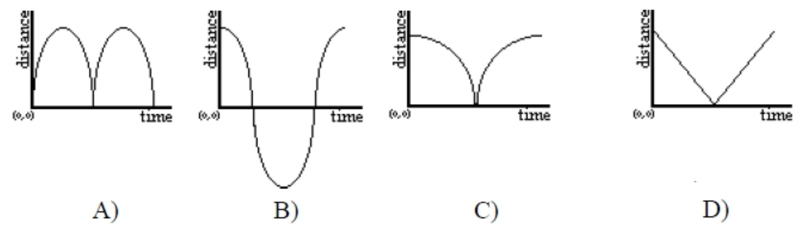


41. Given the graph of the velocity vs. time of a duck flying due south for the winter. At what point did the duck stop its forward motion?
(A) A (B) B (C) C (D) D

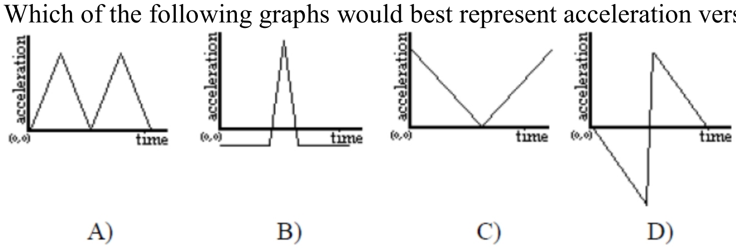
Questions 42-43

The following TWO questions refer to the following information. An ideal elastic rubber ball is dropped from a height of about 2 meters, hits the floor and rebounds to its original height.

42. Which of the following graphs would best represent the distance above the floor versus time for the above bouncing ball?

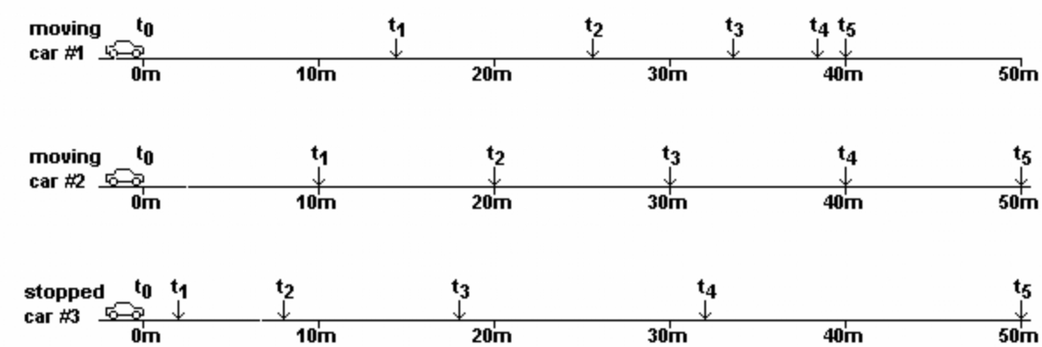


43. Which of the following graphs would best represent acceleration versus time for the bouncing ball?



Questions 44-46

The following TWO questions refer to the following information. At t_0, two cars moving along a highway are side-by-side as they pass a third car stopped on the side of the road. At this moment the driver of the first car steps on the brakes while the driver of the stopped car begins to accelerate. The diagrams below show the positions of each car for the next 5 seconds.

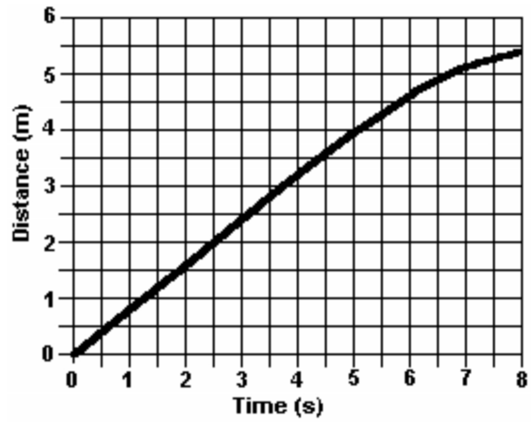


44. During which time interval would cars #2 and #3 be moving at the same average speed?
(A) t_0 to t_1 (B) t_1 to t_2 (C) t_2 to t_3 (D) t_3 to t_4

45. Which of the three cars had the greatest average speed during these 5 seconds?
(A) car #2 and car #3 had the same average speed (B) car #2
(C) all three cars had the same average speed (C) car #3

46. If car #3 continues to constantly accelerate at the same rate what will be its position at the end of 6 seconds?
(A) 24 m (B) 68 m (C) 72 m (D) 78 m

Questions 47-48



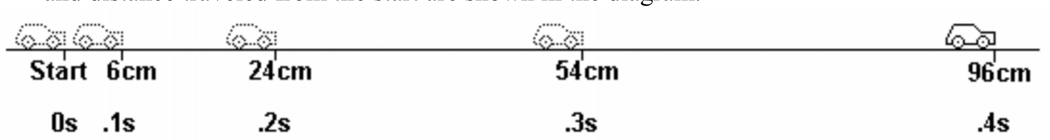
47. The graph represents the relationship between distance and time for an object that is moving along a straight line. What is the instantaneous speed of the object at t = 5.0 seconds?
(A) 0.0 m/s (B) 0.8 m/s (C) 2.5 m/s (D) 4.0 m/s

48. Between what times did the object have a non-zero acceleration?
(A) 0 s on (B) 0 s to 5 s (C) the object was not accelerating at any time (D) 5 s to 8 s

49. If a ball is thrown directly upwards with twice the initial speed of another, how much higher will it be at its apex?
(A) 8 times (B) 2 times (C) 4 times (D) 2 times

Questions 50-51

The diagram below represents a toy car starting from rest and uniformly accelerating across the floor. The time and distance traveled from the start are shown in the diagram.

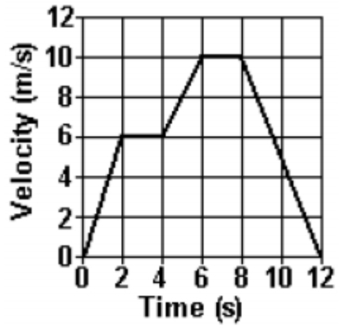


50. What was the acceleration of the cart during the first 0.4 seconds?
(A) 25 m/s^2 (B) 9.8 m/s^2 (C) 50 m/s^2 (D) 12 m/s^2

51. What was the instantaneous velocity of the cart at 96 centimeters from the start?
(A) 0.6 m/s (B) 4.8 m/s (C) 1.9 m/s (D) 60 m/s (E) 2.4 m/s

Questions 52-53

The motion of a circus clown on a unicycle moving in a straight line is shown in the graph below



52. What would be the acceleration of the clown at 5 s?
(A) 1.6 m/s^2 (B) 8.0 m/s^2 (C) 2.0 m/s^2 (D) 3.4 m/s^2

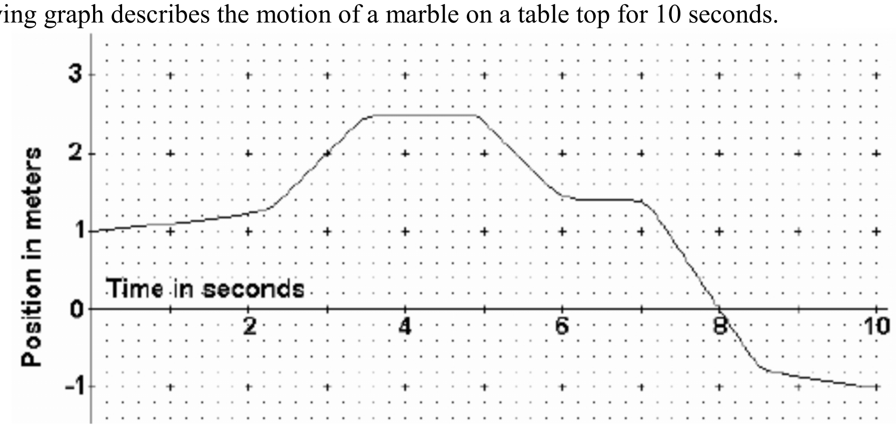
53. After 12 seconds, how far is the clown from her original starting point?
(A) 0 m (B) 10 m (C) 47 m (D) 74 m

54. When an object falls freely in a vacuum near the surface of the earth
(A) the terminal velocity will be greater than when dropped in air
(B) the velocity will increase but the acceleration will be zero
(C) the acceleration will constantly increase
(D) the acceleration will remain constant

55. Two arrows are launched at the same time with the same speed. Arrow A at an angle greater than 45 degrees, and arrow B at an angle less than 45 degrees. Both land at the same spot on the ground. Which arrow arrives first?
(A) arrow A arrives first (B) arrow B arrives first (C) they both arrive together
(D) it depends on the elevation where the arrows land

Questions 56-57

The accompanying graph describes the motion of a marble on a table top for 10 seconds.



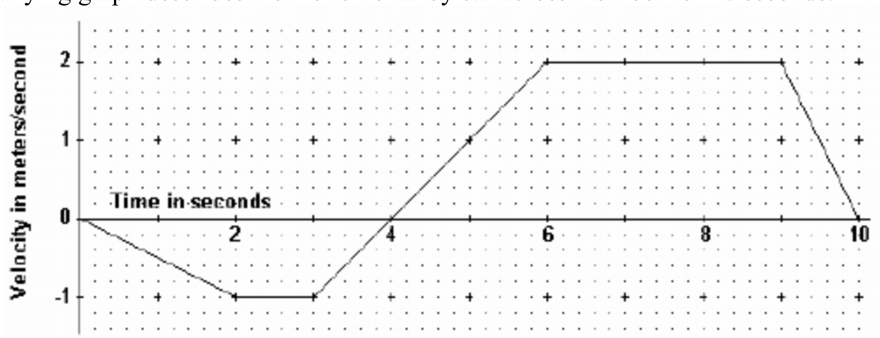
56. For which time interval(s) did the marble have a negative velocity?
(A) from t = 8.0 s to t = 10.0 s only (B) from t = 6.9 s to t = 10.0 s only
(C) from t = 4.8 s to t = 10.0 s only (D) from t = 4.8 s to t = 6.2 s and from t = 6.9 s to t = 10.0 s only

57. For which time interval(s) did the marble have a positive acceleration?
(A) from t = 0.0 s to t = 8.0 s only (B) from t = 0.0 s to t = 3.6 only
(C) from t = 3.8 s to t = 4.8 s and t = 6.2 s to t = 6.8 s only
(D) from t = 2.0 s to t = 2.5 s, from t = 5.8 s to t = 6.2 s, and from t = 8.4 s to t = 8.8 s only

58. What is the marbles average acceleration between $t = 3.1$ s and $t = 3.8$ s
(A) -2.0 m/s^2 (B) 0.8 m/s^2 (C) 2.0 m/s^2 (D) 3.0 m/s^2

Questions 59-60

The accompanying graph describes the motion of a toy car across the floor for 10 seconds.



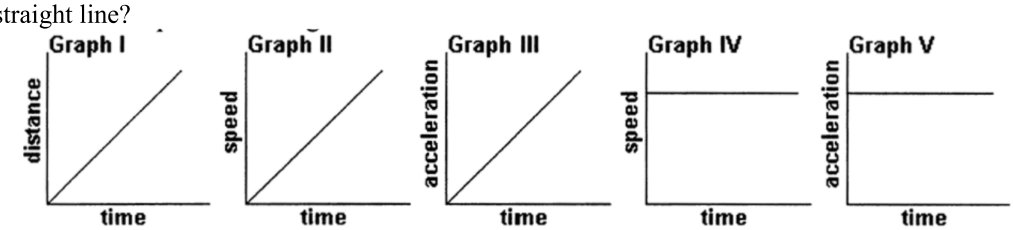
59. What is the acceleration of the toy car at $t = 4$ s?
(A) –1 m/s^2 (B) 0 m/s^2 (C) 1 m/s^2 (D) 2 m/s^2

60. What was the total displacement of the toy car for the entire 10 second interval shown?
(A) 0 meters (B) 6.5 meters (C) 9 meters (D) 10 meters

61. An object is thrown upwards with a velocity of 30 m/s near the surface of the earth. After two seconds what would be the direction of the displacement, velocity and acceleration?

	Displacement	velocity	acceleration
(A)	up	up	up
(B)	up	up	down
(C)	up	down	down
(D)	up	down	up

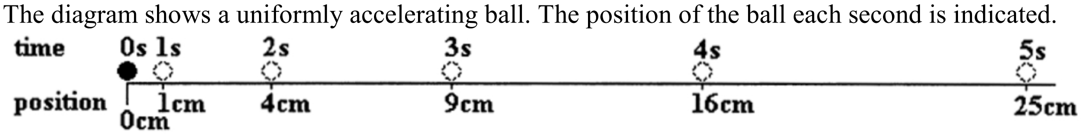
62. Which of the following graphs could correctly represent the motion of an object moving with a constant speed in a straight line?



(A) Graph I only (B) Graphs II and V only (C) Graph II only (D) Graphs I and IV only

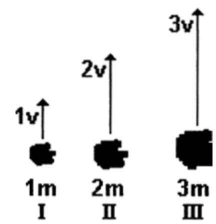
Questions 63-64

The diagram shows a uniformly accelerating ball. The position of the ball each second is indicated.



63. What is the average speed of the ball between 3 and 4 seconds?
(A) 3.0 cm/s (B) 7.0 cm/s (C) 3.5 cm/s (D) 12.5 cm/s

64. Which of the following is closest to the acceleration of the ball?
(A) 1 cm/s^2 (B) 4 cm/s^2 (C) 2 cm/s^2 (D) 5 cm/s^2



65. Three stones of different mass (1 *m, 2m* & *3m)* are thrown vertically upward with different velocities (l v, 2v & 3v respectively). The diagram indicates the mass and velocity of each stone. Rank from high to low the maximum height of each stone. Assume air resistance is negligible.
(A) I, II, III (B) II, I, III (C) III, II, I (D) I, III, II

66. A rubber ball bounces on the ground as shown. After each bounce, the ball reaches one-half the height of the bounce before it. If the time the ball was in the air between the first and second bounce was 1 second. What would be the time between the second and third bounce?
(A) 0.50 sec (B) 0.71 sec (C) 1.0 sec (D) 1.4 sec

67. The driver of a car makes an emergency stop by slamming on the car's brakes and skidding to a stop. How far would the car have skidded if it had been traveling twice as fast?
(A) 4 times as far (B) the same distance (C) 2 times as far (D)the mass of the car must be known

68. A snail is moving along a straight line. Its initial position is $x_0 = -5$ meters and it is moving away from the origin and slowing down. In this coordinate system, the signs of the initial position, initial velocity and acceleration, respectively, are

Choice	x_0	v_0	a
(A)	–	+	+
(B)	–	–	+
(C)	–	–	–
(D)	–	+	–

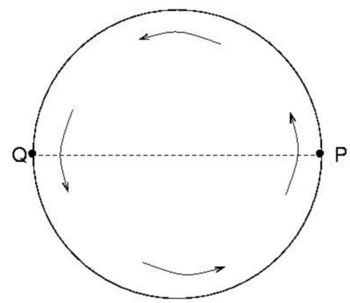
69. A rock is dropped from the top of a tall tower. Half a second later another rock, twice as massive as the first, is dropped. Ignoring air resistance,
(A) the distance between the rocks increases while both are falling.
(B) the acceleration is greater for the more massive rock.
(C) they strike the ground more than half a second apart.
(D) they strike the ground with the same kinetic energy.

70. A cart is initially moving at 0.5 m/s along a track. The cart comes to rest after traveling 1 m. The experiment is repeated on the same track, but now the cart is initially moving at 1 m/s. How far does the cart travel before coming to rest?
(A) 1 m (B) 2 m (C) 3 m (D) 4 m

71. During an interval of time, a tennis ball is moved so that the angle between the velocity and the acceleration of the ball is kept at a constant 120º. Which statement is true about the tennis ball during this interval of time?
(A) Its speed increases and it is changing its direction of travel.
(B) Its speed decreases and it is changing its direction of travel.
(C) Its speed remains constant, but it is changing its direction of travel.
(D) Its speed remains constant and it is not changing its direction of travel.

<u>Questions 72-73</u>

A particle continuously moves in a circular path at constant speed in a counterclockwise direction. Consider a time interval during which the particle moves along this circular path from point P to point Q. Point Q is exactly half-way around the circle from Point P.

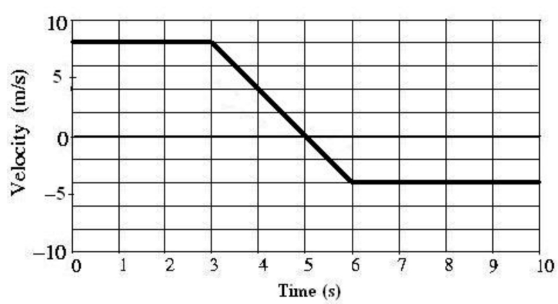


72. What is the direction of the average velocity during this time interval?
(A) → (B) ← (C) ↑ (D) The average velocity is zero.

73.What is the direction of the average acceleration during this time interval?
(A) → (B) ← (C) ↓ (D) The average acceleration is zero.

<u>Questions 74-75</u>

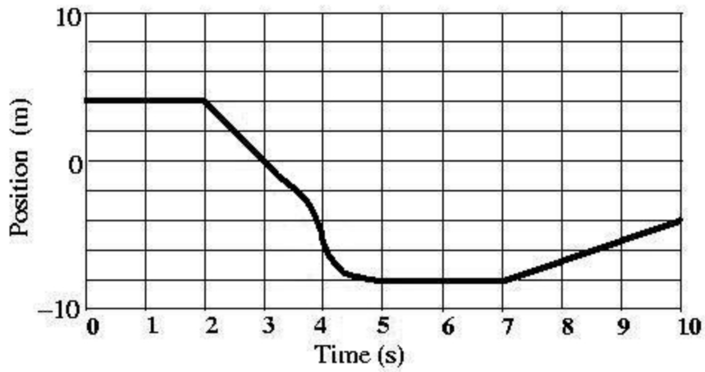
The velocity vs. time graph for the motion of a car on a straight track is shown in the diagram. The thick line represents the velocity. Assume that the car starts at the origin $x = 0$.



74. At which time is the car the greatest distance from the origin?
(A) t = 10 s (B) t = 5s (C) t = 3s (D) t = 0 s

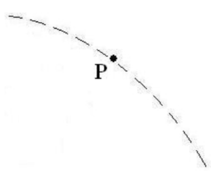
75. What is the average speed of the car for the 10 second interval?
(A) 1.20 m/s (B) 1.40 m/s (C) 3.30 m/s (D) 5.00 m/s

76. Consider the motion of an object given by the position vs. time graph shown. For what time(s) is the speed of the object greatest?



(A) At all times from $t = 0.0\ s \rightarrow t = 2.0\ s$ (B) At time $t = 3.0\ s$ (C) At time $t = 4.0\ s$ (D) At time $t = 8.5\ s$

77. The free fall trajectory of an object thrown horizontally from the top of a building is shown as the dashed line in the figure. Which sets of arrows best correspond to the directions of the velocity and of the acceleration for the object at the point labeled *P* on the trajectory?



	velocity	acceleration
(A)	↘	↓
(B)	→	↓
(C)	→	↖
(D)	↘	↙

78. A toy car moves 3.0 m to the North in one second. The car then moves at 9.0 m/s due South for two seconds. What is the average speed of the car for this three second trip?
(A) 4.0 m/s (B) 5.0 m/s (C) 6.0 m/s (D) 7 m/s

79. Two automobiles are 150 kilometers apart and traveling toward each other. One automobile is moving at 60 km/h and the other is moving at 40 km/h. In how many hours will they meet?
(A) 1.5 (B) 1.75 (C) 2.0 (D) 2.5

80. Is it possible for an object's velocity to increase while its acceleration decreases?
(A) No, because if acceleration is decreasing the object will be slowing down
(B) No, because velocity and acceleration must always be in the same direction
(C) Yes, an example would be a falling object near the surface of the moon
(D) Yes, an example would be a falling object in the presence of air resistance

<u>Questions 81-82</u>

During a recent winter storm, bales of hay had to be dropped from an airplane to a herd of cattle below. Assume the airplane flew horizontally at an altitude of 180 m with a constant velocity of 50 m/s and dropped one bale of hay every two seconds. It is reasonable to assume that air resistance will be negligible for this situation.

81. As the bales are falling through the air, what will happen to their distance of separation?
(A) the distance of separation will increase
(B) the distance of separation will decrease
(C) the distance of separation will remain constant
(D) the distance of separation will depend on the mass of the bales

82. About how far apart from each other will the bales land on the ground?
(A) 300 m (B) 180 m (C) 100 m (D) 50 m

AP Physics Free Response Practice – Kinematics

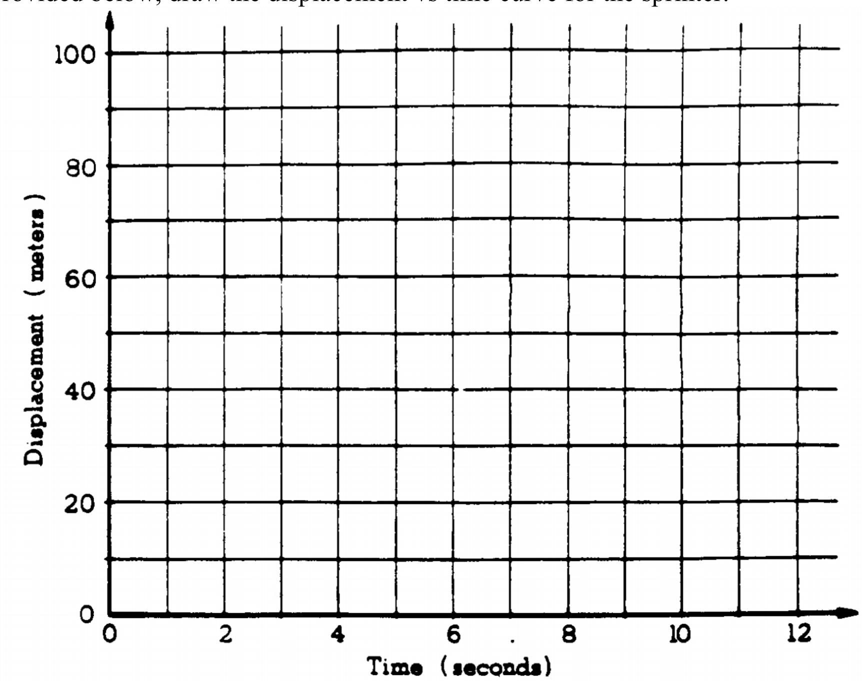
1982B1. The first meters of a 100-meter dash are covered in 2 seconds by a sprinter who starts from rest and accelerates with a constant acceleration. The remaining 90 meters are run with the same velocity the sprinter had after 2 seconds.

a. Determine the sprinter's constant acceleration during the first 2 seconds.

b. Determine the sprinters velocity after 2 seconds have elapsed.

c. Determine the total time needed to run the full 100 meters.

d. On the axes provided below, draw the displacement vs time curve for the sprinter.



2006B2. A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time t and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration a and an approximate value of t for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

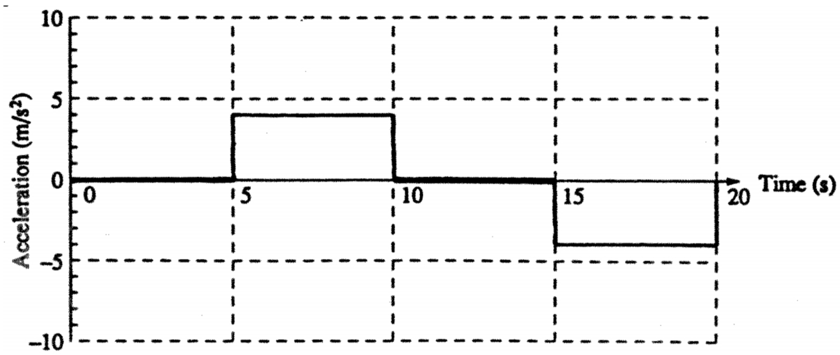
(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

____Stopwatches ____Tape measures ____ Rulers ____ Masking tape

____Metersticks ____ Starter's pistol ____ String ____ Chalk

(b) Outline the procedure that you would use to determine a and t, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).

(c) Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.

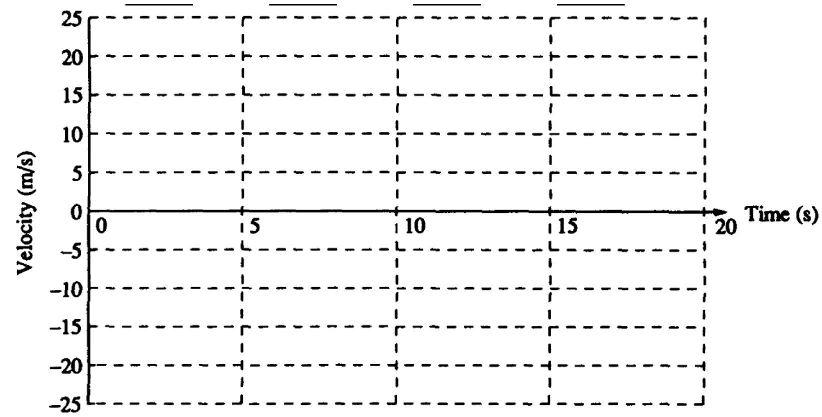


1993B1 (modified) A student stands in an elevator and records his acceleration as a function of time. The data are shown in the graph above. At time t = 0, the elevator is at displacement x = 0 with velocity v = 0. Assume that the positive directions for displacement, velocity, and acceleration are upward.

a. Determine the velocity v of the elevator at the end of each 5-second interval.

i. Indicate your results by completing the following table.

Time Interval (s)	0–5	5–10	10–15	15–20
v (m/s)	_____	_____	_____	_____



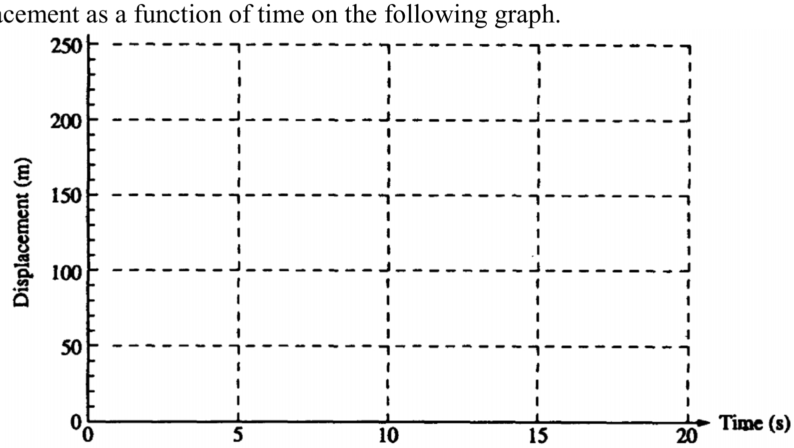
ii. Plot the velocity as a function of time on the following graph.

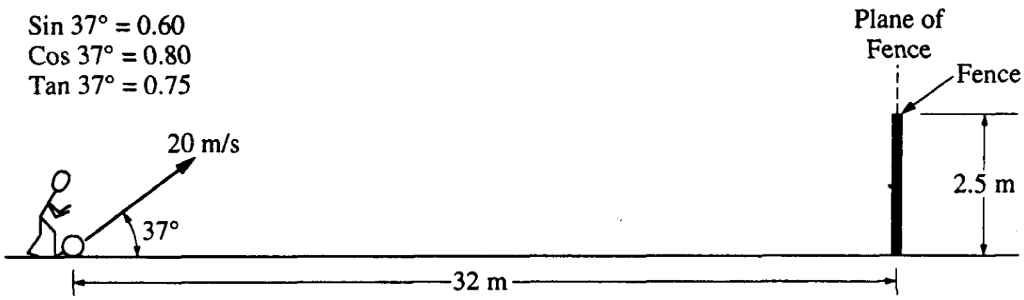
b. Determine the displacement x of the elevator above the starting point at the end of each 5-second interval.

i. Indicate your results by completing the following table.

Time Interval (s)	0–5	5–10	10–15	15–20
x (m)	_____	_____	_____	_____

ii. Plot the displacement as a function of time on the following graph.





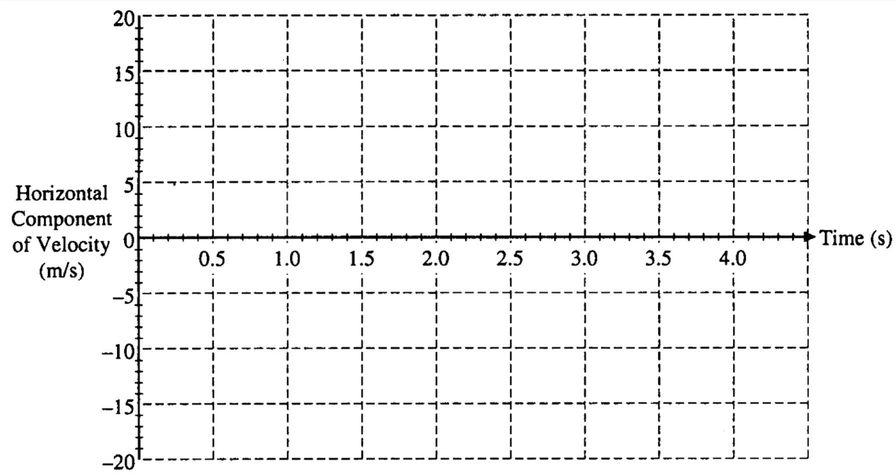
<u>Note</u>: Diagram not drawn to scale.

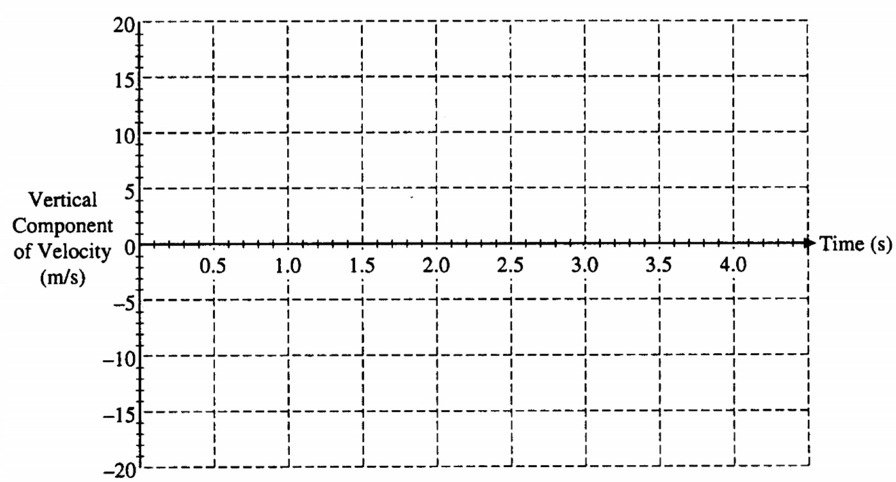
1994B1 (modified) A ball of mass 0.5 kilogram, initially at rest, is kicked directly toward a fence from a point 32 meters away, as shown above. The velocity of the ball as it leaves the kicker's foot is 20 meters per second at an angle of 37° above the horizontal. The top of the fence is 2.5 meters high. The ball hits nothing while in flight and air resistance is negligible.

a. Determine the time it takes for the ball to reach the plane of the fence.

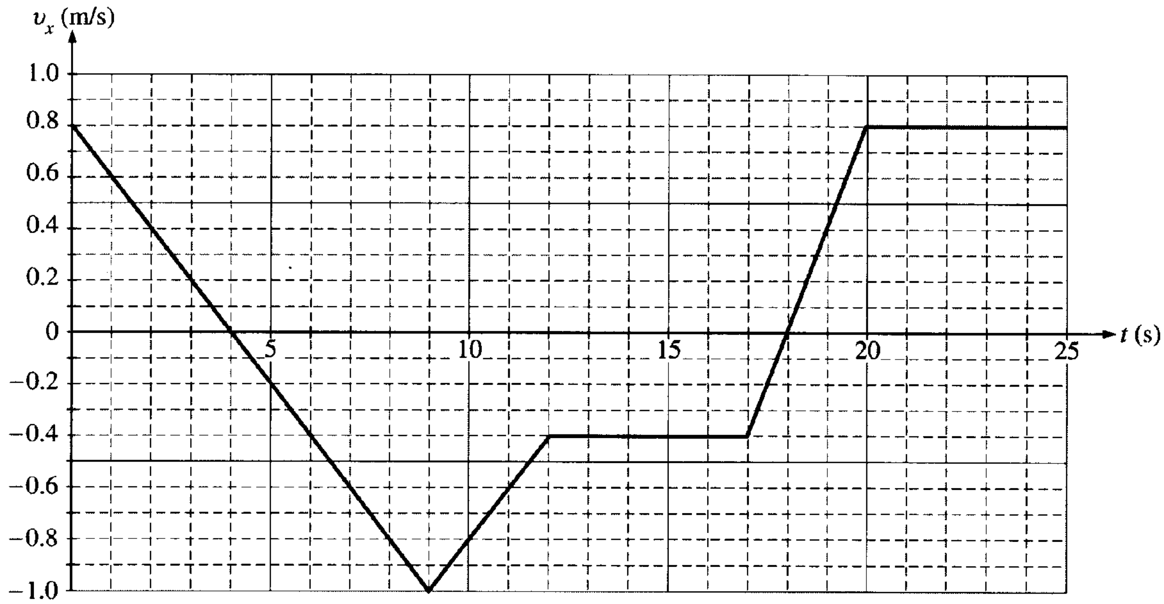
b. Will the ball hit the fence? If so, how far below the top of the fence will it hit? If not, how far above the top of the fence will it pass?

c. On the axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.





2000B1 (modified) A 0.50 kg cart moves on a straight horizontal track. The graph of velocity *v* versus time *t* for the cart is given below.

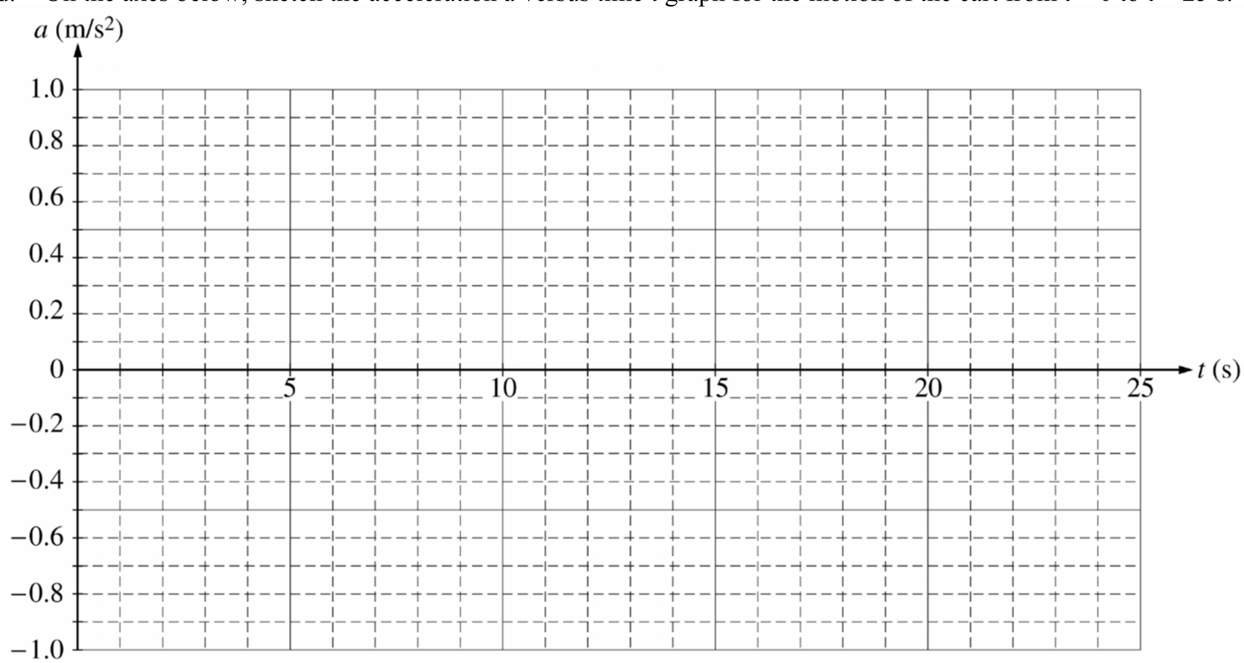


a. Indicate every time t for which the cart is at rest.

b. Indicate every time interval for which the speed (magnitude of velocity) of the cart is increasing.

c. Determine the horizontal position x of the cart at t = 9.0 s if the cart is located at x = 2.0 m at t = 0.

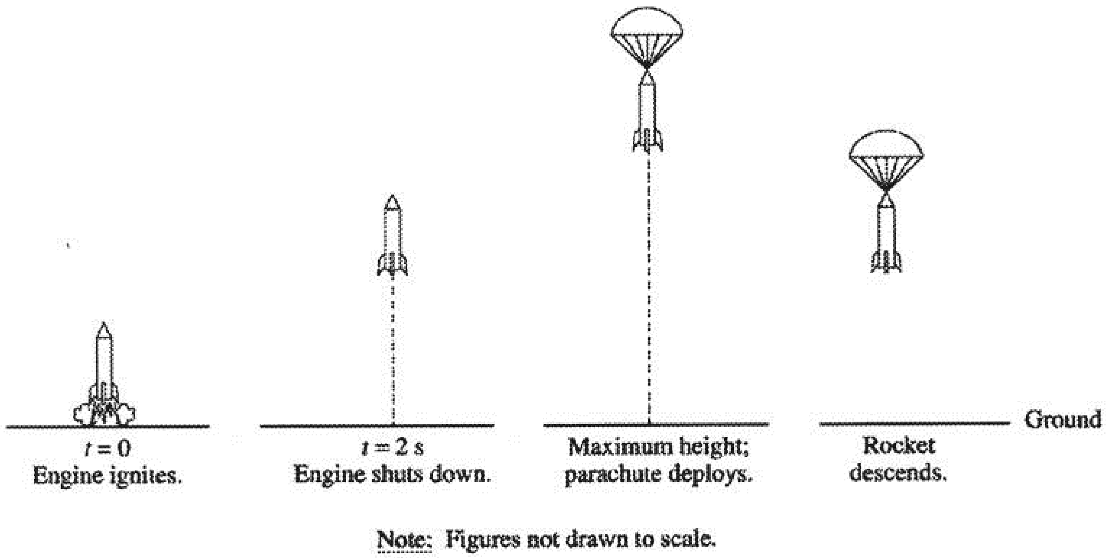
d. On the axes below, sketch the acceleration a versus time t graph for the motion of the cart from t = 0 to t = 25 s.



e. From t = 25 s until the cart reaches the end of the track, the cart continues with constant horizontal velocity. The cart leaves the end of the track and hits the floor, which is 0.40 m below the track. Neglecting air resistance, determine each of the following:

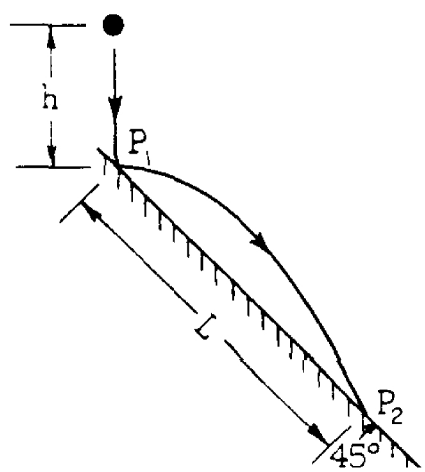
i. The time from when the cart leaves the track until it first hits the floor

ii. The horizontal distance from the end of the track to the point at which the cart first hits the floor



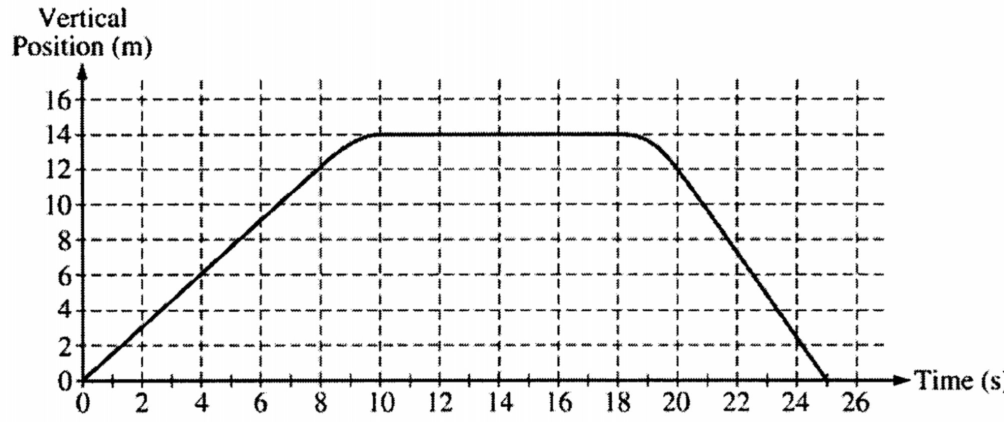
2002B1 (modified) A model rocket is launched vertically with an engine that is ignited at time t = 0, as shown above. The engine provides an upward acceleration of 30 m/s^2 for 2.0 s. Upon reaching its maximum height, the rocket deploys a parachute, and then descends vertically to the ground.

a. Determine the speed of the rocket after the 2 s firing of the engine.
b. What maximum height will the rocket reach?
c. At what time after t = 0 will the maximum height be reached?



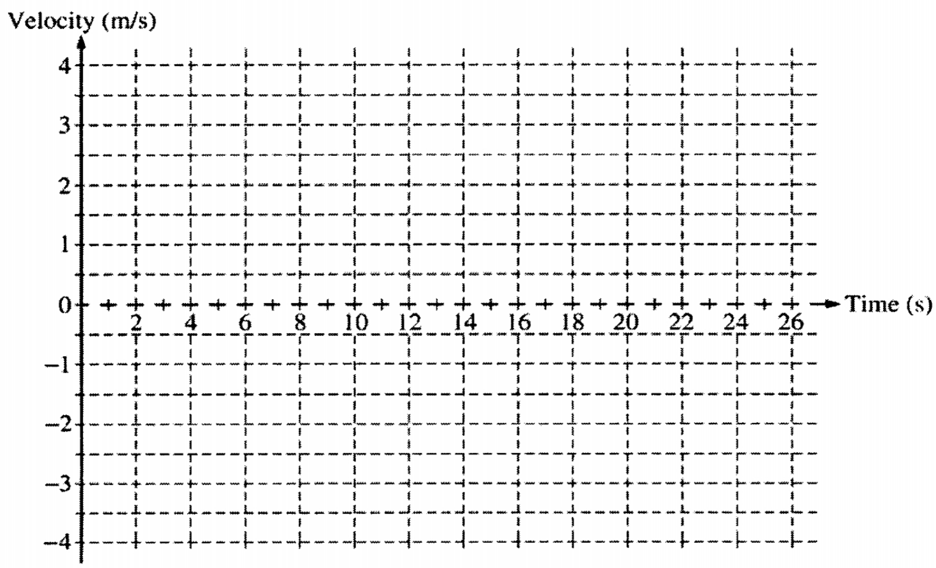
*1979M1 (modified) A ball of mass m is released from rest at a distance h above a frictionless plane inclined at an angle of 45° to the horizontal as shown above. The ball bounces horizontally off the plane at point P_1 with the same speed with which it struck the plane and strikes the plane again at point P_2. In terms of g and h determine each of the following quantities:

a. The speed of the ball just after it first bounces off the plane at P_1.
b. The time the ball is in flight between points P_1 and P_2.
c. The distance L along the plane from P_1 to P_2.
d. The speed of the ball just before it strikes the plane at P_2.

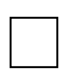


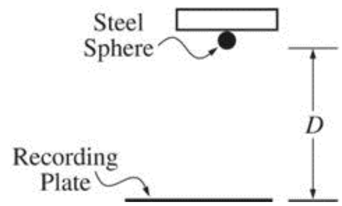
2005B1 (modified) The vertical position of an elevator as a function of time is shown above.

a. On the grid below, graph the velocity of the elevator as a function of time.



b. i. Calculate the average acceleration for the time period t = 8 s to t = 10 s.
ii. On the box below that represents the elevator, draw a vector to represent the direction of this average acceleration.

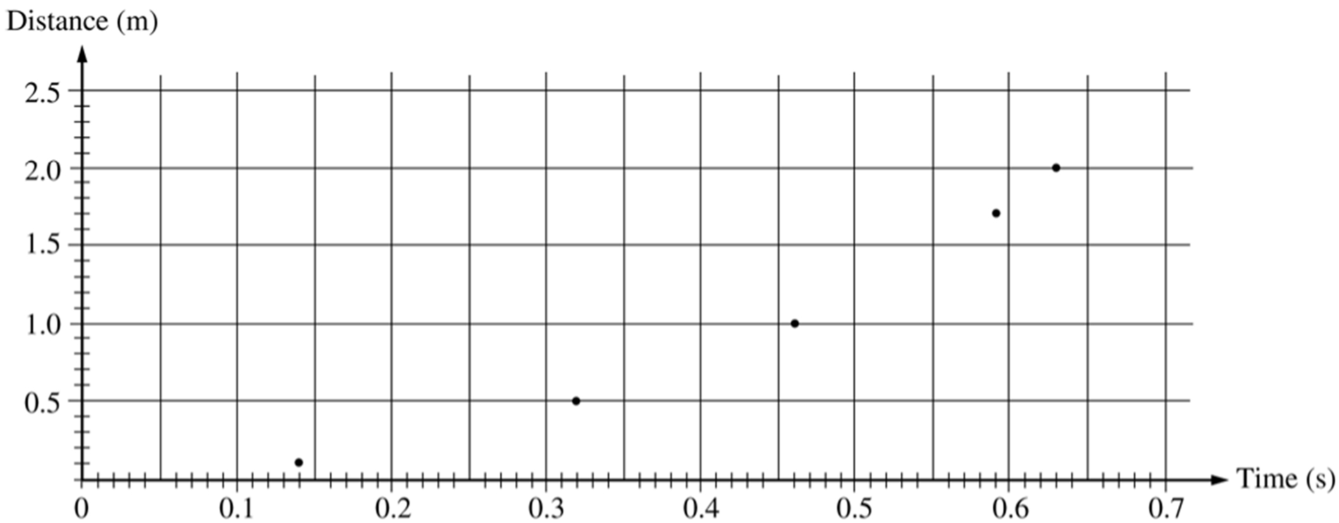




2006Bb1. A student wishing to determine experimentally the acceleration g due to gravity has an apparatus that holds a small steel sphere above a recording plate, as shown above. When the sphere is released, a timer automatically begins recording the time of fall. The timer automatically stops when the sphere strikes the recording plate.

The student measures the time of fall for different values of the distance D shown above and records the data in the table below. These data points are also plotted on the graph.

Distance of Fall (m)	0.10	0.50	1.00	1.70	2.00
Time of Fall (s)	0.14	0.32	0.46	0.59	0.63

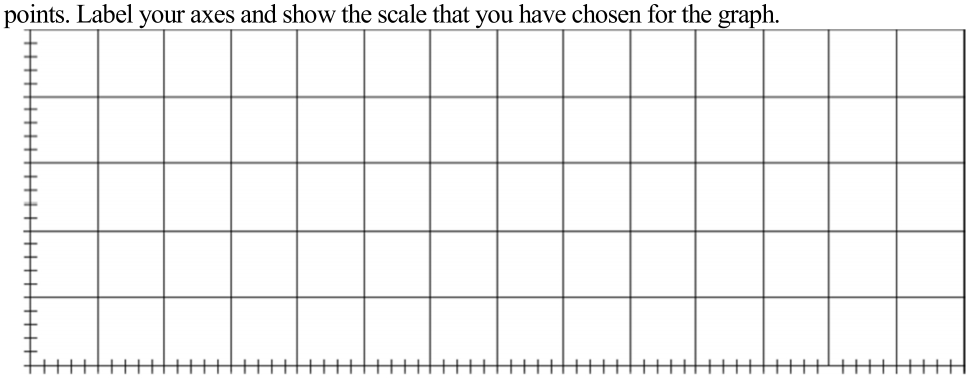


(a) On the grid above, sketch the smooth curve that best represents the student's data

The student can use these data for distance D and time t to produce a second graph from which the acceleration g due to gravity can be determined.

(b) If only the variables D and t are used, what quantities should the student graph in order to produce a linear relationship between the two quantities?

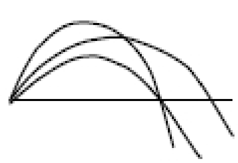
(c) On the grid below, plot the data points for the quantities you have identified in part (b), and sketch the best straight-line fit to the points. Label your axes and show the scale that you have chosen for the graph.



(d) Using the slope of your graph in part (c), calculate the acceleration g due to gravity in this experiment.

(e) State one way in which the student could improve the accuracy of the results if the experiment were to be performed again. Explain why this would improve the accuracy.

ANSWERS - AP Physics Multiple Choice Practice – Kinematics

	Solution	Answer
1.	Area bounded by the curve is the displacement By inspection of particle A the positive area between 0 and 1s will be countered by an equal negative area between 1 and 2s.	B
2.	Constant non-zero acceleration would be a straight line with a non-zero slope	D
3.	Area bounded by the curve is the displacement By inspection of particle A the positive area between 0 and 1s will be countered by an equal negative area between 1 and 2s.	A
4.	Area bounded by the curve is the displacement By inspection the negative area between 0 and 1s will be countered by an equal negative area sometime between 1 and 2s.	B
5.	Between 0 and 1 s; $d_1 = vt$; from 1 to 11 seconds; $d_2 = v_0t + ½ at^2$; $d = d_1 + d_2$	C
6.	The time in the air for a horizontal projectile is dependent on the height and independent of the initial speed. Since the time in the air is the same at speed v and at speed 2v, the distance (d = vt) will be twice as much at a speed of 2v	C
7.	The acceleration is constant and negative which means the slope of the velocity time graph must have a constant negative slope. (Only one choice has the correct acceleration anyway)	D
8.	At the top of its path, the vertical component of the velocity is zero, which makes the speed at the top a minimum. With symmetry, the projectile has the same speed when at the same height, whether moving up or down.	D
9.	g points down in projectile motion. Always.	D
10.	Average speed = total distance/total time = (8 m – 2 m)/(1 second)	D
11.	The area under the curve is the displacement. There is more area under the curve for Car X.	A
12.	Area under the curve is the displacement. Car Y is moving faster as they reach the same point.	B
13.	Uniformly accelerated means the speed-time graph should be a stright line with non-zero slope. The corresponding distance-time graph should have an increasing slope (curve upward)	D
14.	Acceleration is proportional to Δv. $\Delta v = v_2 - v_1 = v_2 + (-v_1)$	D
15.	horizontal velocity v_x remains the same thorughout the flight. g remains the same as well.	D
16.	A velocity-time graph represents the *slope* of the displacement-time graph. Analyzing the v-t graph shows an increasing slope, then a constant slope, then a decreasing slope (to zero)	D
17.	For a horizontal projectile, the initial speed does not affect the time in the air. Use $v_{0y} = 0$ with 10 m = $½ gt^2$ to get $t = \sqrt{2}$ For the horzontal part of the motion; v = d/t	C
18.	A velocity-time graph represents the *slope* of the displacement-time graph. Analyzing the v-t graph shows a constant slope, then a decreasing slope to zero, becoming negative and increasing, then a constant slope. Note this is an analysis of the *values* of v, not the slope of the graph itself	A
19.	By process of elimination (A and B are unrealistic; C is wrong, air resistance should decrease the acceleration)	D
20.	 The 45° angle gives the maximum horizontal travel to the original elevation, but the smaller angle causes the projectile to have a greater horizontal component of velocity, so given the additional time of travel allows such a trajectory to advance a greater horizontal distance. In other words given enough time the smaller angle of launch gives a parabola which will eventual cross the parabola of the 45° launch.	C

21. The area under the curve of an acceleration-time graph is the change in speed. D

22. The slope of the line represents her velocity. Beginning positive and constant, going to zero, then positive and larger than the initial, then negative while the line returns to the time axis B

23. Positive acceleration is an increasing slope (including negative slope increasing toward zero) or upward curvature C

24. Positive acceleration is an increasing slope (including negative slope increasing toward zero) or upward curvature C

25. With air resistance, the acceleration (the slope of the curve) will decrease toward zero as the ball reached terminal velocity. Note: without air resistance, choice (A) would be correct C

26. Since for the first 4 seconds, the car is accelerating positively the entire time, the car will be moving fastest just beofre slowing down after t = 4 seconds. C

27. The area under the curve represents the change in velocity. The car begins from rest with an increasing positive velocity, after 4 seconds the car begins to slow and the area under the curve from 4 to 8 seconds couters the increase in velocity form 0 to 4 seconds, bringing the car to rest. However, the car never changed direction and was moving away from its original starting position the entire time. D

28. The velocity-time graph should represent the slope of the position-time graph and the acceleration-time graph should represent the slope of the velocity-time graph C

29. It's a surprising result, but while both the horizontal and vertical components change at a given height with varying launch angle, the *speed* $(v_x^2 + v_y^2)^{1/2}$ will be independent of α (try it!) C

30. Instantaneous velocity is the slope of the line at that point A

31. Displacement is the area under the curve. Maximum displacement is just before the car turns around at 2.5 seconds. C

32. From the equation $d = \frac{1}{2} at^2$, displacement is proportional to time squared. Traveling from rest for twice the time gives 4 times the displacement (or 4 h). Since the object already travelled h in the first second, during the time interval from 1 s to 2 s the object travelled the remaining 3h C

33. Looking at choices A and D eliminates the possibility of choices B and C (each ball increases its speed by 9.8 m/s each second, negating those choices anyway). Since ball A is moving faster than ball B at all times, it will continue to pull away from ball B (the relative speed between the balls separates them). D

34. Since they all have the same horizontal component of the shell's velocity, the shell that spends the longest time in the air will travel the farthest. That is the shell launched at the largest angle (mass is irrelevant). D

35. Since (from rest) $d = \frac{1}{2} gt^2$, distance is proportional to time squared. An object falling for twice the time will fall four times the distance. D

36. $\bar{v} = \dfrac{v_i + v_f}{2} = \dfrac{d}{t}$ A

37. For a horizontal projectile ($v_{iy} = 0$ m/s) to fall 0.05 m takes (using $0.05 \text{ m} = \frac{1}{2} gt^2$) 0.1 seconds. To travel 20 m in this time requires a speed of d/t = (20 m)/(0.1 s) D

38. Once released, the package is in free-fall (subject to gravity only) D

39. To reach a speed of 30 m/s when dropped takes (using $v = at$) about 3 seconds. The distance fallen after three seconds is found using $d = \frac{1}{2} at^2$ C

40. Falling on the Moon is no different conceptually than falling on the Earth B

41. Since the line is above the t axis for the entire flight, the duck is always moving in the positive (forward) direction, until it stops at point D — D

42. One could analyze the graphs based on slope, but more simply, the graph of position versus time should represent the actual path followed by the ball as seen on a platform moving past you at constant speed. — C

43. Other than the falling portions ($a = -9.8\ m/s^2$) the ball should have a "spike" in the acceleration when it bounces due to the rapid change of velocity from downward to upward. — B

44. The same average speed would be indicated by the same distance traveled in the time interval — C

45. Average speed = (total distance)/(total time). Cars #2 and #3 travelled the same distance. — A

46. If you look at the distance covered in each time interval you should nitce a pattern: 2 m, 6 m, 10 m, 14 m, 18 m; making the distance in the next second 22 m. — C

47. Instantaneous speed is the slope of the line at that point. — B

48. A non-zero accleeration is inidcated by a curve in the line — D

49. Maximum height of a projectile is found from $v_y = 0$ m/s at max height and $(0\ m/s)^2 = v^2 + 2gh$ and gives $h = v^2/2g$. At twice the initial speed, the height will be 4 times as much — C

50. $d = \frac{1}{2} at^2$ (use any point) — D

51. $v = v_i + at$ — B

52. Acceleration is the slope of the line segment — C

53. Displacement is the area under the line — D

54. In a vacuum, there is no air resistance and hence no terminal velocity. It will continue to accelerate. — D

55. A projectile launched at a smaller angle does not go as high and will fall to the ground first. — B

56. Velocity is the slope of the line. — D

57. Positive acceleration is an upward curvature — D

58. Average acceleration = $\Delta v/\Delta t$ — A

59. Acceleration is the slope of the line segment — C

60. Displacement is the area between the line and the t-axis. Area is negative when the line is below the t-axis. — B

61. After two seconds, the object would be above it's original position, still moving upward, but the acceleration due to gravity is always pointing down — B

62. Constant speed is a constant slope on a position-time graph, a horizontal line on a velocity time graph or a zero value on an acceleration-time graph — D

63. Average speed = total distance divided by total time = (7 cm)/(1 s) — B

64. $d = \frac{1}{2} at^2$ (use any point) — C

65. Maximum height of a projectile is found from $v_y = 0$ m/s at max height and $(0\ m/s)^2 = v^2 + 2gh$ and gives $h = v^2/2g$. Mass is irrelevant. Largest initial speed = highest. — C

66. Using $d = \frac{1}{2} at^2$ shows the height is proportional to the time squared. ½ the maximum height is $\frac{1}{\sqrt{2}}$ times the time. — B

67. Stopping distance is found using $v_f = 0 = v_i^2 + 2ad$ which gives $d = v_i^2/2a$ where stopping distance is proportional to initial speed squared. A

68. Moving away from the origin will maintain a negative position and velocity. Slowing down indicates the acceleration is opposite in direction to the velocity. B

69. Since the first rock is always traveling faster, the relative distance between them is always increasing. A

70. Stopping distance is found using $v_f = 0 = v_i^2 + 2ad$ which gives $d = v_i^2/2a$ where stopping distance is proportional to initial speed squared. B

71. At an angle of 120º, there is a component of the acceleration perpendicular to the velocity causing the direction to change and a component in the opposite direction of the velocity, causing it to slow down. B

72. The displacement is directly to the left. The average velocity is proportional to the displacement B

73. The velocity is initially pointing up, the final velocity points down. The acceleration is in the same direction as $\Delta v = v_f + (-v_i)$ C

74. The car is the greatest distance just before it reverses direction at 5 seconds. B

75. Average speed = (total *distance*)/(total time), the total distance is the magnitude of the area under the line (the area below the t-axis is considered positive) D

76. Speed is the slope of the line. C

77. Velocity is pointing tangent to the path, acceleration (gravity) is downward. A

78. Average speed = (total *distance*)/(total time) D

79. The relative speed between the two cars is $v_1 - v_2 = (60\text{ km/h}) - (-40\text{ km/h}) = 100\text{ km/h}$. They will meet in $t = d/v_{relative} = 150\text{ km}/100\text{ km/h}$ A

80. Acceleration is independent of velocity (you can accelerate in any direction while traveling in a ny direction). If the accleration is in the same direction as the velocity, the object is speeding up. D

81. As the first bales dropped will always be traveling faster than the later bales, their relative velocity will cause their separation to always iincrease. A

82. Horizontally, the bales will all travel at the speed of the plane, as gravity will not affect their horizontal motion. $D = vt = (50\text{ m/s})(2\text{ seconds apart})$ C

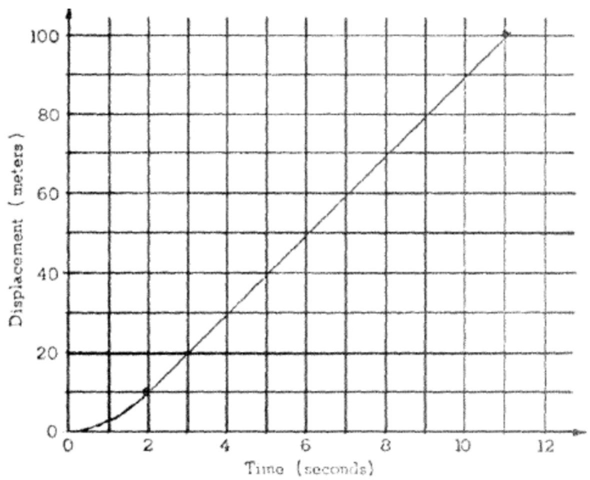
1982B1

a. For the first 2 seconds, while acceleration is constant, d = ½ at^2
Substituting the given values d = 10 meters, t = 2 seconds gives a = 5 m/s^2

b. The velocity after accelerating from rest for 2 seconds is given by v = at, so v = 10 m/s

c. The displacement, time, and constant velocity for the last 90 meters are related by d = vt.
To cover this distance takes t = d/v = 9 s. The total time is therefore 9 + 2 = 11 seconds

d.



2006B2

Two general approaches were used by most of the students.
Approach A: Spread the students out every 10 meters or so. The students each start their stopwatches as the runner starts and measure the time for the runner to reach their positions.

Analysis variant 1: Make a position vs. time graph. Fit the parabolic and linear parts of the graph and establish the position and time at which the parabola makes the transition to the straight line.
Analysis variant 2: Use the position and time measurements to determine a series of average velocities (v_{avg} = $\Delta x/\Delta t$) for the intervals. Graph these velocities vs. time to obtain a horizontal line and a line with positive slope. Establish the position and time at which the sloped and horizontal lines intersect.
Analysis variant 3: Use the position and time measurements to determine a series of average accelerations ($\Delta x = v_0 t + \frac{1}{2} at^2$. Graph these accelerations vs. time to obtain two horizontal lines, one with a nonzero value and one at zero acceleration. Establish the position and time at which the acceleration drops to zero.

Approach B: Concentrate the students at intervals at the end of the run, in order to get a very precise value of the constant speed v_f, or at the beginning in order to get a precise value for a. The total distance D is given by $a = \frac{1}{2} a t_u^2 + v_f(T - t_u)$, where T is the total measured run time. In addition $v_f = a t_u$ These equations can be solved for a and t_u (if v_f is measured directly) or v_f and t_u (if a is measured directly). Students may have also defined and used distances, speeds, and times for the accelerated and constant-speed portions of the run in deriving these relationships.

1993B1

a. i. Use the kinematic equation applicable for constant acceleration: $v = v_0 + at$. For each time interval, substitute the initial velocity for that interval, the appropriate acceleration from the graph and a time of 5 seconds.

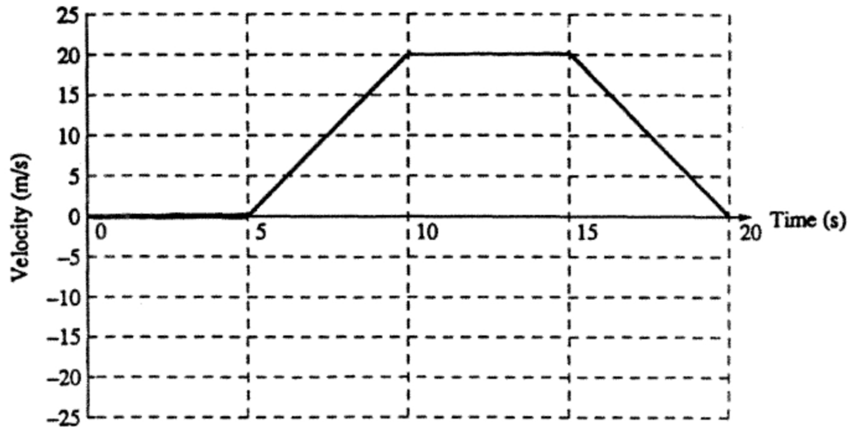
5 seconds: $v = 0 + (0)(5\text{ s}) = 0$

10 seconds: $v = 0 + (4\text{ m/s}^2)(5\text{ s}) = 20\text{ m/s}$

15 seconds: $v = 20\text{ m/s} + (0)(5\text{ s}) = 20\text{ m/s}$

20 seconds: $v = 20\text{ m/s} + (-4\text{ m/s}^2)(5\text{ s}) = 0$

ii.



b. i. Use the kinematic equation applicable for constant acceleration, $x = x_0 + v_0t + \frac{1}{2}at^2$. For each time interval, substitute the initial position for that interval, the initial velocity for that interval from part (a), the appropriate acceleration, and a time of 5 seconds.

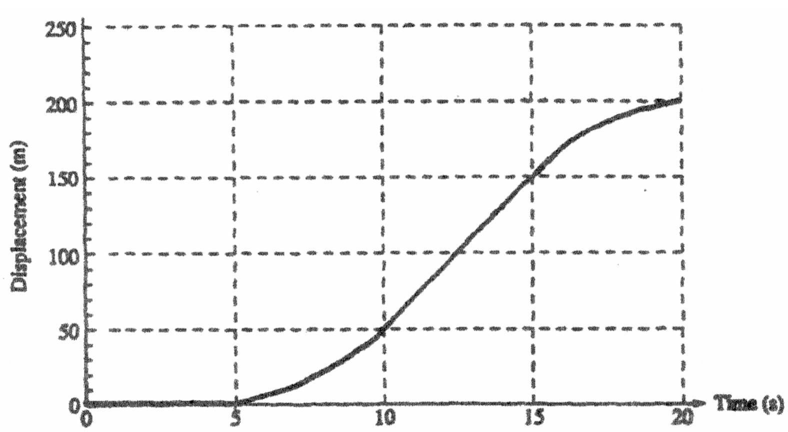
5 seconds: $x = 0 + (0)(5\text{ s}) + \frac{1}{2}(0)(5\text{ s})^2 = 0$

10 seconds: $x = 0 + (0)(5\text{ s}) + \frac{1}{2}(4\text{ m/s}^2)(5\text{ s})^2 = 50\text{ m}$

15 seconds: $x = 50\text{ m} + (20\text{ m/s})(5\text{ s}) + \frac{1}{2}(0)(5\text{ s})^2 = 150\text{ m}$

20 seconds: $x = 150\text{ m} + (20\text{ m/s})(5\text{ s}) + \frac{1}{2}(-4\text{ m/s}^2)(5\text{ s})^2 = 200\text{ m}$

ii.

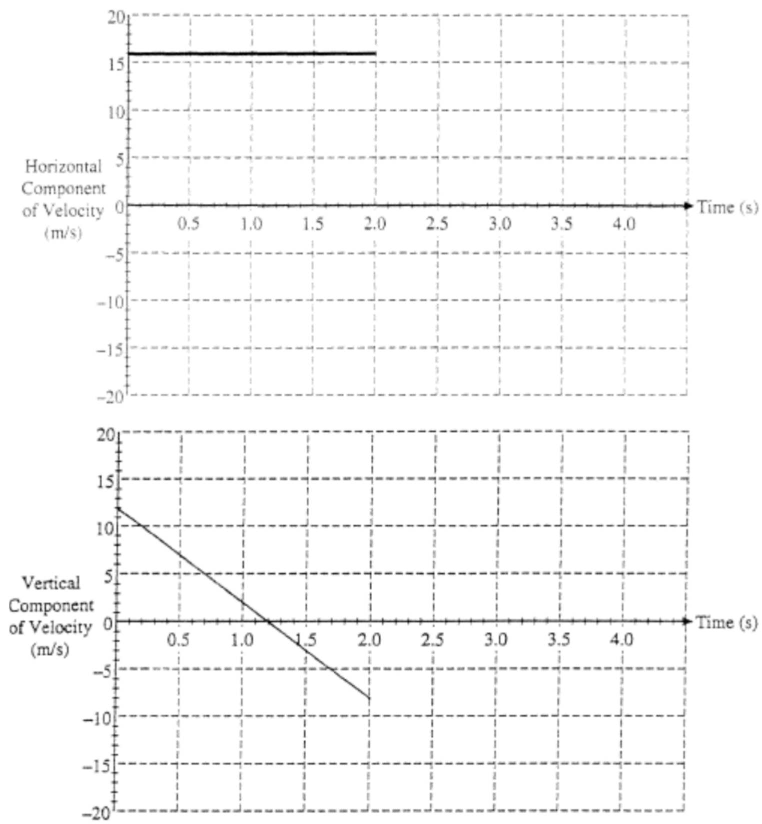


1994B1

a. The horizontal component of the velocity is constant so $v_x t = d$ where $v_x = v_0 \cos\theta = 16$ m/s
$t = d/v = 2$ s

b. The height of the ball during its flight is given by $y = v_{0y}t + \frac{1}{2}gt^2$ where $v_{0y} = v_0 \sin\theta = 12$ m/s and $g = -9.8$ m/s^2 which gives at $t = 2$ s, $y = 4.4$ m. The fence is 2.5 m high so the ball passes above the fence by 4.4 m – 2.5 m = 1.9 m

c.

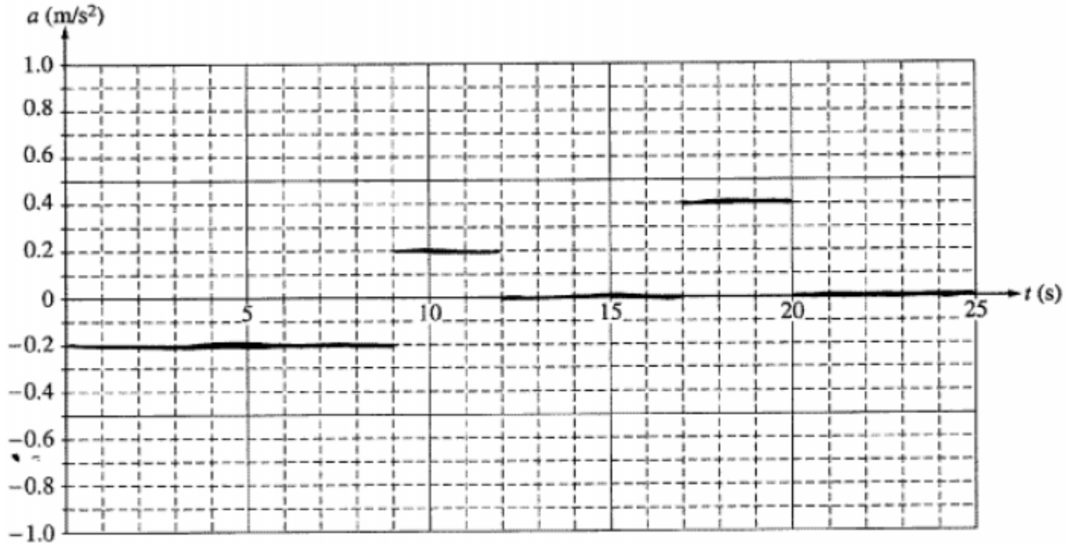


2000B1

a. The car is at rest where the line crosses the t axis. At t = 4 s and 18 s.

b. The speed of the cart increases when the line moves away from the t axis (larger values of v, positive or negative). This occurs during the intervals t = 4 to 9 seconds and t = 18 to 20 seconds.

c. The change in position is equal to the area under the graph. From 0 to 4 seconds the area is positive and from 4 to 9 seconds the area is negative. The total area is –0.9 m. Adding this to the initial position gives $x = x_0 + \Delta x = 2.0\text{ m} + (-0.9\text{ m}) = 1.1$ m d.



e. i. $y = \frac{1}{2}gt^2$ ($v_{0y} = 0$ m/s) gives t = 0.28 seconds.
   ii. $x = v_xt = 0.22$ m

2002B1

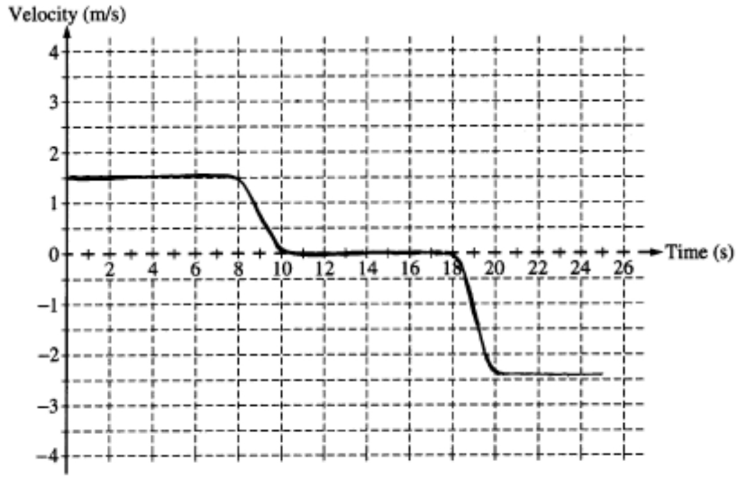
a. $v_1 = v_0 + at = 60$ m/s
b. The height of the rocket when the engine stops firing $y_1 = \frac{1}{2}at^2 = 60$ m
   To determine the extra height after the firing stops, use $v_f^2 = 0$ m/s $= v_1^2 + 2(-g)y_2$ giving $y_2 = 180$ m
   total height $= y_1 + y_2 = 240$ m
c. To determine the time of travel from when the engine stops firing use $v_f = 0$ m/s $= v_1 + (-g)t_2$ giving $t_2 = 6$ s.
   The total time is then 2 s + 6 s = 8 seconds

1979M1

a. The speed after falling a height h is found from $v_f^2 = v_i^2 + 2gh$, where $v_i = 0$ m/s giving $v_f = \sqrt{2gh}$
b/c. During the flight from P_1 to P_2 the ball maintains a horizontal speed of $\sqrt{2gh}$ and travels a horizontal distance of $\frac{L}{\sqrt{2}}$ thus (using d = vt) we have $\frac{L}{\sqrt{2}} = \sqrt{2gh}\,t$. During the same time t the ball travels the same distance vertically given by $\frac{L}{\sqrt{2}} = \frac{1}{2}gt^2$. Setting these expressions equal gives us $\sqrt{2gh}\,t = \frac{1}{2}gt^2$. Solving for t and substituting into the expression of L gives $t = \sqrt{8h/g}$ and $L = 4\sqrt{2}h$
d. During the flight from P_1 to P_2 the ball maintains a horizontal speed of $\sqrt{2gh}$ and the vertical speed at P_2 can be found from $v_y = v_i + at$ where $v_i = 0$, a = g and t is the time found above. Once v_x and v_y are known the speed is $\sqrt{v_x^2 + v_y^2}$ giving $v = \sqrt{10gh}$

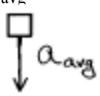
2005B1

a.



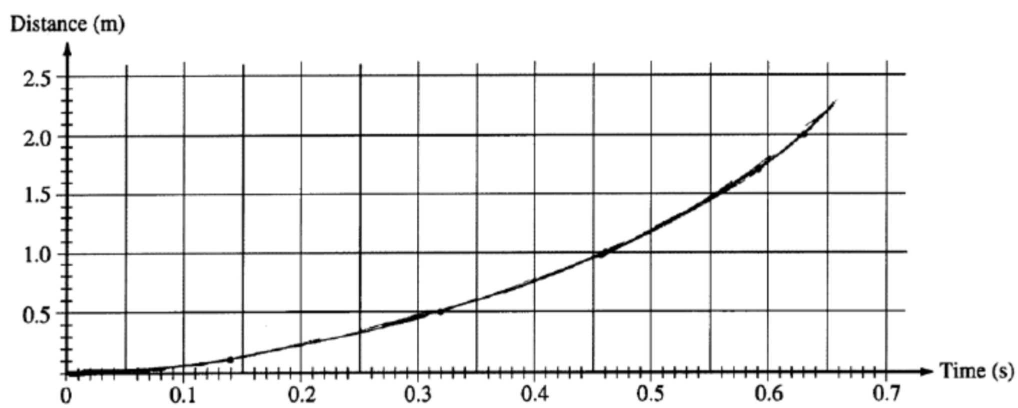
b. i. $a_{avg} = \Delta v/\Delta t = (0 - 1.5\text{ m/s})/(2\text{ s}) = -0.75\text{ m/s}^2$

ii.



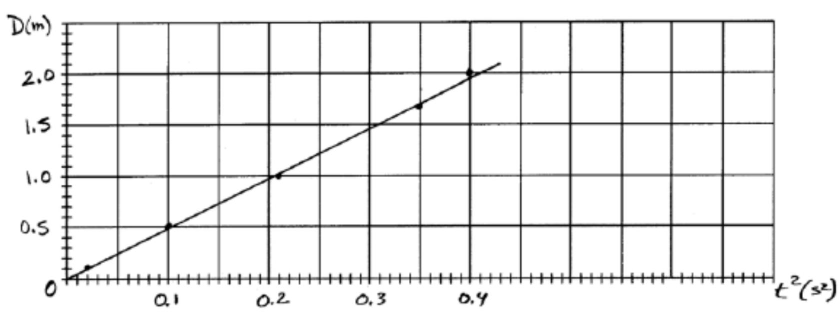
2006Bb1

a.



b. Distance and time are related by the equation $D = \frac{1}{2} gt^2$. To yield a straight line, the quantities that should be graphed are D and t^2 or $\sqrt{D}$ and t.

c.

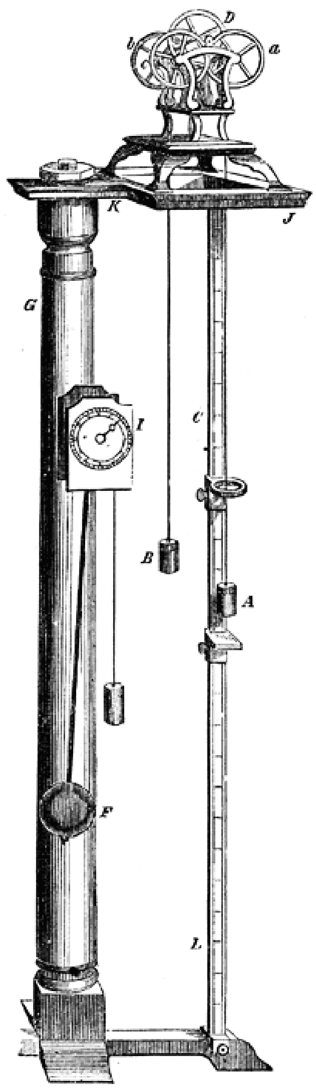


d. The slope of the graph of D vs. t^2 is ½ g. The slope of the line shown is 4.9 m/s^2 giving g = 9.8 m/s^2

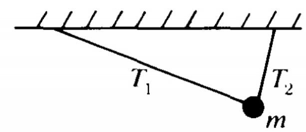
e. (example) Do several trials for each value of *D* and take averages. This reduces personal and random error.

Chapter 2

Dynamics

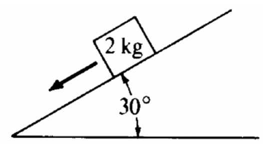


SECTION A – Linear Dynamics



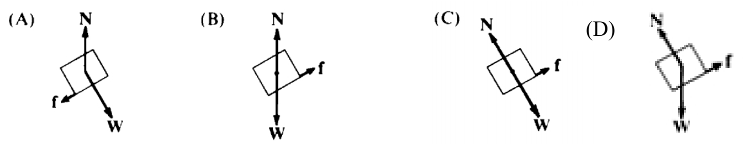
1. A ball of mass m is suspended from two strings of unequal length as shown above. The magnitudes of the tensions T_1 and T_2 in the strings must satisfy which of the following relations?
(A) $T_1 = T_2$ (B) $T_1 > T_2$ (C) $T_1 < T_2$ (D) $T_1 + T_2 = mg$

Questions 2 – 3

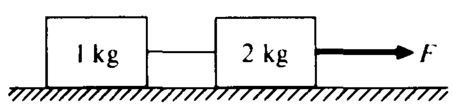


A 2-kg block slides down a 30° incline as shown above with an acceleration of 2 m/s^2.

2. Which of the following diagrams best represents the gravitational force W. the frictional force f, and the normal force N that act on the block?

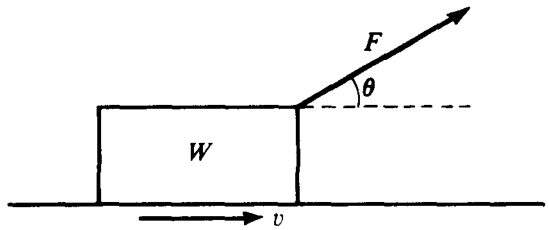


3. Which of the following correctly indicates the magnitudes of the forces acting up and down the incline?
   (A) 20 N down the plane, 16 N up the plane
   (B) 4 N down the plane, 4 N up the plane
   (C) 0 N down the plane, 4 N up the plane
   (D) 10 N down the plane, 6 N up the plane

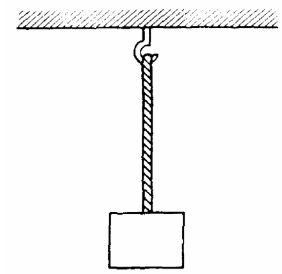


4. When the frictionless system shown above is accelerated by an applied force of magnitude the tension in the string between the blocks is (A) F (B) 2/3 F (C) ½ F (D) 1/3 F

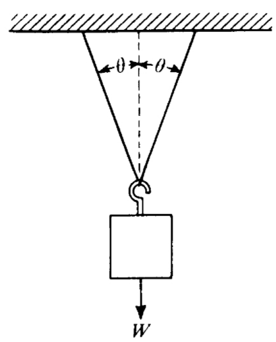
5. A ball falls straight down through the air under the influence of gravity. There is a retarding force F on the ball with magnitude given by F = bv, where v is the speed of the ball and b is a positive constant. The ball reaches a terminal velocity after a time t. The magnitude of the acceleration at time $t/2$ is
   (A) Increasing
   (B) Decreasing
   (C) 10 m/s/s
   (D) Zero



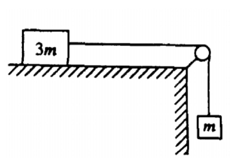
6. A block of weight W is pulled along a horizontal surface at constant speed v by a force F, which acts at an angle of θ with the horizontal, as shown above. The normal force exerted on the block by the surface has magnitude
   (A) greater than W
   (B) greater than zero but less than W
   (C) equal to W
   (D) zero



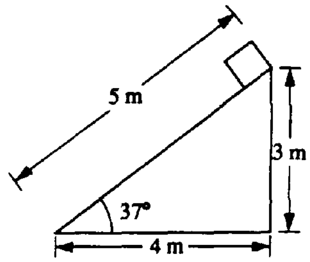
7. A uniform rope of weight 50 N hangs from a hook as shown above. A box of weight 100 N hangs from the rope. What is the tension in the rope?
   (A) 75 N throughout the rope (B) 100 N throughout the rope
   (C) 150 N throughout the rope (D) It varies from 100 N at the bottom of the rope to 150 N at the top.



8. When an object of weight W is suspended from the center of a massless string as shown above, the tension at any point in the string is
   (A) 2Wcosθ (B) ½Wcosθ (D) W/(2cosθ) (E) W/(cosθ)



9. A block of mass 3m can move without friction on a horizontal table. This block is attached to another block of mass m by a cord that passes over a frictionless pulley, as shown above. If the masses of the cord and the pulley are negligible, what is the magnitude of the acceleration of the descending block?
   (A) g/4 (B) g/3 (C) 2g/3 (D) g

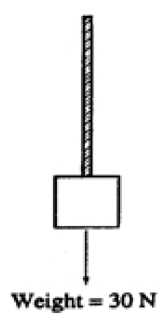


A plane 5 meters in length is inclined at an angle of 37°, as shown above. A block of weight 20 N is placed at the top of the plane and allowed to slide down.

10. The magnitude of the normal force exerted on the block by the plane is
    (A) greater than 20 N
    (B) greater than zero but less than 20 N
    (C) equal to 20 N
    (D) zero

11. **Multiple correct:** Three forces act on an object. If the object is moving to the right in translational equilibrium, which of the following must be true? Select two answers.
    (A) The vector sum of the three forces must equal zero.
    (B) All three forces must be parallel.
    (C) The magnitudes of the three forces must be equal.
    (D) The object must be moving at a constant speed.

12. For which of the following motions of an object must the acceleration always be zero?
    (A) Any motion in a straight line
    (B) Simple harmonic motion
    (C) Any motion at constant speed
    (D) Any single object in motion with constant momentum



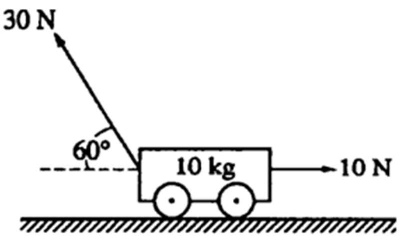
13. A rope of negligible mass supports a block that weighs 30 N, as shown above. The breaking strength of the rope is 50 N. The largest acceleration that can be given to the block by pulling up on it with the rope without breaking the rope is most nearly
    (A) 6.7 m/s^2 (B) 10 m/s^2 (C) 16.7 m/s^2 (D) 26.7 m/s^2

<u>Questions 14-15</u>

A horizontal, uniform board of weight 125 N and length 4 m is supported by vertical chains at each end. A person weighing 500 N is hanging from the board. The tension in the right chain is 250 N.

14. What is the tension in the left chain?
    (A) 125 N (B) 250 N (C) 375 N (D) 625 N

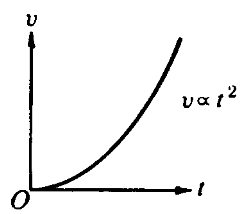
15. Which of the following describes where the person is hanging?
    (A) between the chains, but closer to the left-hand chain
    (B) between the chains, but closer to the right-hand chain
    (C) Right in the middle of the board
    (D) directly below one of the chains



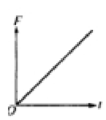
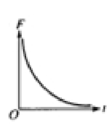
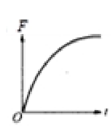
16. **Multiple correct:** The cart of mass 10 kg shown above moves without frictional loss on a level table. A 10 N force pulls on the cart horizontally to the right. At the same time, a 30 N force at an angle of 60° above the horizontal pulls on the cart to the left. Which of the following describes a manner in which this cart could be moving? Select two answers.

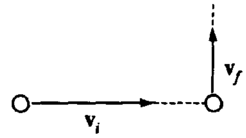
    (A) moving left and speeding up
    (B) moving left and slowing down
    (C) moving right and speeding up
    (D) moving right and slowing down

17. Two people are pulling on the ends of a rope. Each person pulls with a force of 100 N. The tension in the rope is:
    (A) 0 N (B) 50 N (C) 100 N (D) 200 N

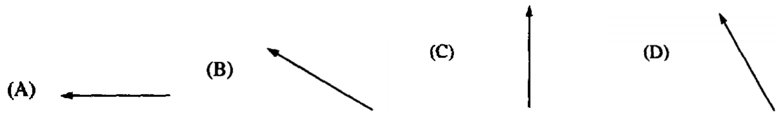


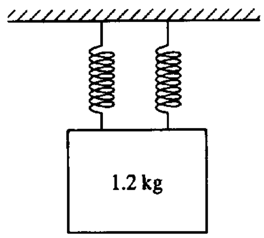
18. The parabola above is a graph of speed v as a function of time t for an object. Which of the following graphs best represents the magnitude F of the net force exerted on the object as a function of time t?

(A)  (B)  (C)  (D) 

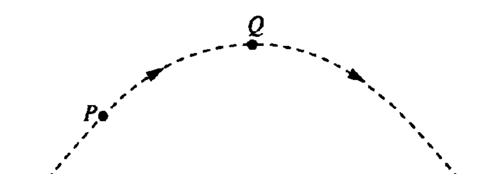


19. A ball initially moves horizontally with velocity v_i, as shown above. It is then struck by a stick. After leaving the stick, the ball moves vertically with a velocity v_f, which is smaller in magnitude than v_i. Which of the following vectors best represents the direction of the average force that the stick exerts on the ball?

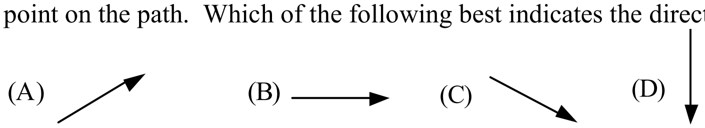


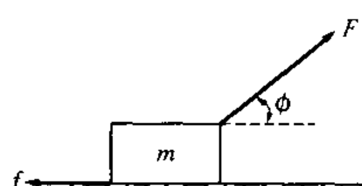


20. Two massless springs, of spring constants k_1 and k_2, are hung from a horizontal support. A block of weight 12 N is suspended from the pair of springs, as shown above. When the block is in equilibrium, each spring is stretched an additional 24 cm. Thus, the equivalent spring constant of the two-spring system is 12 N / 24 cm = 0.5 N/cm. Which of the following statements is correct about k_1 and k_2?
(A) $k_1 = k_2 = 0.25$ N/cm
(B) $1/k_1 + 1/k_2 = 1/(0.5$ N/cm)
(C) $k_1 - k_2 = 0.5$ N/cm
(D) $k_1 + k_2 = 0.5$ N/cm

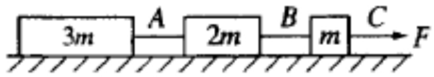


21. A ball is thrown and follows a parabolic path, as shown above. Air friction is negligible. Point Q is the highest point on the path. Which of the following best indicates the direction of the net force on the ball at point P ?

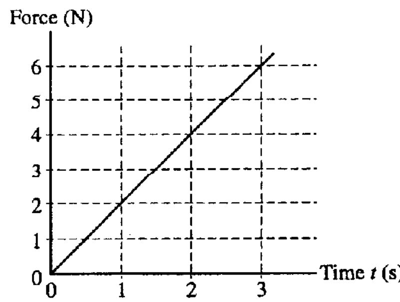




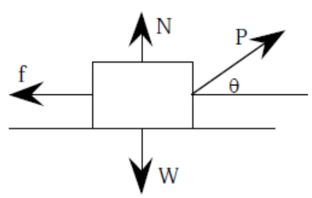
22. A block of mass m is accelerated across a rough surface by a force of magnitude F that is exerted at an angle ϕ with the horizontal, as shown above. The frictional force on the block exerted by the surface has magnitude *f*. What is the acceleration of the block?
(A) F/m (B) $(F\cos\phi)/m$ (C) $(F-f)/m$ (D) $(F\cos\phi - f)/m$



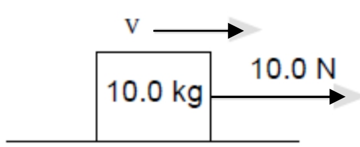
23. Three blocks of masses 3*m*, 2*m*, and*s* are connected to strings *A, B*, and *C* as shown above. The blocks are pulled along a rough surface by a force of magnitude *F* exerted by string *C*. The coefficient of friction between each block and the surface is the same. Which string must be the strongest in order not to break?
(A) *A* (B) *B* (C) *C* (D) They must all be the same strength.



24. A block of mass 3 kg, initially at rest, is pulled along a frictionless, horizontal surface with a force shown as a function of time t by the graph above. The acceleration of the block at t = 2 s is
(A) 4/3 m/s^2 (B) 2 m/s^2 (C) 8 m/s^2 (D) 12 m/s^2

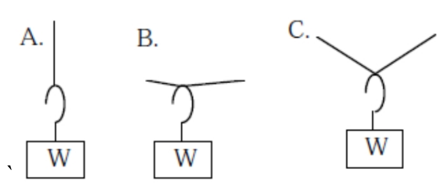


25. A student pulls a wooden box along a rough horizontal floor at constant speed by means of a force *P* as shown to the right. Which of the following must be true?
(A) P > f and N < W.
(B) P > f and N = W.
(C) P = f and N > W.
(D) P = f and N = W.

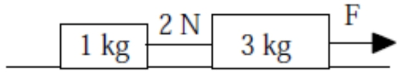


26. The 10.0 kg box shown in the figure to the right is sliding to the right along the floor. A horizontal force of 10.0 N is being applied to the right. The coefficient of kinetic friction between the box and the floor is 0.20. The box is moving with:
(A) acceleration to the left. (B) acceleration to the right.
(C) constant speed and constant velocity. (D) constant speed but not constant velocity.

27. Assume the objects in the following diagrams have equal mass and the strings holding them in place are identical. In which case would the string be most likely to break?

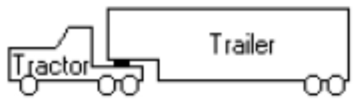


D. All would be equally likely to break



28. Two blocks of mass 1.0 kg and 3.0 kg are connected by a string which has a tension of 2.0 N. A force *F* acts in the direction shown to the right. Assuming friction is negligible, what is the value of *F*?
(A) 2.0 N (B) 4.0 N (C) 6.0 N (D) 8.0 N

29. A 50-kg student stands on a scale in an elevator. At the instant the elevator has a downward acceleration of 1.0 m/s^2 and an upward velocity of 3.0 m/s, the scale reads approximately
(A) 350 N (B) 450 N (C) 500 N (D) 550 N



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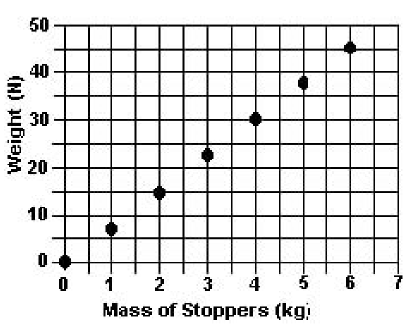
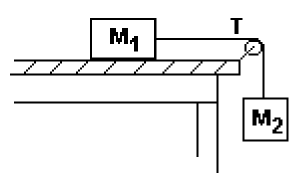
30. A tractor-trailer truck is traveling down the road. The mass of the trailer is 4 times the mass of the tractor. If the tractor accelerates forward, the force that the trailer applies on the tractor is
(A) 4 times greater than the force of the tractor on the trailer.
(B) 2 times greater than the force of the tractor on the trailer.
(C) equal to the force of the tractor on the trailer.
(D) ¼ the force of the tractor on the trailer.

31. A wooden box is first pulled across a horizontal steel plate as shown in the diagram A. The box is then pulled across the same steel plate while the plate is inclined as shown in diagram B. How does the force required to overcome friction in the inclined case (B) compare to the horizontal case (A)?
(A) the frictional force is the same in both cases
(B) the inclined case has a greater frictional force
(C) the inclined case has less frictional force
(D) the frictional force increases with angle until the angle is 90º, then drops to zero



32. The graph at left shows the relationship between the mass of a number of rubber stoppers and their resulting weight on some far-off planet. The slope of the graph is a representation of the:
(A) mass of a stopper
(B) density of a stopper
(C) acceleration due to gravity
(D) number of stoppers for each unit of weight

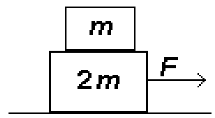


33. Two masses, m_1 and m_2, are connected by a cord and arranged as shown in the diagram with m_1 sliding along on a frictionless surface and m_2 hanging from a light frictionless pulley. What would be the mass of the falling mass, m_2, if both the sliding mass, m_1, and the tension, T, in the cord were known?
(A) $\frac{m_1 g - T}{g}$ (B) $\frac{1}{2}Tg$ (C) $\frac{m_1(T-g)}{(gm_1 - T)}$ (D) $\frac{Tm_1}{(gm_1 - T)}$

34. A mass is suspended from the roof of a lift (elevator) by means of a spring balance. The lift (elevator) is moving upwards and the readings of the spring balance are noted as follows:

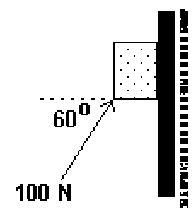
Speeding up: R_U Constant speed: R_C Slowing down: R_D

Which of the following is a correct relationship between the readings?
(A) $R_U > R_C$ (B) $R_U = R_D$ (C) $R_C < R_D$ (D) $R_C < R_D$



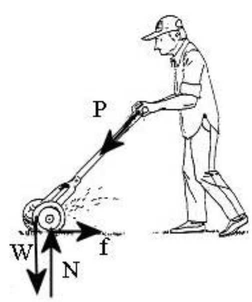
35. A small box of mass *m* is placed on top of a larger box of mass *2m* as shown in the diagram at right. When a force *F* is applied to the large box, both boxes accelerate to the right with the same acceleration. If the coefficient of friction between all surfaces is μ, what would be the force accelerating the smaller mass?
(A) $\frac{F}{3} - mg\mu$ (B) $F - 3mg\mu$ (C) $F - mg\mu$ (D) $\frac{F - mg\mu}{3}$

36. A 6.0 kg block initially at rest is pushed against a wall by a 100 N force as shown. The coefficient of kinetic friction is 0.30 while the coefficient of static friction is 0.50. What is true of the friction acting on the block after a time of 1 second?
(A) Static friction acts upward on the block.
(B) Kinetic friction acts upward on the block
(C) Kinetic friction acts downward on the block.
(D) Static friction acts downward on the block.



37. A homeowner pushes a lawn mower across a horizontal patch of grass with a constant speed by applying a force P. The arrows in the diagram correctly indicate the directions but not necessarily the magnitudes of the various forces on the lawn mower. Which of the following relations among the various force magnitudes, *W, f, N, P* is correct?

(A) $P > f$ and $N > W$
(B) $P < f$ and $N = W$
(C) $P > f$ and $N < W$
(D) $P = f$ and $N > W$

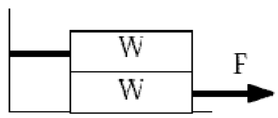


38. A mass, M, is at rest on a frictionless surface, connected to an ideal horizontal spring that is unstretched. A person extends the spring 30 cm from equilibrium and holds it at this location by applying a 10 N force. The spring is brought back to equilibrium and the mass connected to it is now doubled to 2M. If the spring is extended back 30 cm from equilibrium, what is the necessary force applied by the person to hold the mass stationary there?
(A) 20.0 N (B) 14.1 N (C) 10.0 N (D) 7.07 N

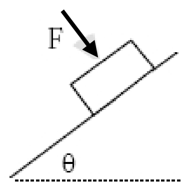
39. A crate of toys remains at rest on a sleigh as the sleigh is pulled up a hill with an increasing speed. The crate is not fastened down to the sleigh. What force is responsible for the crate's increase in speed up the hill?
(A) the contact force (normal force) of the ground on the sleigh
(B) the force of static friction of the sleigh on the crate
(C) the gravitational force acting on the sleigh
(D) no force is needed

40. A box slides to the right across a horizontal floor. A person called Ted exerts a force T to the right on the box. A person called Mario exerts a force M to the left, which is half as large as the force T. Given that there is friction f and the box accelerates to the right, rank the sizes of these three forces exerted on the box.
(A) $f < M < T$ (B) $M < f < T$ (C) $M < T < f$ (D) $f = M < T$

41. A spaceman of mass 80 kg is sitting in a spacecraft near the surface of the Earth. The spacecraft is accelerating upward at five times the acceleration due to gravity. What is the force of the spaceman on the spacecraft?
(A) 4800 N (B) 4000 N (C) 3200 N (D) 800 N

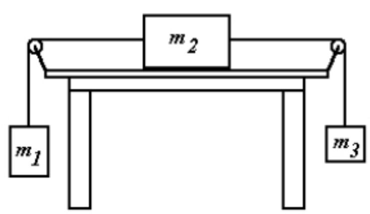


42. Two identical blocks of weight W are placed one on top of the other as shown in the diagram above. The upper block is tied to the wall. The lower block is pulled to the right with a force F. The coefficient of static friction between all surfaces in contact is μ. What is the largest force F that can be exerted before the lower block starts to slip?
(A) μW (B) $2\mu W$ (C) $3\mu W$ (D) $3\mu W/2$



43. A force F is used to hold a block of mass m on an incline as shown in the diagram (see above). The plane makes an angle of θ with the horizontal and F is perpendicular to the plane. The coefficient of friction between the plane and the block is μ. What is the minimum force, F, necessary to keep the block at rest?
(A) $mg\cos\theta$ (B) $mg\sin\theta$ (C) $mg\sin\theta/\mu$ (D) $mg(\sin\theta - \mu\cos\theta)/\mu$

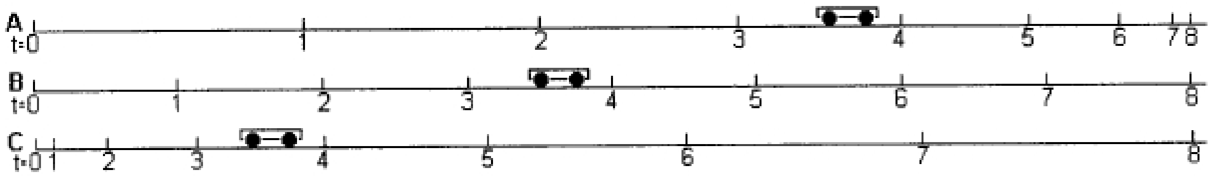
44. When the speed of a rear-drive car is increasing on a horizontal road, what is the direction of the frictional force on the tires?
(A) backward on the front tires and forward on the rear tires
(B) forward on the front tires and backward on the rear tires
(C) forward on all tires
(D) backward on all tires



45. Given the three masses as shown in the diagram above, if the coefficient of kinetic friction between the large mass (m_2) and the table is μ, what would be the upward acceleration of the small mass (m_3)? The mass and friction of the cords and pulleys are small enough to produce a negligible effect on the system.
(A) $g(m_1 + m_2\mu)/(m_1 + m_2 + m_3)$ (B) $g\mu(m_1 + m_2 + m_3)/ (m_1 - m_2 - m_3)$
(C) $g\mu(m_1 - m_2 - m_3)/ (m_1 + m_2 + m_3)$ (D) $g(m_1 - \mu m_2 - m_3)/ (m_1 + m_2 + m_3)$

Questions 47-48

Three identical laboratory carts A, B, and C are each subject to a constant force F_A, F_B, and F_C, respectively. One or more of these forces may be zero. The diagram below shows the position of each cart at each second of an 8.0 second interval.

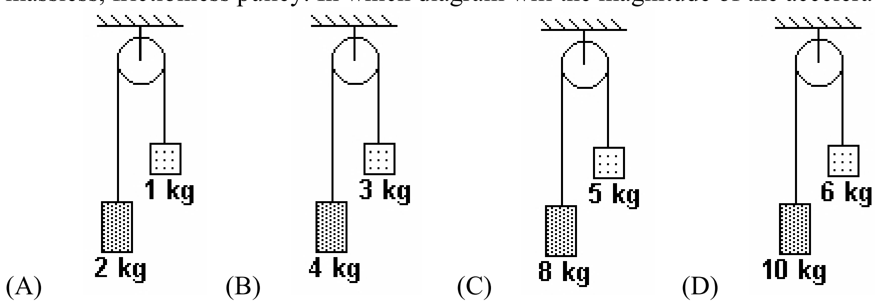


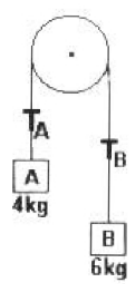
47. Which car has the greatest average velocity during the interval?
(A) A (B) B (C) C (D) all three average velocities are equal

48. How does the magnitude of the force acting on each car compare?
(A) $F_A > F_B > F_C$ (B) $F_A = F_C > F_B$ (C) $F_A > F_C = F_B$ (D) $F_A = F_B > F_C$

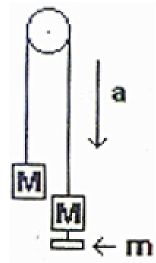
49. A skydiver is falling at terminal velocity before opening her parachute. After opening her parachute, she falls at a much smaller terminal velocity. How does the total upward force before she opens her parachute compare to the total upward force after she opens her parachute?
(A) The ratio of the forces is equal to the ratio of the velocities.
(B) The upward force with the parachute will depend on the size of the parachute.
(C) The upward force before the parachute will be greater because of the greater velocity.
(D) The upward force in both cases must be the same.

50. Each of the diagrams below represents two weights connected by a massless string which passes over a massless, frictionless pulley. In which diagram will the magnitude of the acceleration be the largest?

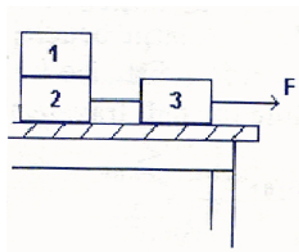




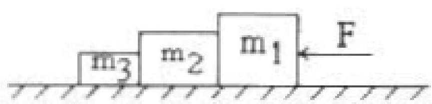
51. A simple Atwood's machine is shown in the diagram above. It is composed of a frictionless lightweight pulley with two cubes connected by a light string. If cube A has a mass of 4.0 kg and cube B has a mass of 6.0 kg, the system will move such that cube B accelerates downwards. What would be the tension in the two parts of the string between the pulley and the cubes?
(A) $T_A = 47$ N ; $T_B = 71$ N (B) $T_A = 47$ N ; $T_B = 47$ N (C) $T_A = 47$ N ; $T_B = 42$ N
(D) $T_A = 39$ N ; $T_B = 39$ N



52. A simple Atwood's machine remains motionless when equal masses M are placed on each end of the chord. When a small mass m is added to one side, the masses have an acceleration a. What is M? You may neglect friction and the mass of the cord and pulley.
(A) $\frac{m(g-a)}{2a}$ (B) $\frac{2m(g-a)}{a}$ (C) $\frac{2m(g+a)}{a}$ (D) $\frac{m(g+a)}{2a}$



53. Block 1 is stacked on top of block 2. Block 2 is connected by a light cord to block 3, which is pulled along a frictionless surface with a force F as shown in the diagram. Block 1 is accelerated at the same rate as block 2 because of the frictional forces between the two blocks. If all three blocks have the same mass m, what is the minimum coefficient of static friction between block 1 and block 2?
(A) 2F/mg (B) F/mg (C) 3F/2mg (D) F/3mg

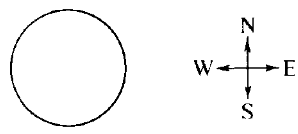


54. Three blocks (m_1, m_2, and m_3) are sliding at a constant velocity across a rough surface as shown in the diagram above. The coefficient of kinetic friction between each block and the surface is μ. What would be the force of m_1 on m_2?
(A) $(m_2 + m_3)g\mu$ (B) $F - (m_2 - m_3)g\mu$ (C) F (D) $m_1 g\mu - (m_2 + m_3)g\mu$

SECTION B – Circular Motion

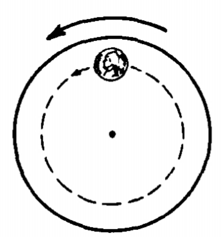
1. **Multiple Correct:** A person stands on a merry-go-round which is rotating at constant angular speed. Which of the following are true about the frictional force exerted on the person by the merry-go-round? Select two answers.
   (A) The force is greater in magnitude than the frictional force exerted on the person by the merry-go-round.
   (B) The force is opposite in direction to the frictional force exerted on the merry-go-round by the person.
   (C) The force is directed away from the center of the merry-go-round.
   (D) The force is dependent on the person's mass.

2. A ball attached to a string is whirled around in a horizontal circle having a radius R. If the radius of the circle is changed to 4R and the same centripetal force is applied by the string, the new speed of the ball is which of the following?
   (A) One-quarter the original speed
   (B) One-half the original speed
   (C) The same as the original speed
   (D) Twice the original speed

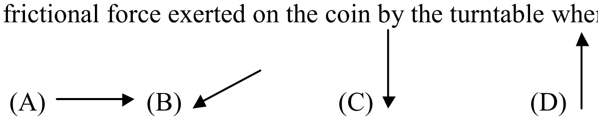


View of Track from Above

3. A racing car is moving around the circular track of radius 300 meters shown above. At the instant when the car's velocity is directed due east, its acceleration is directed due south and has a magnitude of 3 meters per second squared. When viewed from above, the car is moving
   (A) clockwise at 30 m/s
   (B) clockwise at 10 m/s
   (C) counterclockwise at 30 m/s
   (D) counterclockwise at 10 m/s

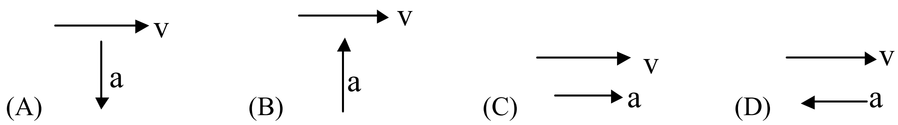

View from Above

4. The horizontal turntable shown above rotates at a constant rate. As viewed from above, a coin on the turntable moves counterclockwise in a circle as shown. Which of the following vectors best represents the direction of the frictional force exerted on the coin by the turntable when the coin is in the position shown?



5. In which of the following situations would an object be accelerated? Select two answers.
   (A) It moves in a straight line at constant speed.
   (B) It moves with uniform circular motion.
   (C) It travels as a projectile in a gravitational field with negligible air resistance.
   (D) It is at rest.

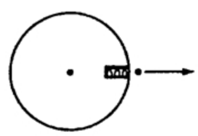
6. An automobile moves at constant speed down one hill and up another hill along the smoothly curved surface shown above. Which of the following diagrams best represents the directions of the velocity and the acceleration of the automobile at the instant that it is at the lowest position. as shown?



7. A car initially travels north and then turns to the left along a circular curve. This causes a package on the seat of the car to slide toward the right side of the car. Which of the following is true of the net force on the package while it is sliding?
(A) The force is directed away from the center of the circle.
(B) There is not enough force directed north to keep the package from sliding.
(C) There is not enough force tangential to the car's path to keep the package from sliding.
(D) There is not enough force directed toward the center of the circle to keep the package from sliding.

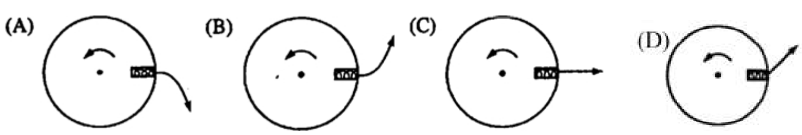
8. A child has a toy tied to the end of a string and whirls the toy at constant speed in a horizontal circular path of radius R. The toy completes each revolution of its motion in a time period T. What is the magnitude of the acceleration of the toy?

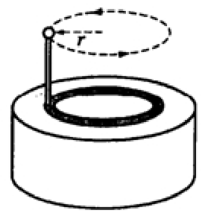
(A) Zero (B) $\frac{4\pi^2 R}{T^2}$ (C) $\frac{\pi R}{T^2}$ (D) g



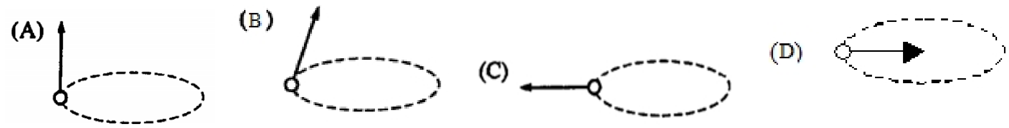
Top View

9. A compressed spring mounted on a disk can project a small ball. When the disk is not rotating, as shown in the top view above, the ball moves radially outward. The disk then rotates in a counterclockwise direction as seen from above, and the ball is projected outward at the instant the disk is in the position shown above. Which of the following best shows the subsequent path of the ball relative to the ground?

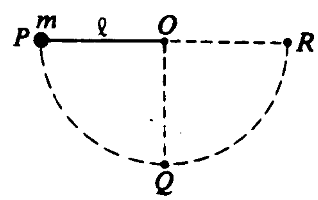




10. A steel ball supported by a stick rotates in a circle of radius *r*, as shown above. The direction of the net force acting on the ball when it is in the position shown is indicated by which of the following?



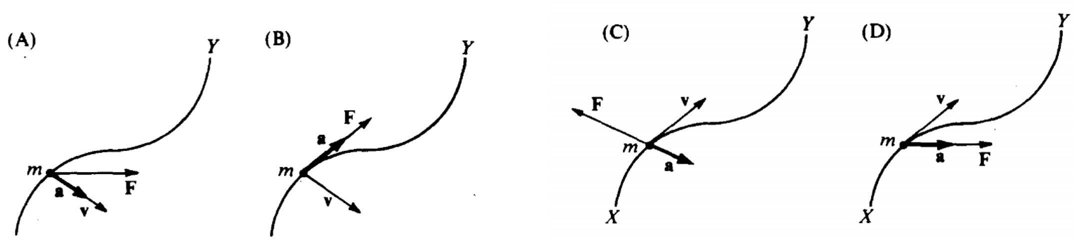
11. Inside a washing machine, the radius of the cylinder where the clothes sit is 0.50 m. In one of its settings the machine spins the cylinder at 2.0 revolutions per second. What is the acceleration of an item of clothing?
(A) 0.080 m/s^2 (B) 1.6 m/s^2 (C) 8.0 m/s^2 (D) 79 m/s^2

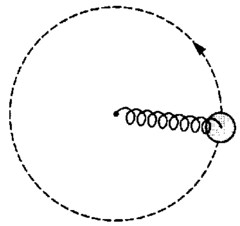


12. A ball of mass m is attached to the end of a string of length Q as shown above. The ball is released from rest from position P. where the string is horizontal. It swings through position Q. where the string is vertical, and then to position R. where the string is again horizontal. What are the directions of the acceleration vectors of the ball at positions Q and R?

Position Q	Position R
(A) Downward	Downward
(B) Downward	To the right
(C) Upward	Downward
(D) Upward	To the left

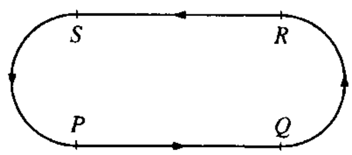
13. A mass m moves on a curved path from point X to point Y. Which of the following diagrams indicates a possible combination of the net force F on the mass, and the velocity *v* and acceleration *a* of the mass at the location shown?



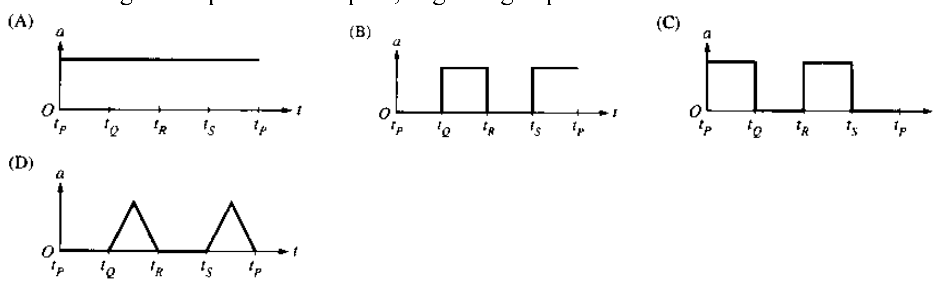


Top View

14. A spring has a force constant of 100 N/m and an unstretched length of 0.07 m. One end is attached to a post that is free to rotate in the center of a smooth table, as shown in the top view above. The other end is attached to a 1 kg disc moving in uniform circular motion on the table, which stretches the spring by 0.03 m. Friction is negligible. What is the centripetal force on the disc?
(A) 0.3 N (B) 3N (C) 10 N (D) 300 N



15. A figure of a dancer on a music box moves counterclockwise at constant speed around the path shown above. The path is such that the lengths of its segments, *PQ, QR, RS*, and *SP*, are equal. Arcs *QR* and *SP* are semicircles. Which of the following best represents the magnitude of the dancer's acceleration as a function of time t during one trip around the path, beginning at point *P* ?

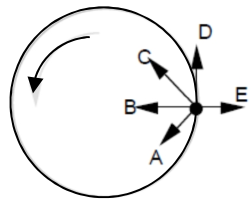


16. A car travels forward with constant velocity. It goes over a small stone, which gets stuck in the groove of a tire. The initial acceleration of the stone, as it leaves the surface of the road, is
(A) vertically upward
(B) horizontally forward
(C) horizontally backward
(D) zero

17. A car is traveling on a road in hilly terrain, see figure to the right. Assume the car has speed v and the tops and bottoms of the hills have radius of curvature R. The driver of the car is most likely to feel weightless:

(A) at the top of a hill when $v > \sqrt{gR}$ (B) at the bottom of a hill when $v > \sqrt{gR}$

(C) going down a hill when $v = \sqrt{gR}$ (D) at the top of a hill when $v = gR$

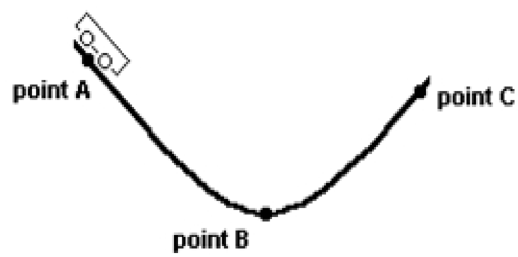


18. An object shown in the accompanying figure moves in uniform circular motion. Which arrow best depicts the net force acting on the object at the instant shown?
(A) A (B) B (C) C (D) D

19. **Multiple Correct:** A child whirls a ball at the end of a rope, in a uniform circular motion. Which of the following statements is true? Select two answers.
(A) The speed of the ball is constant
(B) The velocity is of the ball is constant
(C) The magnitude of the ball's acceleration is constant
(D) The net force on the ball is directed radially outwards

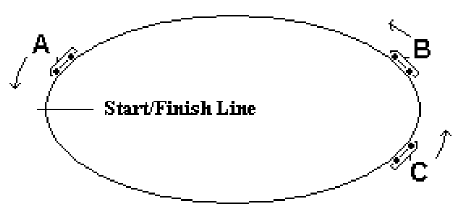
20. An astronaut in an orbiting space craft attaches a mass *m* to a string and whirls it around in uniform circular motion. The radius of the circle is *R*, the speed of the mass is *v*, and the tension in the string is *F*. If the mass, radius, and speed were all to double the tension required to maintain uniform circular motion would be
(A) *F* (B) 2*F* (C) 4*F* (D) 8*F*

21. Assume the roller coaster cart rolls along the curved track from point A to point C under the influence of gravity. Assume the friction between the track and the cart is negligible. What would be the direction of the cart's acceleration at point B?
(A) upward
(B) downward
(C) forward
(D) backward



Questions 22 – 23

The diagram below is a snapshot of three cars all moving counterclockwise during a one lap race on an elliptical track.

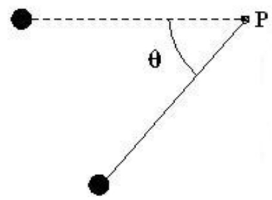


22. Which car has had the lowest average speed during the race so far?
(A) car A
(B) car B
(C) car C
(D) all three cars have had the same average speed

23. Which car at the moment of the snapshot MUST have a net force acting on it?
(A) car A
(B) car B
(C) car C
(D) all three cars have net forces acting on them

24. A centripetal force of 5.0 newtons is applied to a rubber stopper moving at a constant speed in a horizontal circle. If the same force is applied, but the radius is made smaller, what happens to the speed, v, and the frequency, f, of the stopper?

(A) v increases and f increases
(B) v decreases and f decreases
(C) v increases and f decreases
(D) v decreases and f increases



25. Astronauts on the Moon perform an experiment with a simple pendulum that is released from the horizontal position at rest. At the moment shown in the diagram with $0° < \theta < 90°$, the total acceleration of the mass may be directed in which of the following ways?
(A) straight to the right
(B) straight upward
(C) straight downward
(D) straight along the connecting string toward point P (the pivot)

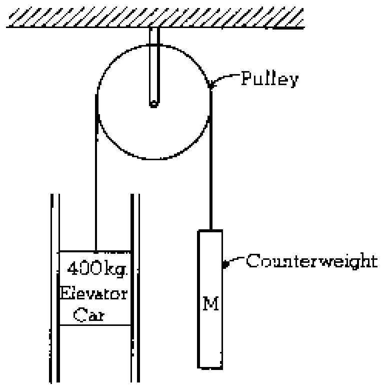
26. A 4.0 kg mass is attached to one end of a rope 2 m long. If the mass is swung in a vertical circle from the free end of the rope, what is the tension in the rope when the mass is at its highest point if it is moving with a speed of 5 m/s?
(A) 5.4 N (B) 10.8 N (C) 50 N (D) 65.4 N

27. A ball of mass m is fastened to a string. The ball swings at constant speed in a vertical circle of radius R with the other end of the string held fixed. Neglecting air resistance, what is the difference between the string's tension at the bottom of the circle and at the top of the circle?
(A) mg (B) $2mg$ (C) $4mg$ (D) $8mg$

28. An object weighing 4 newtons swings on the end of a string as a simple pendulum. At the bottom of the swing, the tension in the string is 6 newtons. What is the magnitude of the centripetal acceleration of the object at the bottom of the swing?
(A) 0.5 g (B) g (C) 1.5 g (D) 2.5 g

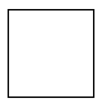
29. Riders in a carnival ride stand with their backs against the wall of a circular room of diameter 8.0 m. The room is spinning horizontally about an axis through its center at a rate of 45 rev/min when the floor drops so that it no longer provides any support for the riders. What is the minimum coefficient of static friction between the wall and the rider required so that the rider does not slide down the wall?
(A) 0.056 (B) 0.11 (C) 0.53 (D) 8.9

SECTION A – Linear Dynamics



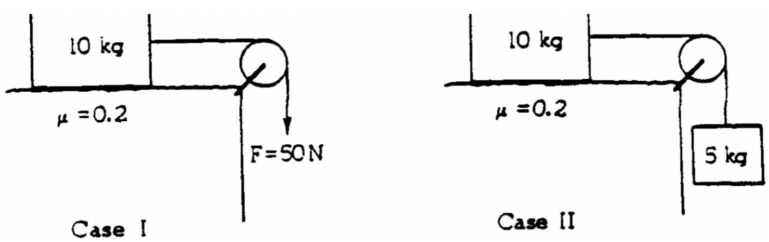
1976B1. The two guide rails for the elevator shown above each exert a constant friction force of 100 newtons on the elevator car when the elevator car is moving upward with an acceleration of 2 meters per second squared. The pulley has negligible friction and mass. Assume g = 10 m/sec^2.

a. On the diagram below, draw and label all forces acting on the elevator car. Identify the source of each force.



b. Calculate the tension in the cable lifting the 400-kilogram elevator car during an upward acceleration of 2 m/sec^2. (Assume g 10 m/sec^2.)

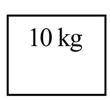
c. Calculate the mass M the counterweight must have to raise the elevator car with an acceleration of 2 m/sec^2.

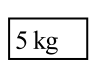


1979B2. A 10-kilogram block rests initially on a table as shown in cases I and II above. The coefficient of sliding friction between the block and the table is 0.2. The block is connected to a cord of negligible mass, which hangs over a massless frictionless pulley. In case I a force of 50 newtons is applied to the cord. In case II an object of mass 5 kilograms is hung on the bottom of the cord. Use g = 10 meters per second squared.

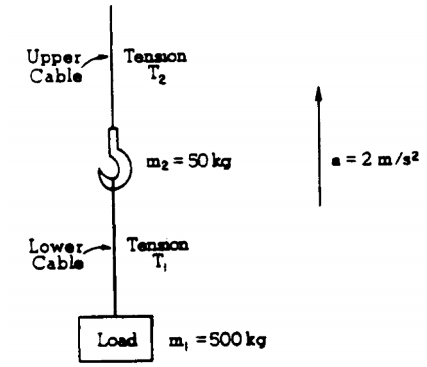
a. Calculate the acceleration of the 10-kilogram block in case I.

b. On the diagrams below, draw and label all the forces acting on each block in case II





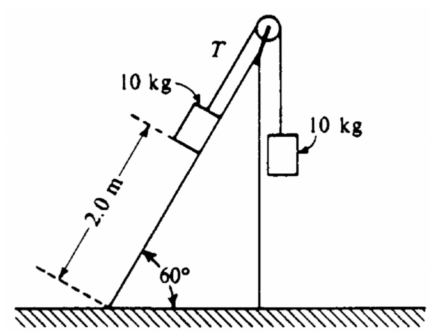
c. Calculate the acceleration of the 10-kilogram block in case II.



1982B2. A crane is used to hoist a load of mass m_1 = 500 kilograms. The load is suspended by a cable from a hook of mass m_2 = 50 kilograms, as shown in the diagram above. The load is lifted upward at a constant acceleration of 2 m/s^2.

a. On the diagrams below draw and label the forces acting on the hook and the forces acting on the load as they accelerate upward

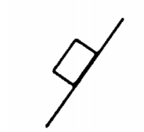
b. Determine the tension T_1 in the lower cable and the tension T_2 in the upper cable as the hook and load are accelerated upward at 2 m/s^2. Use g = 10 m/s^2.



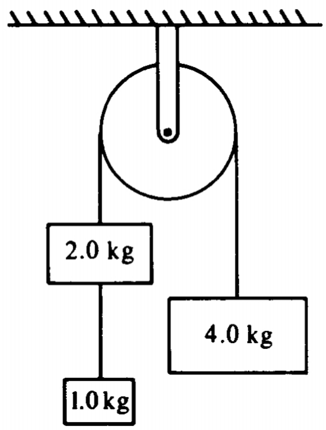
1985B2 (modified) Two 10-kilogram boxes are connected by a massless string that passes over a massless frictionless pulley as shown above. The boxes remain at rest, with the one on the right hanging vertically and the one on the left 2.0 meters from the bottom of an inclined plane that makes an angle of 60° with the horizontal. The coefficients of kinetic friction and static friction between the left-hand box and the plane are 0.15 and 0.30, respectively. You may use g = 10 m/s^2, sin 60° = 0.87, and cos 60° = 0.50.

a. What is the tension T in the string?

b. On the diagram below, draw and label all the forces acting on the box that is on the plane.



c. Determine the magnitude of the frictional force acting on the box on the plane.



1986B1. Three blocks of masses 1.0, 2.0, and 4.0 kilograms are connected by massless strings, one of which passes over a frictionless pulley of negligible mass, as shown above. Calculate each of the following.

a. The acceleration of the 4-kilogram block
b. The tension in the string supporting the 4-kilogram block
c. The tension in the string connected to the l-kilogram block

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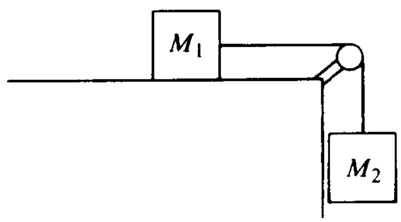
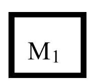


1987B1. In the system shown above, the block of mass M_1 is on a rough horizontal table. The string that attaches it to the block of mass M_2 passes over a frictionless pulley of negligible mass. The coefficient of kinetic friction μ_k between M_1 and the table is less than the coefficient of static friction μ_s

a. On the diagram below, draw and identify all the forces acting on the block of mass M_1.



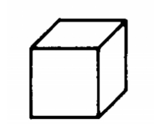
b. In terms of M_1 and M_2 determine the minimum value of μ_s that will prevent the blocks from moving.

The blocks are set in motion by giving M_2 a momentary downward push. In terms of M_1, M_2, μ_k, and g, determine each of the following:

c. The magnitude of the acceleration of M_1
d. The tension in the string.

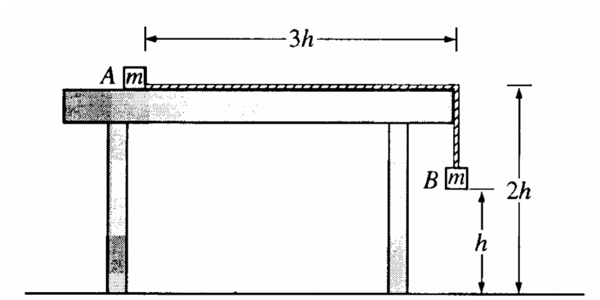
1988B1. A helicopter holding a 70-kilogram package suspended from a rope 5.0 meters long accelerates upward at a rate of 5.2 m/s^2. Neglect air resistance on the package.

a. On the diagram below, draw and label all of the forces acting on the package.



b. Determine the tension in the rope.

c. When the upward velocity of the helicopter is 30 meters per second, the rope is cut and the helicopter continues to accelerate upward at 5.2 m/s^2. Determine the distance between the helicopter and the package 2.0 seconds after the rope is cut.



1998B1 Two small blocks, each of mass m, are connected by a string of constant length 4h and negligible mass. Block A is placed on a smooth tabletop as shown above, and block B hangs over the edge of the table. The tabletop is a distance 2h above the floor. Block B is then released from rest at a distance h above the floor at time t = 0. Express all algebraic answers in terms of h, m, and g.

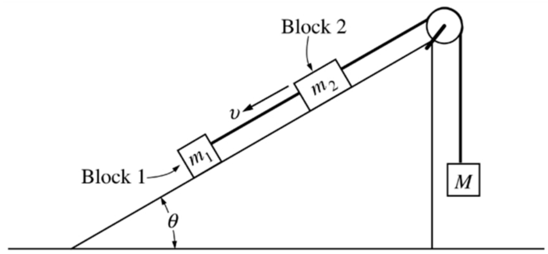
a. Determine the acceleration of block B as it descends.

b. Block B strikes the floor and does not bounce. Determine the time $t = t_1$ at which block B strikes the floor.

c. Describe the motion of block A from time t = 0 to the time when block B strikes the floor.

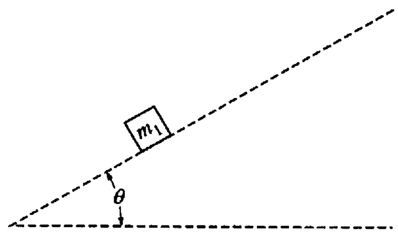
d. Describe the motion of block A from the time block B strikes the floor to the time block A leaves the table.

e. Determine the distance between the landing points of the two blocks.



2000B2. Blocks 1 and 2 of masses m_1 and m_2, respectively, are connected by a light string, as shown above. These blocks are further connected to a block of mass M by another light string that passes over a pulley of negligible mass and friction. Blocks l and 2 move with a constant velocity v down the inclined plane, which makes an angle θ with the horizontal. The kinetic frictional force on block 1 is f and that on block 2 is 2f.

a. On the figure below, draw and label all the forces on block m_1.

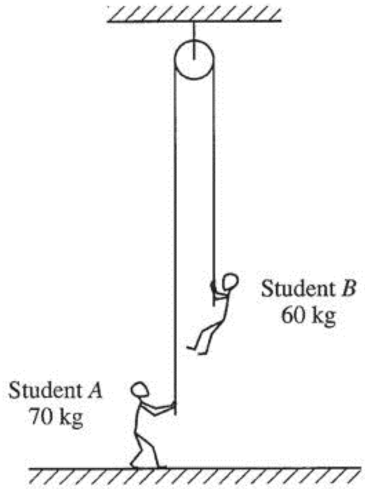


Express your answers to each of the following in terms of m_1, m_2, g, θ, and f.

b. Determine the coefficient of kinetic friction between the inclined plane and block 1.

c. Determine the value of the suspended mass M that allows blocks 1 and 2 to move with constant velocity down the plane.

d. The string between blocks 1 and 2 is now cut. Determine the acceleration of block 1 while it is on the inclined plane.



2003B1 A rope of negligible mass passes over a pulley of negligible mass attached to the ceiling, as shown above. One end of the rope is held by Student A of mass 70 kg, who is at rest on the floor. The opposite end of the rope is held by Student B of mass 60 kg, who is suspended at rest above the floor. Use $g = 10\ m/s^2$.

a. On the dots below that represent the students, draw and label free-body diagrams showing the forces on Student A and on Student B.

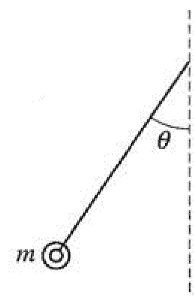
b. Calculate the magnitude of the force exerted by the floor on Student A.

Student B now climbs up the rope at a constant acceleration of $0.25\ m/s^2$ with respect to the floor.

c. Calculate the tension in the rope while Student B is accelerating.

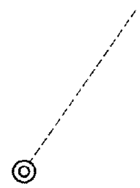
d. As Student B is accelerating, is Student A pulled upward off the floor? Justify your answer.

e. With what minimum acceleration must Student B climb up the rope to lift Student A upward off the floor?



2003Bb1 (modified) An airplane accelerates uniformly from rest. A physicist passenger holds up a thin string of negligible mass to which she has tied her ring, which has a mass m. She notices that as the plane accelerates down the runway, the string makes an angle θ with the vertical as shown above.

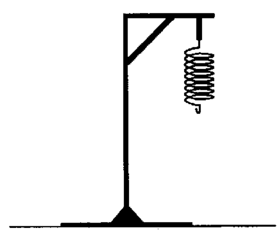
a. In the space below, draw a free-body diagram of the ring, showing and labeling all the forces present.



The plane reaches a takeoff speed of 65 m/s after accelerating for a total of 30 s.

b. Determine the minimum length of the runway needed.

c. Determine the angle θ that the string makes with the vertical during the acceleration of the plane before it leaves the ground.

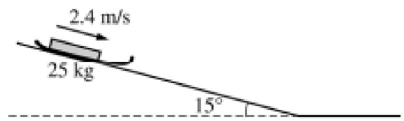


*1996B2 (modified) A spring that can be assumed to be ideal hangs from a stand, as shown above. You wish to determine experimentally the spring constant k of the spring.

a. i. What additional, commonly available equipment would you need?
ii. What measurements would you make?
iii. How would k be determined from these measurements?

Suppose that the spring is now used in a spring scale that is limited to a maximum value of 25 N, but you would like to weigh an object of mass M that weighs more than 25 N. You must use commonly available equipment and the spring scale to determine the weight of the object without breaking the scale.

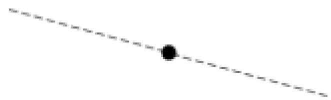
b. i. Draw a clear diagram that shows one way that the equipment you choose could be used with the spring scale to determine the weight of the object,
ii. Explain how you would make the determination.



B2007B1. An empty sled of mass 25 kg slides down a muddy hill with a constant speed of 2.4 m/s. The slope of the hill is inclined at an angle of 15° with the horizontal as shown in the figure above.

a. Calculate the time it takes the sled to go 21 m down the slope.

b. On the dot below that represents the sled, draw/label a free-body diagram for the sled as it slides down the slope



c. Calculate the frictional force on the sled as it slides down the slope.

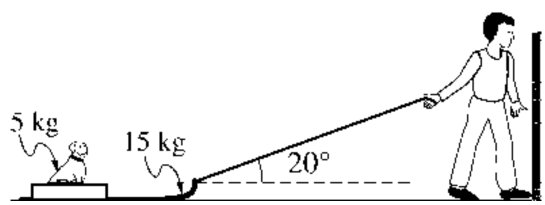
d. Calculate the coefficient of friction between the sled and the muddy surface of the slope.

e. The sled reaches the bottom of the slope and continues on the horizontal ground. Assume the same coefficient of friction.

i. In terms of velocity and acceleration, describe the motion of the sled as it travels on the horizontal ground.

ii. On the axes below, sketch a graph of speed v versus time t for the sled. Include both the sled's travel down the slope and across the horizontal ground. Clearly indicate with the symbol t_{ℓ} the time at which the sled leaves the slope.

B2007b1 (modified) A child pulls a 15 kg sled containing a 5.0 kg dog along a straight path on a horizontal surface. He exerts a force of 55 N on the sled at an angle of 20° above the horizontal, as shown in the figure. The coefficient of friction between the sled and the surface is 0.22.

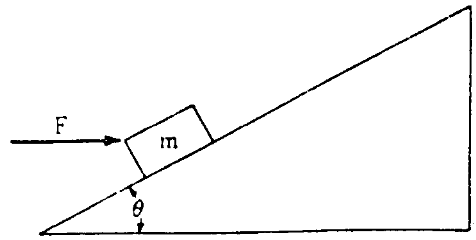


a. On the dot below that represents the sled-dog system, draw and label a free-body diagram for the system as it is pulled along the surface.

b. Calculate the normal force of the surface on the system.

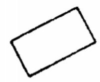
c. Calculate the acceleration of the system.

d. At some later time, the dog rolls off the side of the sled. The child continues to pull with the same force. On the axes below, sketch a graph of speed v versus time t for the sled. Include both the sled's travel with and without the dog on the sled. Clearly indicate with the symbol t_r the time at which the dog rolls off.



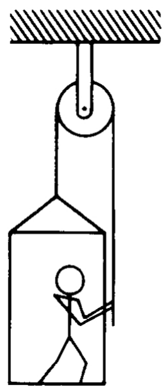
1981M1. A block of mass m, acted on by a force of magnitude F directed horizontally to the right as shown above, slides up an inclined plane that makes an angle θ with the horizontal. The coefficient of sliding friction between the block and the plane is μ.

a. On the diagram of the block below, draw and label all the forces that act on the block as it slides up the plane.



b. Develop an expression in terms of m, θ, F, μ, and g, for the block's acceleration up the plane.

c. Develop an expression for the magnitude of the force F that will allow the block to slide up the plane with constant velocity. What relation must θ and μ satisfy in order for this solution to be physically meaningful?



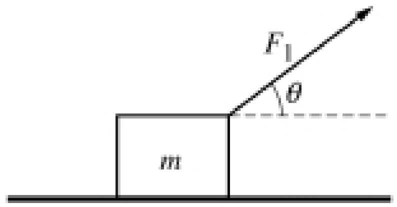
1986M1. The figure above shows an 80-kilogram person standing on a 20-kilogram platform suspended by a rope passing over a stationary pulley that is free to rotate. The other end of the rope is held by the person. The masses of the rope and pulley are negligible. You may use $g = 10\ m/s^2$. Assume that friction is negligible, and the parts of the rope shown remain vertical.

a. If the platform and the person are at rest, what is the tension in the rope?

The person now pulls on the rope so that the acceleration of the person and the platform is $2\ m/s^2$ upward.

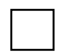
b. What is the tension in the rope under these new conditions?

c. Under these conditions, what is the force exerted by the platform on the person?



2007M1. A block of mass m is pulled along a rough horizontal surface by a constant applied force of magnitude F_1 that acts at an angle θ to the horizontal, as indicated above. The acceleration of the block is a_1. Express all algebraic answers in terms of m, F_1, θ , a_1, and fundamental constants.

a. On the figure below, draw and label a free-body diagram showing all the forces on the block.



b. Derive an expression for the normal force exerted by the surface on the block.

c. Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

d. On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.

e. If the applied force is large enough, the block will lose contact with the surface. Derive an expression for the magnitude of the greatest acceleration a_{max} that the block can have and still maintain contact with the ground.

1996M2. A 300-kg box rests on a platform attached to a forklift, shown above. Starting from rest at time = 0, the box is lowered with a downward acceleration of 1.5 m/s^2

a. Determine the upward force exerted by the horizontal platform on the box as it is lowered.

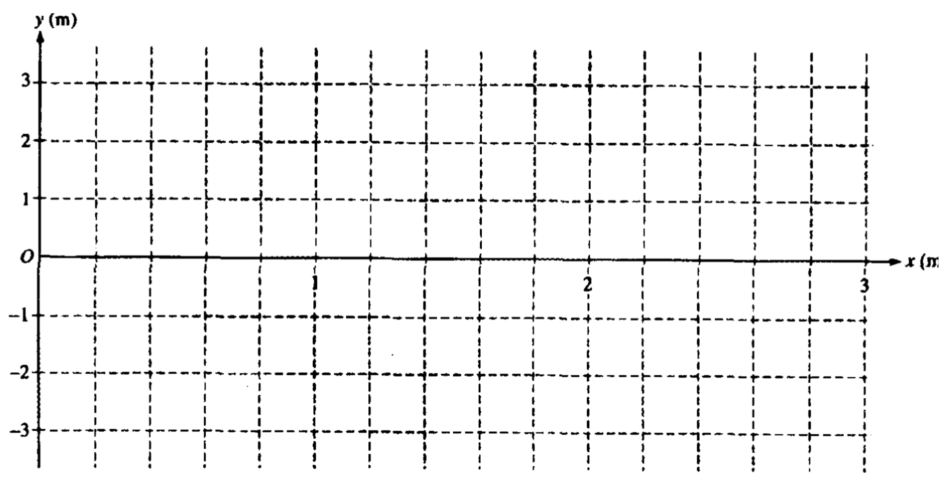
At time t = 0, the forklift also begins to move forward with an acceleration of 2 m/s^2 while lowering the box as described above. The box does not slip or tip over.

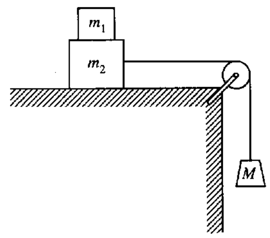
b. Determine the frictional force on the box.

c. Given that the box does not slip, determine the minimum possible coefficient of friction between the box and the platform.

d. Determine an equation for the path of the box that expresses y as a function of x (and <u>not</u> of t), assuming that, at time t = 0, the box has a horizontal position x = 0 and a vertical position y = 2 m above the ground, with zero velocity.

e. On the axes below sketch the path taken by the box





1998M3. Block 1 of mass m_1 is placed on block 2 of mass m_2 which is then placed on a table. A string connecting block 2 to a hanging mass M passes over a pulley attached to one end of the table, as shown above. The mass and friction of the pulley are negligible. The coefficients of friction between blocks 1 and 2 and between block 2 and the tabletop are nonzero and are given in the following table.

	Coefficient Between Blocks 1 and 2	Coefficient Between Block 2 and the Tabletop
Static	μ_{s1}	μ_{s2}
Kinetic	μ_{k1}	μ_{k2}

Express your answers in terms of the masses, coefficients of friction, and g, the acceleration due to gravity.

a. Suppose that the value of M is small enough that the blocks remain at rest when released. For each of the following forces, determine the magnitude of the force and draw a vector on the block provided to indicate the direction of the force if it is nonzero.

i. The normal force N_1 exerted on block 1 by block 2

m_1

ii. The friction force f_1 exerted on block 1 by block 2

m_1

iii. The force T exerted on block 2 by the string

m_2

iv. The normal force N_2 exerted on block 2 by the tabletop

m_2

v. The friction force f_2 exerted on block 2 by the tabletop

m_2

b. Determine the largest value of M for which the blocks can remain at rest.

c. Now suppose that M is large enough that the hanging block descends when the blocks are released. Assume that blocks 1 and 2 are moving as a unit (no slippage). Determine the magnitude *a* of their acceleration.

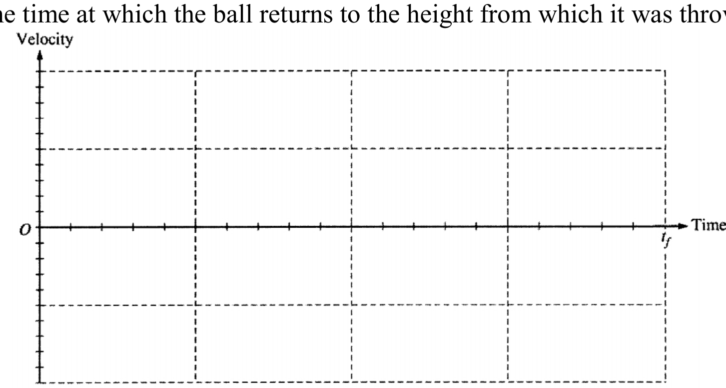
d. Now suppose that M is large enough that as the hanging block descends, block 1 is slipping on block 2. Determine each of the following.

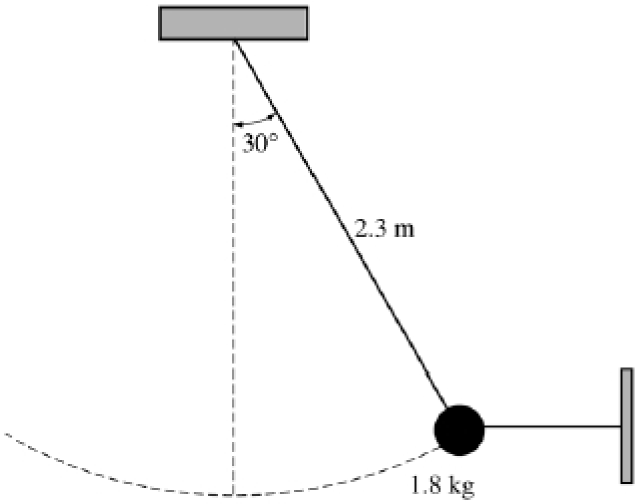
i. The magnitude a_1 of the acceleration of block 1

ii. The magnitude a_2 of the acceleration of block 2

*2005M1 (modified) A ball of mass M is thrown vertically upward with an initial speed of v_o. It experiences a force of air resistance given by $F = -kv$, where k is a positive constant. The positive direction for all vector quantities is upward. Express all algebraic answers in terms of M, k, v_o, and fundamental constants.

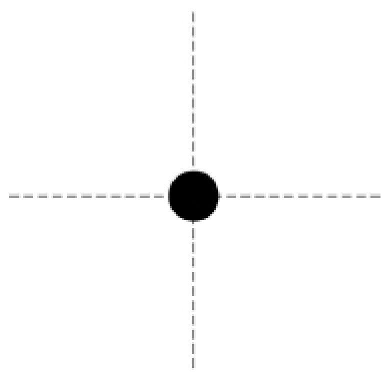
a. Does the magnitude of the acceleration of the ball increase, decrease, or remain the same as the ball moves upward?
   ____ increases ____ decreases ____ remains the same
   Justify your answer.
b. Determine the terminal speed of the ball as it moves downward.
c. Does it take longer for the ball to rise to its maximum height or to fall from its maximum height back to the height from which it was thrown?
   ____ longer to rise ____ longer to fall
   Justify your answer.
d. On the axes below, sketch a graph of velocity versus time for the upward and downward parts of the ball's flight, where t_f is the time at which the ball returns to the height from which it was thrown.



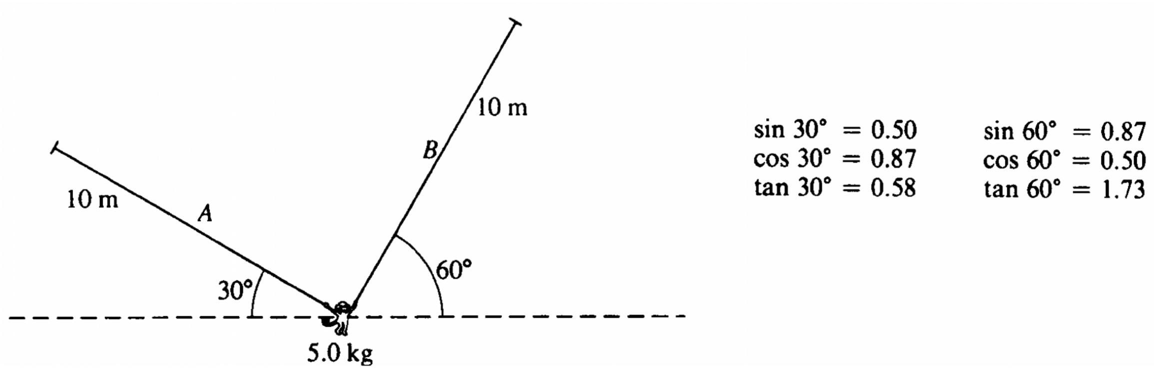


2005B2. A simple pendulum consists of a bob of mass 1.8 kg attached to a string of length 2.3 m. The pendulum is held at an angle of 30° from the vertical by a light horizontal string attached to a wall, as shown above.

(a) On the figure below, draw a free-body diagram showing and labeling the forces on the bob in the position shown above.



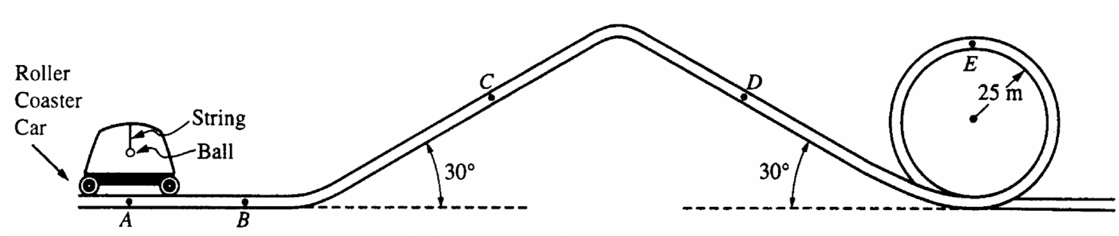
(b) Calculate the tension in the horizontal string.



1991B1. A 5.0-kilogram monkey hangs initially at rest from two vines, A and B. as shown above. Each of the vines has length 10 meters and negligible mass.

a. On the figure below, draw and label all of the forces acting on the monkey. (Do not resolve the forces into components, but do indicate their directions.)

b. Determine the tension in vine B while the monkey is at rest.



Note: Figure not drawn to scale.

1995B3. Part of the track of an amusement park roller coaster is shaped as shown above. A safety bar is oriented lengthwise along the top of each car. In one roller coaster car, a small 0.10-kilogram ball is suspended from this bar by a short length of light, inextensible string.

a. Initially, the car is at rest at point A.

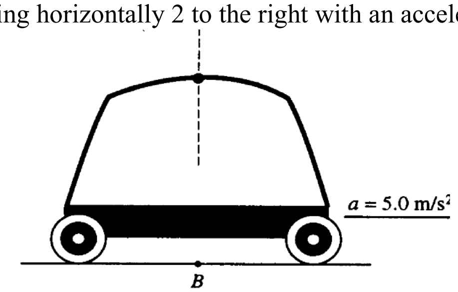
i. On the diagram below, draw and label all the forces acting on the 0.10-kilogram ball.

ii. Calculate the tension in the string.

The car is then accelerated horizontally, goes up a 30° incline, goes down a 30° incline, and then goes around a vertical circular loop of radius 25 meters. For each of the four situations described in parts (b) to (e), do all three of the following. In each situation, assume that the ball has stopped swinging back and forth.

1) Determine the horizontal component T_h of the tension in the string in newtons and record your answer in the space provided.
2)Determine the vertical component T_v of the tension in the string in newtons and record your answer in the space provided.
3)Show on the adjacent diagram the approximate direction of the string with respect to the vertical. The dashed line shows the vertical in each situation.

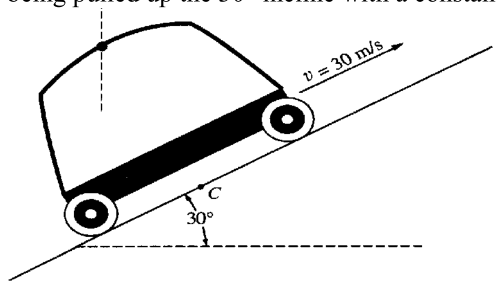
b. The car is at point B moving horizontally 2 to the right with an acceleration of 5.0 m/s .



T_h =__________________________

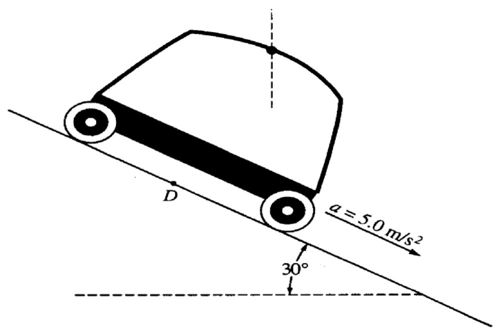
T_v = __________________________

c. The car is at point C and is being pulled up the 30° incline with a constant speed of 30 m/s.



T_h = ____________________________

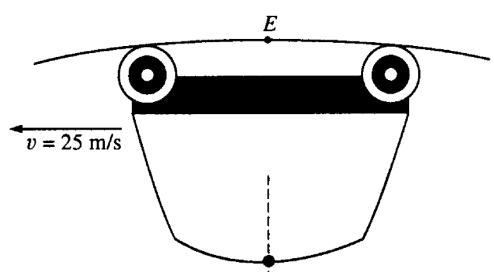
T_v = ____________________________



d. The car is at point D moving down the incline with an acceleration of 5.0 m/s^2 .

T_h = ____________________________

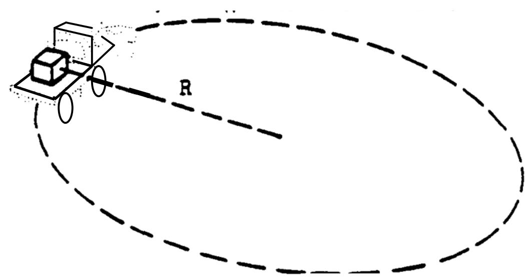
T_v = ____________________________



e. The car is at point E moving upside down with an instantaneous speed of 25 m/s and no tangential acceleration at the top of the vertical loop of radius 25 meters.

T_h = ____________________________

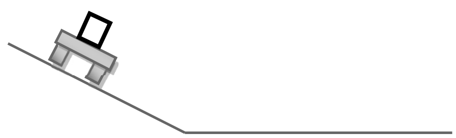
T_v = ____________________________



1977 B2. A box of mass M, held in place by friction, rides on the flatbed of a truck which is traveling with constant speed v. The truck is on an unbanked circular roadway having radius of curvature R.

a. On the diagram provided above, indicate and clearly label all the force vectors acting on the box.

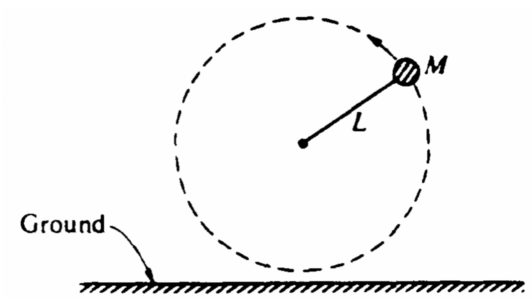
b. Find what condition must be satisfied by the coefficient of static friction μ between the box and the truck bed. Express your answer in terms of v, R, and g.



If the roadway is properly banked, the box will still remain in place on the truck for the same speed v even when the truck bed is frictionless.

c. On the diagram above indicate and clearly label the two forces acting on the box under these conditions

d. Which, if either, of the two forces acting on the box is greater in magnitude?



1984B1. A ball of mass M attached to a string of length L moves in a circle in a vertical plane as shown above. At the top of the circular path, the tension in the string is twice the weight of the ball. At the bottom, the ball just clears the ground. Air resistance is negligible. Express all answers in terms of M, L, and g.

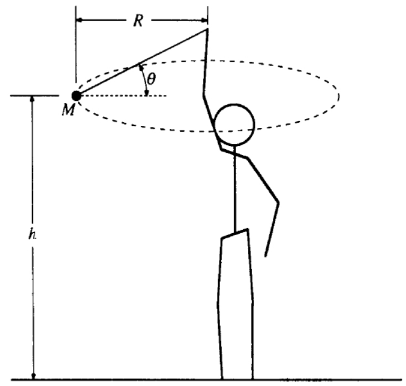
a. Determine the magnitude and direction of the net force on the ball when it is at the top.

b. Determine the speed v_o of the ball at the top.

The string is then cut when the ball is at the top.

c. Determine the time it takes the ball to reach the ground.

d. Determine the horizontal distance the ball travels before hitting the ground.

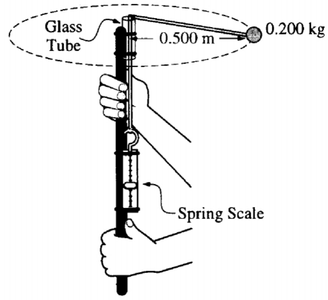


1989B1. An object of mass M on a string is whirled with increasing speed in a horizontal circle, as shown above. When the string breaks, the object has speed v_o and the circular path has radius R and is a height h above the ground. Neglect air friction.

a. Determine the following, expressing all answers in terms of h, v_o, and g.
   i. The time required for the object to hit the ground after the string breaks
   ii. The horizontal distance the object travels from the time the string breaks until it hits the ground
   iii. The speed of the object just before it hits the ground

b. On the figure below, draw and label all the forces acting on the object when it is in the position shown in the diagram above.

c. Determine the tension in the string just before the string breaks. Express your answer in terms of M, R, v_o, & g.



Not Necessarily
To Scale

1997B2 (modified) To study circular motion, two students use the hand-held device shown above, which consists of a rod on which a spring scale is attached. A polished glass tube attached at the top serves as a guide for a light cord attached the spring scale. A ball of mass 0.200 kg is attached to the other end of the cord. One student swings the teal around at constant speed in a horizontal circle with a radius of 0.500 m. Assume friction and air resistance are negligible.

a. Explain how the students, by using a timer and the information given above, can determine the speed of the ball as it is revolving.

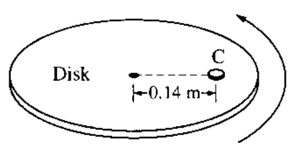
b. The speed of the ball is determined to be 3.7 m/s. Assuming that the cord is horizontal as it swings, calculate the expected tension in the cord.

c. The actual tension in the cord as measured by the spring scale is 5.8 N. What is the percent difference between this measured value of the tension and the value calculated in part b.?

The students find that, despite their best efforts, they cannot swing the ball so that the cord remains exactly horizontal.

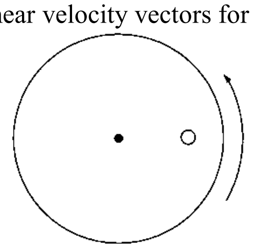
d. i. On the picture of the ball below, draw vectors to represent the forces acting on the ball and identify the force that each vector represents.

ii. Explain why it is not possible for the ball to swing so that the cord remains exactly horizontal.
iii. Calculate the angle that the cord makes with the horizontal.



1999B5 A coin C of mass 0.0050 kg is placed on a horizontal disk at a distance of 0.14 m from the center, as shown above. The disk rotates at a constant rate in a counterclockwise direction as seen from above. The coin does not slip, and the time it takes for the coin to make a complete revolution is 1.5 s.

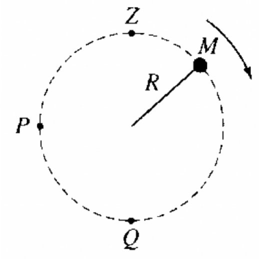
a. The figure below shows the disk and coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.



b. Determine the linear speed of the coin.

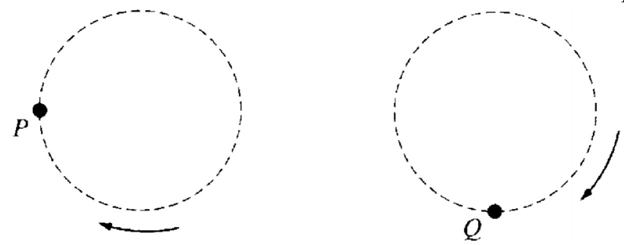
c. The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and the disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

d. If the experiment in part (c) were repeated with a second, identical coin glued to the top of the first coin, how would this affect the answer to part (c)? Explain your reasoning.

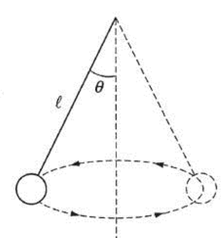


2001B1. A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point P, the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

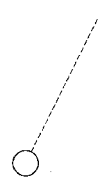
a. On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q, respectively.



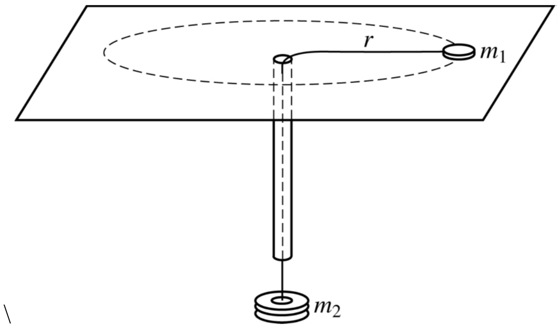
b. Derive an expression for v_{min} the minimum speed the ball can have at point Z without leaving the circular path.
c. The maximum tension the string can have without breaking is T_{max} Derive an expression for v_{max}, the maximum speed the ball can have at point Q without breaking the string.
d. Suppose that the string breaks at the instant the ball is at point P. Describe the motion of the ball immediately after the string breaks.



2002B2B A ball attached to a string of length l swings in a horizontal circle, as shown above, with a constant speed. The string makes an angle θ with the vertical, and T is the magnitude of the tension in the string. Express your answers to the following in terms of the given quantities and fundamental constants.
a. On the figure below, draw and label vectors to represent all the forces acting on the ball when it is at the position shown in the diagram. The lengths of the vectors should be consistent with the relative magnitudes of the forces.



b. Determine the mass of the ball.
c. Determine the speed of the ball.
d. Determine the frequency of revolution of the ball.
e. Suppose that the string breaks as the ball swings in its circular path. Qualitatively describe the trajectory of the ball after the string breaks but before it hits the ground.



2009Bb1 An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string. A student holding the tube makes the disk rotate in a circle of constant radius r, while another student measures the period P.

a. Derive the equation $P = 2\pi\sqrt{\dfrac{m_1 r}{m_2 g}}$ that relates P and m_2.

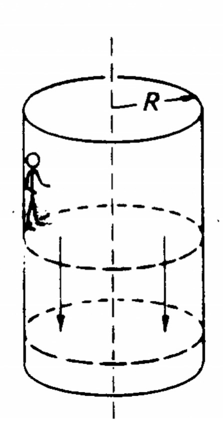
The procedure is repeated, and the period P is determined for four different values of m_2, where $m_1 = 0.012$ kg and $r = 0.80$ m. The data, which are presented below, can be used to compute an experimental value for g.

m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75

b. What quantities should be graphed to yield a straight line with a slope that could be used to determine g?

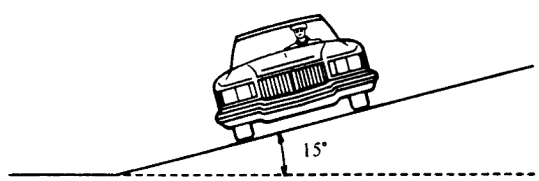
c. On the grid below, plot the quantities determined in part (b), label the axes, and draw the best-fit line to the data. You may use the blank rows above to record any values you may need to calculate.

d. Use your graph to calculate the experimental value of g.



*1984M1 (modified) An amusement park ride consists of a rotating vertical cylinder with rough canvas walls. The floor is initially about halfway up the cylinder wall as shown above. After the rider has entered and the cylinder is rotating sufficiently fast, the floor is dropped down, yet the rider does not slide down. The rider has mass of 50 kilograms, The radius R of the cylinder is 5 meters, the frequency of the cylinder when rotating is $1/\pi$ revolutions per second, and the coefficient of static friction between the rider and the wall of the cylinder is 0.6.

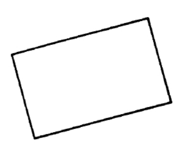
a. On the diagram above, draw and identify the forces on the rider when the system is rotating and the floor has dropped down.
b. Calculate the centripetal force on the rider when the cylinder is rotating and state what provides that force.
c. Calculate the upward force that keeps the rider from falling when the floor is dropped down and state what provides that force.
d. At the same rotational speed, would a rider of twice the mass slide down the wall? Explain your answer.



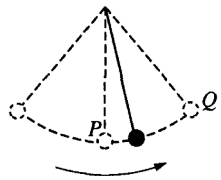
1988M1. A highway curve that has a radius of curvature of 100 meters is banked at an angle of 15° as shown above.

a. Determine the vehicle speed for which this curve is appropriate if there is no friction between the road and the tires of the vehicle.

On a dry day when friction is present, an automobile successfully negotiates the curve at a speed of 25 m/s.

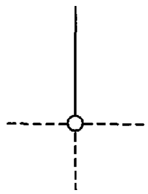


b. On the diagram above, in which the block represents the automobile, draw and label all of the forces on the automobile.
c. Determine the minimum value of the coefficient of friction necessary to keep this automobile from sliding as it goes around the curve.

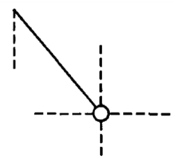


1998B6 A heavy ball swings at the end of a string as shown above, with negligible air resistance. Point P is the lowest point reached by the ball in its motion, and point Q is one of the two highest points.

a. On the following diagrams draw and label vectors that could represent the velocity and acceleration of the ball at points P and Q. If a vector is zero, explicitly state this fact. The dashed lines indicate horizontal and vertical directions.

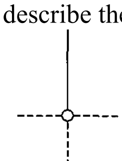


i. Point P

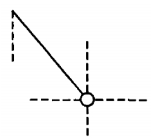


ii. Point Q

b. After several swings, the string breaks. The mass of the string and air resistance are negligible. On the following diagrams, sketch the path of the ball if the break occurs when the ball is at point P or point Q. In each case, briefly describe the motion of the ball after the break.



i. Point P



ii. Point Q

ANSWERS - AP Physics Multiple Choice Practice – Dynamics

SECTION A – Linear Dynamics

	Solution	Answer
1.	As T_2 is more vertical, it is supporting more of the weight of the ball. The horizontal components of T_1 and T_2 are equal.	C
2.	Normal force is perpendicular to the incline, friction acts up, parallel to the incline (opposite the motion of the block), gravity acts straight down.	D
3.	The component of the weight down the plane is 20 N sin θ. The net force is 4 N, so the friction force up the plane must be 4 N less than 20 N.	D
4.	The force between objects is the applied force times the ratio of the mass behind the rope to the total mass being pulled. This can be derived from $a = F/m_{total}$ and $F_T = m_{\text{behind the rope}}a$	D
5.	Since the ball's speed is increasing from rest, the retarding force F is also increasing. The net force, which is the weight of the ball minus *F*, is thus decreasing. So the acceleration also must decrease. Time *t* /2 is before the constant-speed motion begins, so the acceleration has not yet decreased to zero.	B
6.	For vertical equilibrium, the weight equals the normal force plus the vertical component of F. This leads to the normal force being W – something. The block remains in contact with the surface, so the normal force does not reach zero.	B
7.	The bottom of the rope supports the box, while the top of the rope must support the rope itself and the box.	D
8.	The vertical components of the tension in the rope are two equal upward components of $T\cos\theta$, which support the weight. $\Sigma F_y = 0 = 2T\cos\theta - W$	D
9.	$\Sigma F_{external} = m_{total}a$; mg is the only force acting from outside the system of masses so we have mg = (4m)a	A
10.	The weight component perpendicular to the plane is 20 N sin 37^o. To get equilibrium perpendicular to the plane, the normal force must equal this weight component, which must be less than 20 N.	B
11.	(A) is the definition of translational equilibrium. Equilibrium means no net force and no acceleration, so (D) is also correct.	A,D
12.	Motion at constant speed includes, for example, motion in a circle, in which the direction of the velocity changes and thus acceleration exists. Constant momentum for a single object means , that the velocity doesn't change.	D
13.	$\Sigma F = ma$; $F_T - mg = ma$; Let $F_T = 50$ N (the maximum possible tension) and m = W/g = 3 kg	A
14.	The sum of the tensions in the chains (250 N + T_{left}) must support the weight of the board and the person (125 N + 500 N)	C
15.	The board itself provides the same torque about the attachment point of both chains, but since the left chain provides a bigger force on the board, the person must be closer to the left chain in order to provide an equivalent torque on both chains by $\tau = Fd$.	A
16.	The horizontal component of the 30 N force is 15 N left. So the net force is 5 N left. So the acceleration is left. This could mean either A or D – when acceleration is opposite velocity, an object slows down.	A,D

17. Consider that no part of the system is in motion, this means at each end of the rope, a person pulling with 100 N of force is reacted to with a tension in the rope of 100 N. C

18. As v is proportional to t^2 and a is proportional to $\Delta v/t$, this means a should be proportional to t A

19. The direction of the force is the same as the direction of the acceleration, which is proportional to $\Delta v = v_f + (-v_i)$ B

20. A force diagram will show that the forces provided by each spring add up to 12 N: $F_1 + F_2 = 12$ N. Each force is kx; each spring is stretched the same amount x = 24 cm. So $k_1x + k_2x = 12$ N; dividing both sides by x shows that $k_1 + k_2 = 0.5$ N/cm. D

21. Net force is the gravitational force which acts downward D

22. $\Sigma F = ma = F\cos\phi - f$ D

23. The string pulling all three masses (total $6m$) must have the largest tension. String A is only pulling the block of mass $3m$ and string B is pulling a total mass of $5m$. C

24. At t = 2 s the force is 4 N. F = ma A

25. Since P is at an upward angle, the normal force is decreased as P supports some of the weight. Since a component of P balances the frictional force, P itself must be larger than f. A

26. The force of friction = $\mu F_N = 0.2 \times 10\text{ kg} \times 9.8\text{ m/s}^2 = 19.6$ N, which is greater than the applied force, which means the object is accelerating to the left, or slowing down A

27. The upward component of the tension is $T_{up} = T\sin\theta$, where θ is the angle to the horizontal. This gives $T = T_{up}/\sin\theta$. Since the upward components are all equal to one half the weight, the rope at the smallest angle (and the smallest value of sinθ) will have the greatest tension, and most likely break B

28. From the 1 kg block: F = ma giving a = 2 m/s^2. For the system: F = (4 kg)(2 m/s^2) D

29. Elevator physics: F_N represents the scale reading. $\Sigma F = ma$; $F_N - mg = ma$, or $F_N = m(g + a)$. The velocity of the elevator is irrelevant. B

30. Newton's third law C

31. The normal force is mgcosθ. For a horizontal surface, $F_N = mg$. At any angle $F_N < mg$ and F_f is proportional to F_N. C

32. Slope = $\Delta y/\Delta x$ = Weight/mass = acceleration due to gravity C

33. Newton's second law applied to m_1: $T = m_1a$, or $a = T/m_1$, substitute this into Newton's second law for the hanging mass: $m_2g - T = m_2a$ D

34. Elevator physics: R represents the scale reading. $\Sigma F = ma$; $R - mg = ma$, or $R = m(g + a)$. This ranks the value of R from largest to smallest as accelerating upward, constant speed, accelerating downward A

35. $\Sigma F = ma$ for the whole system gives $F - \mu(3m)g = (3m)a$ and solving for a gives $a = (F - 3\mu mg)/3m$. For the top block, $F_m = ma = m[(F - 3\mu mg)/3m]$ A

36. The normal force comes from the perpendicular component of the applied force which is Fcosθ = 50 N. The maximum value of static friction is then $\mu F_N = 25$ N. The upward component of the applied force is Fsinθ = 87 N. $\Sigma F_y = F_{up} - mg = 87\text{ N} - 60\text{ N} > 25$ N. Since the net force on the block is great than static friction can hold, the block will begin moving up the wall. Since it is in motion, kinetic friction is acting opposite the direction of the block's motion C

37. Since P is at a downward angle, the normal force is increased. Since a component of P balances the frictional force, P itself must be larger than f. A

38. Since the force is applied horizontally, the mass has no effect. C

39. The only force in the direction of the crate's acceleration is the force of friction from the sleigh B

40. Given that the box accelerates toward Ted, Ted's force must be greater than Mario's force plus the force of friction. Since Mario's force is ½ of Ted's force, the force of frction must be less than half of Ted's force. A

41. $\Sigma F = ma$; $F - mg = m(5g)$ or $F = 6mg$ A

42. Between the lower block and the tabletop, there is a force of friction to the left of maximum magnitude $\mu(2W)$ as both blocks are pushing down on the tabletop. There is also a force of friction acting to the left on the upper surface of the lower block due to the upper block of maximum magnitude μW. The total maximum static frictional force holding the lower block in place is therefore $\mu(2W) + \mu W$ C

43. The normal force on the block can be found from $\Sigma F_y = 0 = F_N - mg\cos\theta - F$. The force of friction necessary to hold the block in place is $mg\sin\theta$. Setting the force of friction equal to $mg\sin\theta$ gives $\mu F_N = mg\sin\theta = \mu(F + mg\cos\theta)$ D

44. This is a tricky one. In order to move the car forward, the rear tires roll back against the ground, the force of friction pushing forward on the rear tires. The front tires, however, are not trying to roll on their own, rather they begin rolling due to the friction acting backward, increasing their rate of rotation A

45. The external forces acting on the system of masses are the weights of block 1 (pulling the system to the left), the weight of block 3 (pulling the system to the right) and the force of friction on block 2 (pulling the system to the left with a magnitude $\mu F_N = \mu m_2 g$) $\Sigma F_{external} = m_{total}a$ gives $(m_1 g - \mu m_2 g - m_3 g) = (m_1 + m_2 + m_3)a$ D

46. $F = ma$ gives $30\text{ N} = (12\text{ kg})a$ or an acceleration of 2.5 m/s^2. The 5 kg block is accelerating due to the tension in the rope $F_T = ma = (5\text{ kg})(2.5\text{ m/s}^2) = 12.5\text{ N}$. C

47. As they are all at the same position after 8 seconds, they all have the same average velocity D

48. Car A decelerates with the same magnitude that C accelerates. Car B is moving at constant speed, which means $F_B = 0$. B

49. When falling with terminal velocity, the force of air resistance equals your weight, regardless of the speed. D

50. For each case, $\Sigma F_{external} = m_{total}a$ gives $Mg - mg = (M + m)a$, or $a = \dfrac{M - m}{M + m} g$. A

51. The two ends of the light string must have the same tension, eliminating choices A and C. If choice D was correct, both masses would be accelerating downward and T_A must be greater than the weight of block A. B

52. $\Sigma F_{external} = m_{total}a$ gives $(M + m)g - Mg = (2M + m)a$ A

53. As the entire system moves as one, $F = (3m)a$, or $a = F/(3m)$. The force of friction acting on block 1 is the force moving block 1 and we have $\mu mg = m(F/(3m))$ D

54. Since the system is moving at constant velocity, m_1 is pushing m_2 and m_3 with a force equal to the force of friction acting on those two blocks, which is $\mu(F_{N2} + F_{N3})$ A

SECTION B – Circular Motion

1. Newton's third law and friction force — B,D
2. $F = mv^2/r$; $v = \sqrt{\frac{Fr}{m}}$; all other variables being constant, if r is quadrupled, v is doubled — D
3. With acceleration south the car is at the top (north side) of the track as the acceleration points toward the center of the circular track. Moving east indicates the car is travelling clockwise. The magnitude of the acceleration is found from $a = v^2/r$ — A
4. The frictional force acts as the centripetal force (toward the center) — C
5. Acceleration occurs when an object is changing speed and/or direction — B,C
6. Velocity is tangential, acceleration points toward the center of the circular path — B
7. To move in a circle, a force directed toward the center of the circle is required. While the package slides to the right in the car, it is actually moving in its original straight line path while the car turns from under it. — D
8. $a = v^2/r$ and $v = 2\pi r/T$ giving $a = 4\pi^2 r/T^2$ — B
9. Once projected, the ball is no longer subject to a force and will travel in a straight line with a component of its velocity tangent to the circular path and a component outward due to the spring — D
10. The net force is inward. The normal force is counteracted by gravity. — C
11. $a = v^2/r$ where $v = 2\pi rf$ and $f = 2.0$ rev/sec — D
12. At Q the ball is in circular motion and the acceleration should point to the center of the circle. At R, the ball comes to rest and is subject to gravity as in free-fall. — C
13. The net force and the acceleration must point in the same direction. Velocity points tangent to the objects path. — D
14. The centripetal force is provided by the spring where $F_C = F_s = kx$ — B
15. In the straight sections there is no acceleration, in the circular sections, there is a centripetal acceleration — B
16. Once the stone is stuck, it is moving in circular motion. At the bottom of the circle, the acceleration points toward the center of the circle at that point. — A
17. Feeling weightless is when the normal force goes to zero, which in only possible going over the top of the hill where mg (inward) – F_N (outward) = mv^2/R. Setting F_N to zero gives a maximum speed of $\sqrt{gR}$ — A
18. Centripetal force points toward the center of the circle — B
19. While speed may be constant, the changing direction means velocity cannot be constant as velocity is a vector. In uniform circular motion, acceleration is constant. — A,C
20. $F = mv^2/r$. $F_{new} = (2m)(2v)^2/(2r) = 4(mv^2/r) = 4F$ — C
21. Assuming the track is circular at the bottom, the acceleration points toward the center of the circular path — A
22. Average speed = (total *distance*)/(total time). Lowest average speed is the car that covered the — C

least distance

23. As all the cars are changing direction, there must be a net force to change the direction of their velocity vectors D

24. $F = mv^2/r$; $v^2 = rF/m$, if r decreases, v will decrease with the same applied force. Also, $v = 2\pi r f$ so $4\pi^2 r^2 f = rF/m$, or $f = F/(4\pi^2 rm)$ and as r decreases, f increases. D

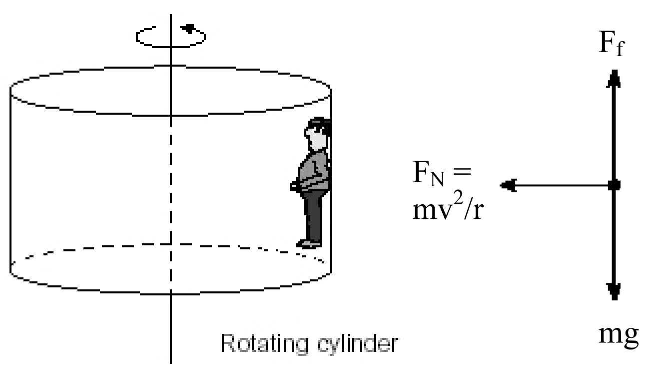
25. There is a force acting downward (gravity) and a centripetal force acting toward the center of the circle (up and to the right). Adding these vectors cannot produce resultants in the directions of B, C or D A

26. $\Sigma F = ma$; $mg + F_T = mv^2/r$ giving $F_T = mv^2/r - mg$ B

27. At the top of the circle, $\Sigma F = F_T + mg = mv^2/R$, giving $F_T = mv^2/R - mg$. At the bottom of the circle, $\Sigma F = F_T - mg = mv^2/R$, giving $F_T = mv^2/R + mg$ The difference is $(mv^2/R + mg) - (mv^2/R - mg)$ B

28. At the bottom of the swing, $\Sigma F = F_T - mg = ma_c$; since the tension is 1.5 times the weight of the object we can write $1.5mg - mg = ma_c$, giving $0.5mg = ma_c$ A

29. B

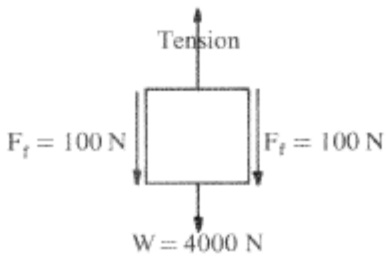


$F_f = mg$ to balance
$\mu F_N = \mu mv^2/r = mg$, where $v = 2\pi rf$ which gives $\mu = g/(4\pi^2 rf^2)$
Be careful! f is given in rev/min (45 rev/min = 0.75 rev/sec) and 8.0 m is the ride's diameter

SECTION A – Linear Dynamics

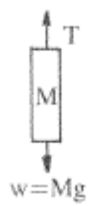
1976B1

a.



b. $\Sigma F = ma$; $T - W - 2F_f = 800$ N; $T = 5000$ N

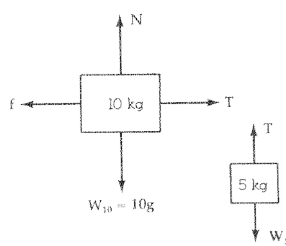
c. Looking at the FBD for the counterweight we have $\Sigma F = ma$; $Mg - T = Ma$
$M = T/(g - a)$ where $T = 5000$ N gives $M = 625$ kg



1979B2

a. $\Sigma F = ma$; $50 \text{ N} - f = ma$ where $f = \mu N$ and $N = mg$ gives $50 \text{ N} - \mu mg = ma$; $a = 3 \text{ m/s}^2$

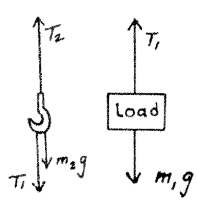
b.



c. $\Sigma F = ma$ for each block gives $W_5 - T = m_5a$ and $T - f = m_{10}a$. Adding the two equations gives
$W_5 - f = (m_5 + m_{10})a$, or $a = 2 \text{ m/s}^2$

1982B2

a.

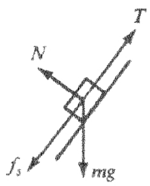


b. T_1 is in internal system force and will cancel in combined equations. Using $\Sigma F_{external} = m_{total}a$ gives
$T_2 - m_1g - m_2g = (m_1 + m_2)a$, solving yields $T_2 = 6600$ N. Now using $\Sigma F = ma$ for the load gives
$T_1 - m_1g = m_1a$ and $T_1 = 6000$ N

1985B2

a. Note that the system is at rest. The only forces on the hanging block are gravity and the tension in the rope, which means the tension must equal the weight of the hanging block, or 100 N. You cannot use the block on the incline because friction is acting on that block and the amount of friction is unknown.

b.

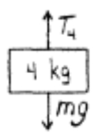


c. $\Sigma F = 0$; $f_s + mg \sin\theta - T = 0$ gives $f_s = 13$ N

1986B1

a. $\Sigma F_{external} = m_{total}a$; $m_4g - m_1g - m_2g = (m_4 + m_2 + m_1)a$ gives $a = 1.4\ m/s^2$

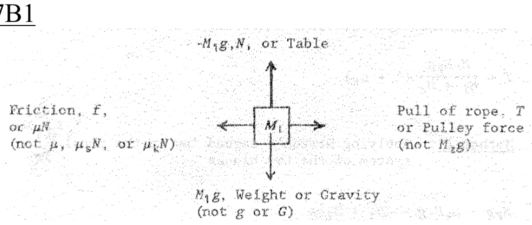
b. For the 4 kg block:
$\Sigma F = ma$
$mg - T_4 = ma$ gives
$T_4 = 33.6$ N



c. Similarly for the 1 kg block: $T_1 - mg = ma$ gives $T_1 = 11.2$ N

1987B1

a.

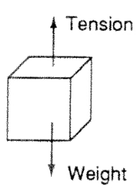


b. $\Sigma F_{ext} = m_{tot}a$; Where the maximum force of static friction on mass M_1 is μ_sN and $N = M_1g$; $M2g - \mu_sM_1g = 0$ gives $\mu_s = M_2/M_1$

c/d. $\Sigma F_{ext} = m_{tot}a$ where we now have kinetic friction acting gives $M_2g - \mu_kM_1g = (M_1 + M_2)a$
so $a = (M_2g - \mu_kM_1g)/(M_1 + M_2)$
$\Sigma F = ma$ for the hanging block gives $M_2g - T = M_2a$ and substituting a from above gives $T = \frac{M_1M_2g}{M_1+M_2}(1+\mu_k)$

1988B1

a.



b. $\Sigma F = ma$ gives $T - mg = ma$ and $T = 1050$ N

c. The helicopter and the package have the same initial velocity, 30 m/s upward. Use $d = v_it + ½ at^2$
$d_h = (+30\ m/s)t + ½ (+5.2\ m/s^2)t^2$ and $d_p = (+30\ m/s)t + ½ (–9.8\ m/s^2)t^2$.
The difference between d_h and d_p is 30 m, but they began 5 m apart so the total distance is 35 m.

1998B1

a. $\Sigma F_{ext} = m_{tot}a$ gives $mg = 2ma$, or $a = g/2$

b. $d = v_0t + ½ at^2$; $h = 0 + ½ (g/2)t^2$ gives $t = 2\sqrt{\frac{h}{g}}$

c. Block A accelerates across the table with an acceleration equal to block B (g/2).

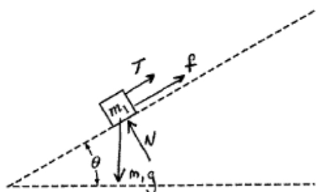
d. Block A is still in motion, but with no more applied force, Block A will move at constant speed across the table.

e. Since block B falls straight to the floor and stops, the distance between the landing points is equal to the horizontal distance block A lands from the edge of the table. The speed with which block A leaves the tabletop is the speed with which block B landed, which is found from $v = v_0 + at = \frac{g}{2}\left(2\sqrt{\frac{h}{g}}\right) = \sqrt{hg}$ and the time for block A to reach the floor is found from $2h = ½ gt^2$, which gives $t = 2\sqrt{\frac{h}{g}}$.

The distance is now $d = vt = \sqrt{hg} \times 2\sqrt{\frac{h}{g}} = 2h$

2000B2

a.



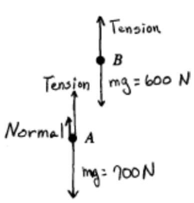
b. $f = \mu N$ where $N = m_1g \cos \theta$ gives $\mu = \frac{f}{m_1 g \cos\theta}$

c. constant velocity means $\Sigma F = 0$ where $\Sigma F_{external} = m_1g \sin\theta + m_2g \sin \theta - f - 2f - Mg = 0$
solving for M gives $M = (m_1 + m_2) \sin \theta - (3f)/g$

d. Applying Newton's second law to block 1 gives $\Sigma F = m_1g \sin \theta - f = m_1a$ which gives $a = g \sin \theta - f/m_1$

2003B1

a.



b. The tension in the rope is equal to the weight of student B: $T = m_Bg = 600$ N
$\Sigma F_A = T + N - m_Ag = 0$ gives $N = 100$ N

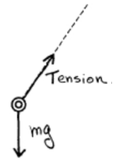
c. For the climbing student $\Sigma F = ma$; $T - m_Bg = m_Ba$ gives $T = 615$ N

d. For student A to be pulled off the floor, the tension must exceed the weight of the student, 700 N. No, the student is not pulled off the floor.

e. Applying Newton's second law to student B with a tension of 700 N gives $\Sigma F = T - m_Bg = m_Ba$ and solving gives $a = 1.67$ m/s^2

2003Bb1

a.



b. We can find the acceleration from $a = \Delta v/t = 2.17\ m/s^2$ and use $d = ½\ at^2$ to find $d = 975\ m$

c. The x and y components of the tension are $T_x = T \sin \theta$ and $T_y = T \cos \theta$ (this is using the angle to the vertical)
Relating these to the other variables gives $T \sin \theta = ma$ and $T \cos \theta = mg$.
Dividing the two equations gives $\tan \theta = a/g = (2.17\ m/s^2)/(9.8\ m/s^2)$ and $\theta = 12.5º$

1996B2

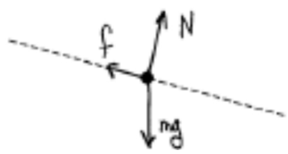
a. There are other methods, but answers are restricted to those taught to this point in the year.
   i. A device to measure distance and a calibrated mass or force scale or sensor
   ii. Hang the mass from the bottom of the spring and measure the spring extension (Δx) or pull on the spring with a known force and measure the resulting extension.
   iii. Use hooke's law with the known force or weight of the known mass $F = k\Delta x$ or $mg = k\Delta x$ and solve for k

b. Many methods are correct, for example, place the object held by the scale on an inclined plane and find the weight using $W\sin\theta = k\Delta x$. One could similarly use a pulley system to reduce the effort applied by the spring scale.

2007B1

a. $x = vt$ gives $t = (21\ m)/(2.4\ m/s) = 8.75\ s$

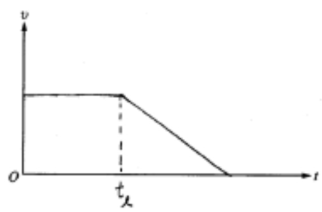
b.



c. $\Sigma F = 0$ if the sled moves at constant speed. This gives $mg \sin \theta - f = 0$, or $f = mg \sin \theta = 63.4\ N$

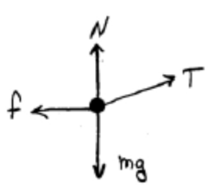
d. $f = \mu N$ where $N = mg \cos \theta$ so $\mu = f/N = (mg \sin \theta)/(mg \cos \theta) = \tan \theta = 0.27$

e. i. The velocity of the sled decreases while its acceleration remains constant
   ii.



2007B1B

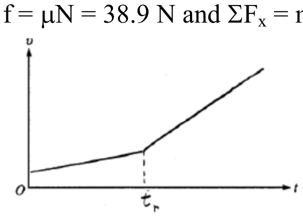
a.



b. $\Sigma F_y = 0$; $N + T \sin \theta - mg = 0$ gives $N = mg - T \sin \theta = 177\ N$

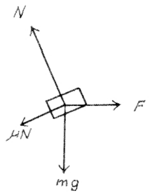
c. $f = \mu N = 38.9\ N$ and $\Sigma F_x = ma$; $T \cos \theta - f = ma$ yields $a = 0.64\ m/s^2$

d.



1981M1

a.



b. F can be resolved into two components: F sin θ acting into the incline and F cos θ acting up the incline. The normal force is then calculated with ΣF = 0; N – F sin θ – mg cos θ = 0 and f = μN
Putting this together gives ΣF = ma; F cos θ – mg sin θ – μ(F sin θ + mg cos θ) = ma, solve for a

c. for constant velocity, a = 0 in the above equation becomes F cos θ – mg sin θ – μ(F sin θ + mg cos θ) = 0
solving for F gives $F = mg\left(\frac{\mu\cos\theta+\sin\theta}{\cos\theta-\mu\sin\theta}\right)$ In order that F remain positive (acting to the right), the denominator must remain positive. That is cos θ > μ sin θ, or tan θ < 1/μ

1986M1

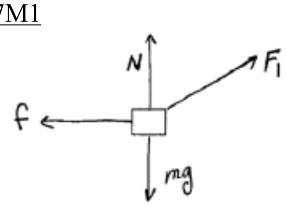
a. Combining the person and the platform into one object, held up by two sides of the rope we have ΣF = ma; 2T = (80 kg + 20 kg)g giving T = 500 N

b. Similarly, ΣF = ma; 2T – 1000 N = (100 kg)(2 m/s^2) giving T = 600 N

c. For the person only: ΣF = ma; N + 600 N – mg = ma gives N = 360 N

2007M1

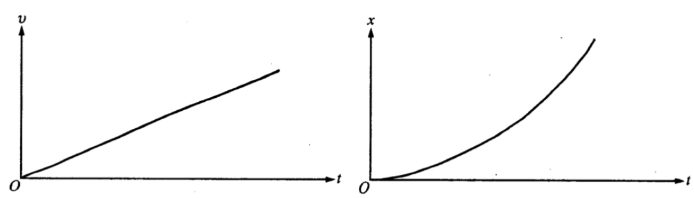
a.



b. $\Sigma F_y = 0$; $N + F_1 \sin\theta - mg = 0$ gives $N = mg - F_1 \sin\theta$

c. $\Sigma F_x = ma$; $F_1 \cos\theta - \mu N = ma_1$. Substituting N from above gives $\mu = (F_1 \cos\theta - ma_1)/(mg - F_1 \sin\theta)$

d.



e. The condition for the block losing contact is when the normal force goes to zero, which means friction is zero as well. $\Sigma F_x = F_{max} \cos\theta = ma_{max}$ and $\Sigma F_y = F_{max} \sin\theta - mg = 0$ giving $F_{max} = mg/(\sin\theta)$ and $a_{max} = (F_{max} \cos\theta)/m$ which results in $a_{max} = g \cot\theta$

1996M2

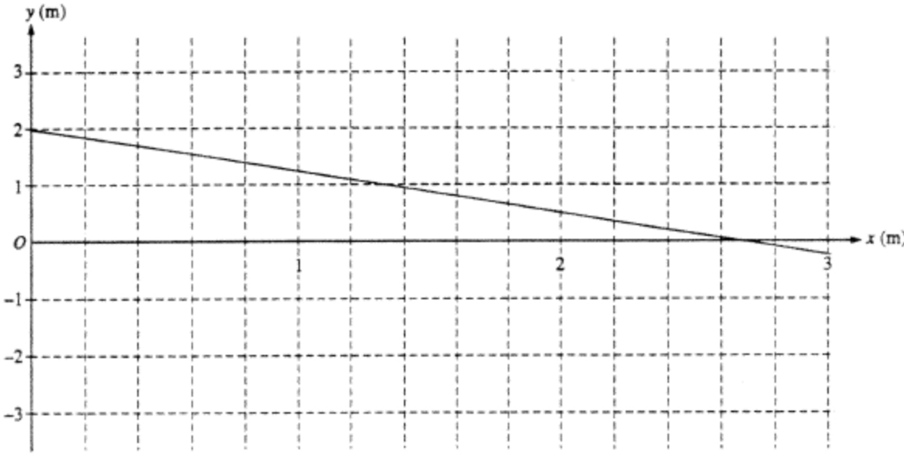
a. $\Sigma F = ma$; using downward as the positive direction, $mg - N = ma_y$ gives $N = m(g - a_y) = 2490$ N

b. Friction is the only horizontal force exerted; $\Sigma F = f = ma_x = 600$ N

c. At the minimum coefficient of friction, static friction will be at its maximum value $f = \mu N$, giving $\mu = f/N =$ (600 N)/(2490 N) = 0.24

d. $y = y_0 + v_{0y}t + \frac{1}{2} a_y t^2 = 2\text{ m} + \frac{1}{2}(-1.5\text{ m/s}^2)t^2$ and $x = x_0 + v_{0x}t + \frac{1}{2} a_x t^2 = \frac{1}{2}(2\text{ m/s}^2)t^2$, solving for t^2 in the x equation gives $t^2 = x$. Substituting into the y equation gives y as a function of x: $y = 2 - 0.75x$

e.

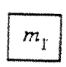


1998M3

a. i.

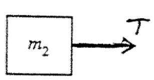
$N_1 = m_1 g$

ii.



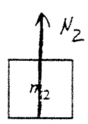
$f_1 = 0$

iii.



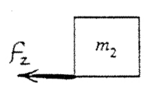
$T = Mg$

iv.



$N_2 = (m_1 + m_2)g$

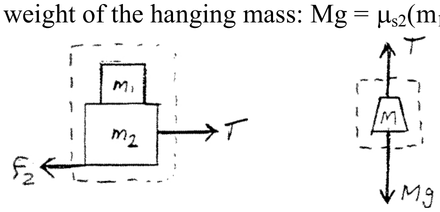
v.



$f_2 = Mg$

b. The maximum friction force on the blocks on the table is $f_{2max} = \mu_{s2}N_2 = \mu_{s2}(m_1 + m_2)g$ which is balanced by the weight of the hanging mass: $Mg = \mu_{s2}(m_1 + m_2)g$ giving $M = \mu_{s2}(m_1 + m_2)$

c.

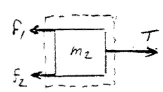


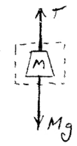
For the hanging block: $Mg - T = Ma$; For the two blocks on the plane: $T - f_2 = (m_1 + m_2)a$

Combining these equations (by adding them to eliminate T) and solving for a gives $a = \left|\frac{M - \mu_{k2}(m_1 + m_2)}{M + m_1 + m_2}\right| g$

d. i. $f_1 = \mu_{k1} m_1 g = m_1 a_1$ giving $a_1 = \mu_{k1} g$

ii.





For the two blocks: $Mg - T = Ma_2$ and $T - f_1 - f_2 = m_2 a_2$. Eliminating T and substituting values for friction gives $a_2 = \left|\frac{M - \mu_{k1} m_1 - \mu_{k2}(m_1 + m_2)}{M + m_2}\right| g$

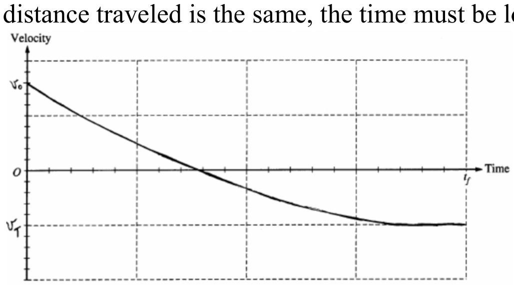
2005M1

a. The magnitude of the acceleration decreases as the ball moves upward. Since the velocity is upward, air resistance is downward, in the same direction as gravity. The velocity will decrease, causing the force of air resistance to decrease. Therefore, the net force and thus the total acceleration both decrease.

b. At terminal speed $\Sigma F = 0$. $\Sigma F = -Mg + kv_T$ giving $v_T = Mg/k$

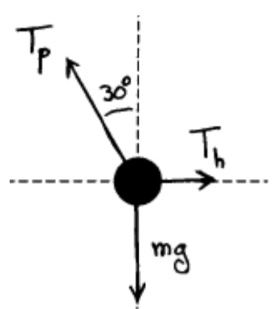
c. It takes longer for the ball to fall. Friction is acting on the ball on the way up and on the way down, where it begins from rest. This means the average speed is greater on the way up than on the way down. Since the distance traveled is the same, the time must be longer on the way down.

d.



2005B2.

(a)



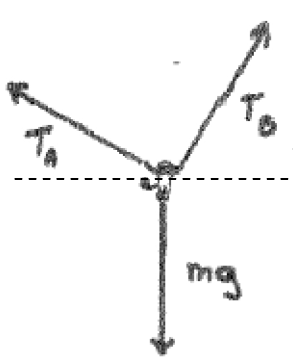
(b) Apply

$F_{net(X)} = 0$
$T_P \cos 30 = mg$
$T_P = 20.37$ N

$F_{net(Y)} = 0$
$T_P \sin 30 = T_H$
$T_H = 10.18$ N

1991B1.

a)



(b) SIMULTANEOUS EQUATIONS

$F_{net(X)} = 0$
$T_a \cos 30 = T_b \cos 60$

$F_{net(Y)} = 0$
$T_a \sin 30 + T_b \sin 60 - mg = 0$

…. Solve above for T_b and plug into Fnet(y) eqn and solve

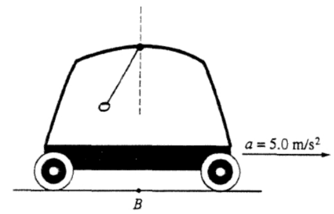
$T_a = 24$ N $T_b = 42$ N

1995B3

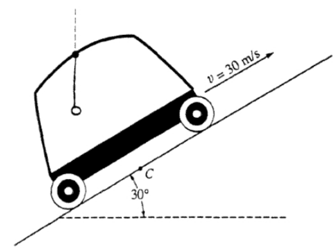
a) i)

ii) T = mg = 1 N

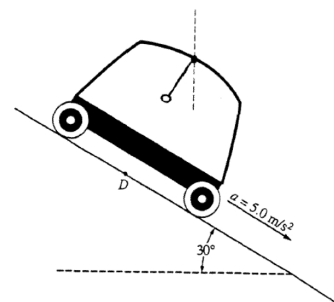
b) The horizontal component of the tension supplies the horizontal acceleration.
$T_h = ma = 0.5$ N
The vertical component of the tension is equal to the weight of the ball, as in (a) ii. $T_v = 1$ N



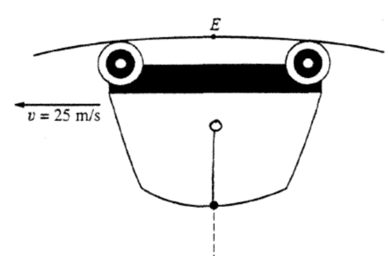
c) Since there is no acceleration, the sum of the forces must be zero, so the tension is equal and opposite to the weight of the ball. T_h =zero, T_v = 1N



d) The horizontal component of the tension is responsible for the horizontal component of the acceleration. Applying Newton's second law:
$T_h = ma \cos \theta$, where θ is the angle between the acceleration and horizontal
$T_h = (0.10 \text{ kg})(5.0 \text{ m/s}^2) \cos 30°$, $T_h = 0.43$ N
The vertical component of the tension counteracts only part of the gravitational force, resulting in a vertical component of the acceleration.
Applying Newton's second law. $Tv = mg - ma \sin \theta$
$Tv = (0.10 \text{ kg})(10 \text{ m/s}^2) - (0.10 \text{ kg})(5.0 \text{ m/s}^2) \sin 30°$, T_v =0.75 N

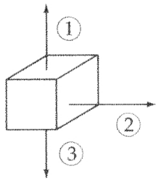


e) Since there is no horizontal acceleration, there is no horizontal component of the tension. T_h = zero
Assuming for the moment that the string is hanging downward, the centripetal is the difference between the gravitational force and the tension. Applying Newton's second law.
$mv^2/r = mg - T_v$, Solving for the vertical component of tension:
$T_v = -1.5$ N i.e. the string is actually pulling down on the ball.



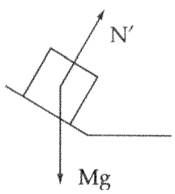
SECTION B – Circular Motion

1977B2

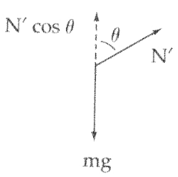
a. 

1 = normal force; 2 = friction; 3 = weight

b. Friction, $f \le \mu N$ where $N = Mg$. Friction provides the necessary centripetal force so we have $f = Mv^2/R$
$Mv^2/R \le \mu Mg$, or $\mu \ge v^2/Rg$

c. 

d. from the diagram below, a component of the normal force N′ balances gravity so N′ must be greater than mg



1984B1

a. At the top of the path, tension and gravity apply forces downward, toward the center of the circle.
$\Sigma F = T + mg = 2Mg + Mg = 3Mg$

b. In the circular path, $F = mv^2/r$ which gives $3Mg = mv_0^2/L$ and $v_0 = \sqrt{3Lg}$

c. The ball is moving horizontally ($v_{0y} = 0$) from a height of 2L so this gives $2L = \frac{1}{2} gt^2$ or $t = 2\sqrt{L/g}$

d. $x = v_0 t = \sqrt{3Lg} \times 2\sqrt{L/g} = 2\sqrt{3}L$

1989B1

a. i. $v_{iy} = 0$ so we have $h = \frac{1}{2} gt^2$ which gives $t = \sqrt{\frac{2h}{g}}$

ii. $x = v_0 t = v_0\sqrt{\frac{2h}{g}}$

iii. $v_x = v_0$; $v_y = v_{iy} + gt = \sqrt{2gh}$
$v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{{v_0}^2 + 2gh}$

b. 

c. Horizontal forces: $T \cos\theta = Mv_0^2/R$; Vertical forces: $T \sin\theta = Mg$. Squaring and adding the equations gives
$T = M\sqrt{g^2 + \frac{{v_0}^4}{R^2}}$

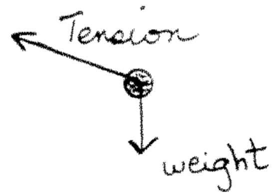
1997B2

a. The circumference of the path, d, can be calculated from the given radius. Use the timer to obtain the period of revolution, t, by timing a number of revolutions and dividing the total time by that number of revolutions. Calculate the speed using v = d/t.

b. If the cord is horizontal, $T = mv^2/r = 5.5$ N

c. (5.5 N – 5.8 N)/(5.8 N) × 100 = –5.2%

d. i.

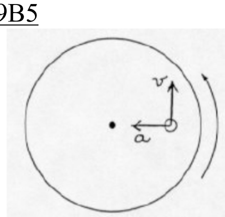


ii. The cord cannot be horizontal because the tension must have a vertical component to balance the weight of the ball.

iii. Resolving tension into components gives $T \sin\theta = mg$ and $T \cos\theta = mv^2/r$ which gives $\theta = 21^\circ$

1999B5

a.



b. v = circumference/period = $2\pi R/T = 2\pi(0.14\text{ m})/(1.5\text{ s}) = 0.6$ m/s

c. The coin will slip when static friction has reached its maximum value of $\mu_s N = \mu_s mg = mv^2/r$ which gives $v = \sqrt{\mu_s g r} = 0.83$ m/s

d. It would not affect the answer to part (c) as the mass cancelled out of the equation for the speed of the coin.

2001B1

a.

b. The minimum speed occurs when gravity alone supplies the necessary centripetal force at the top of the circle (i.e. tension is zero and is not required). Therefore we have $Mg = Mv_{min}^2/R$ which gives $v_{min} = \sqrt{Rg}$

c. At the bottom of the swing $\Sigma F = ma$ becomes $T - Mg = Mv^2/R$ which gives $T_{max} - Mg = Mv_{max}^2/R$ and solving for v_{max} gives $v_{max} = \sqrt{\frac{R}{M}(T_{max} - Mg)}$

d. At point P the ball is moving straight up. If the string breaks at that point, the ball would continue to move straight up, slowing down until it reaches a maximum height and fall straight back to the ground.

2002B2B

a.

b. $\Sigma F_y = 0$; $T \cos \theta - mg = 0$ gives $m = (T \cos \theta)/g$

c. The centripetal force is supplied by the horizontal component of the tension: $F_C = T \sin \theta = mv^2/r$. Substituting the value of m found in part b. and the radius as ($l \sin \theta$) gives $v = \sqrt{gl \sin \theta \tan \theta}$

d. substituting the answer above into $v = 2\pi rf$ gives $f = \frac{1}{2\pi} \sqrt{\frac{g}{l \cos \theta}}$

e. The initial velocity of the ball is horizontal and the subsequent trajectory is parabolic.

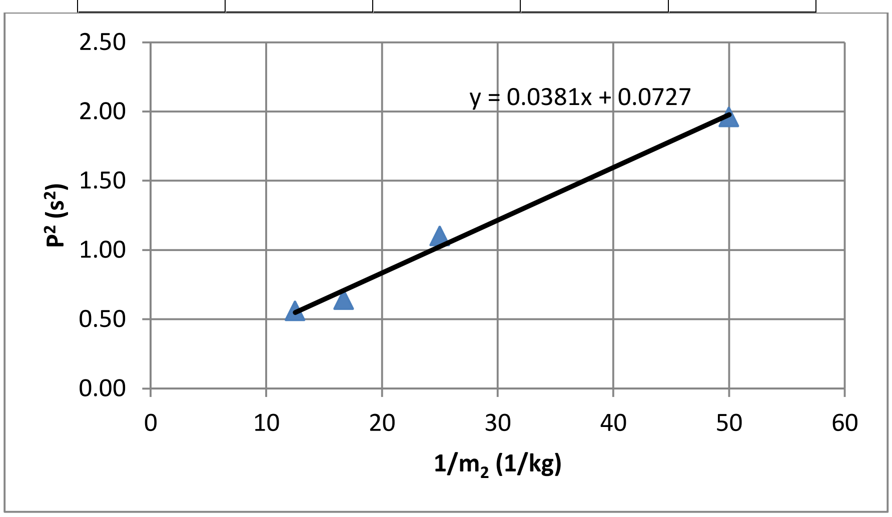
2009B1B

a. The centripetal force is provided by the weight of the hanging mass: $F_C = m_2 g = m_1 v^2/r$ and v is related to the period of the motion $v = 2\pi r/P$. This gives $m_2 g = \frac{m_1 v^2}{r} = \frac{m_1}{r} \frac{4\pi^2 r^2}{P^2}$ and thus $P^2 = 4\pi^2 \left(\frac{m_1 r}{m_2 g}\right)$

b. The quantities that may be graphed to give a straight line are P^2 and $1/m_2$, which will yield a straight line with a slope of $4\pi^2 \left(\frac{m_1 r}{g}\right)$

c.

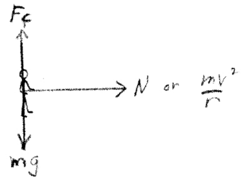
$1/m_2$ (kg^{-1})	50	25	16.7	12.5
m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75
P^2 (s^2)	1.96	1.10	0.64	0.56



d. Using the slope of the line (0.038 kg/s^2) in the equation from part b. gives g = 9.97 m/s^2

1984M1

a.



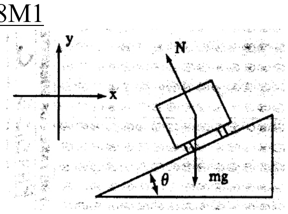
b. $F = mv^2/r$ where $v = 2\pi rf = 2\pi r(1/\pi) = 2r = 10$ m/s giving $F = 1000$ N provided by the normal force

c. $\Sigma F_y = 0$ so the upward force provided by friction equals the weight of the rider = mg = 490 N

d. Since the frictional force is proportional to the normal force and equal to the weight of the rider, m will cancel from the equation, meaning a rider with twice the mass, or any different mass, will not slide down the wall as mass is irrelevant for this condition.

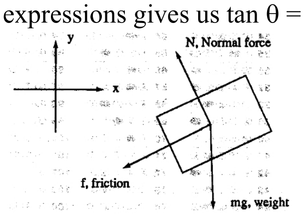
1988M1

a.



Toward the center of the turn we have $\Sigma F = N \sin\theta = mv^2/r$ and vertically $N \cos\theta = mg$. Dividing the two expressions gives us $\tan\theta = v^2/rg$ and $v = 16$ m/s

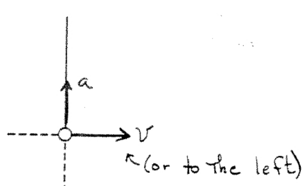
b.



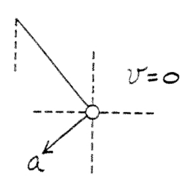
c. $\Sigma F_y = N \cos\theta - f \sin\theta - mg = 0$ and $\Sigma F_x = N \sin\theta + f \cos\theta = mv^2/r$ solve for N and f and substitute into $f = \mu N$ gives $\mu_{min} = 0.32$

1998B6

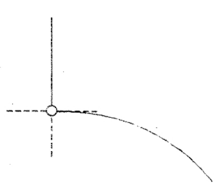
a. i.



ii.

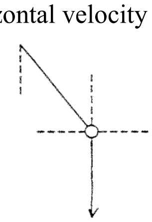


b. i.



The horizontal velocity is constant, the vertical motion is in free fall and the path is parabolic

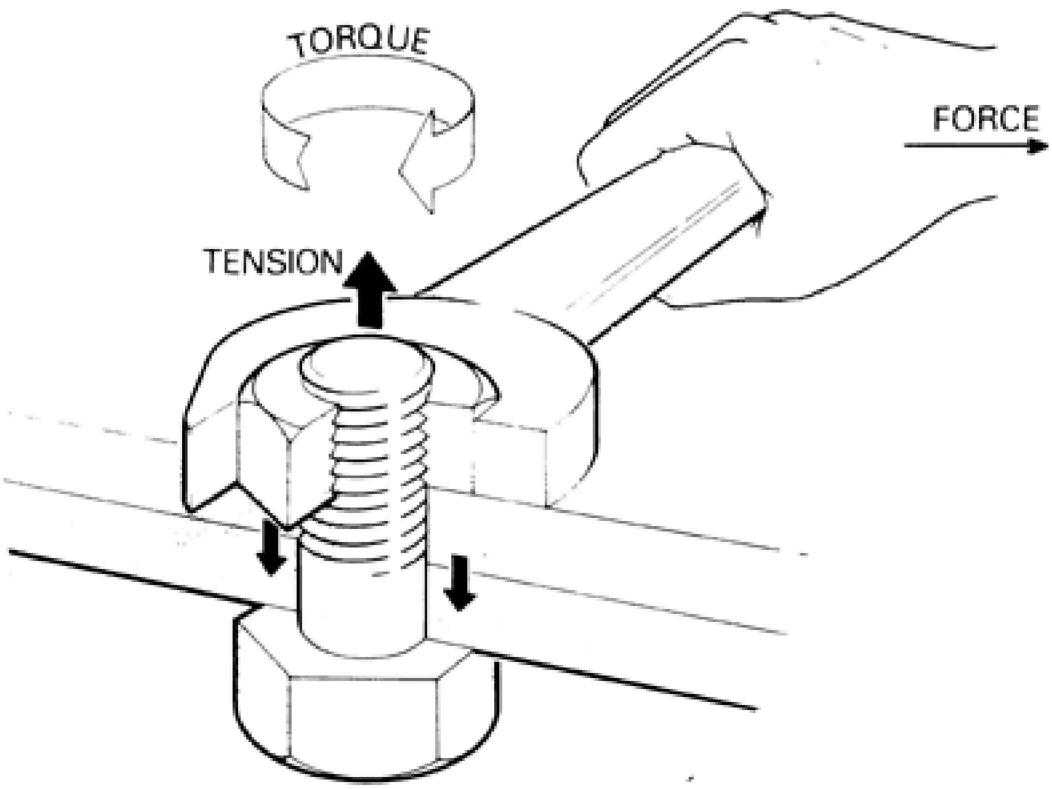
ii.



The ball falls straight down in free fall

Chapter 3

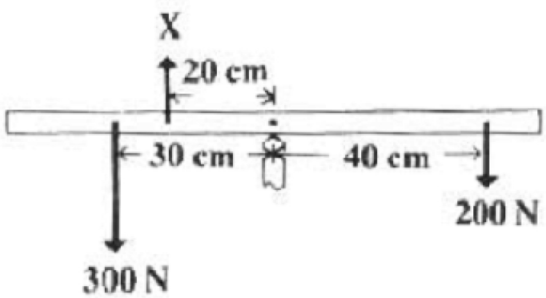
Torque



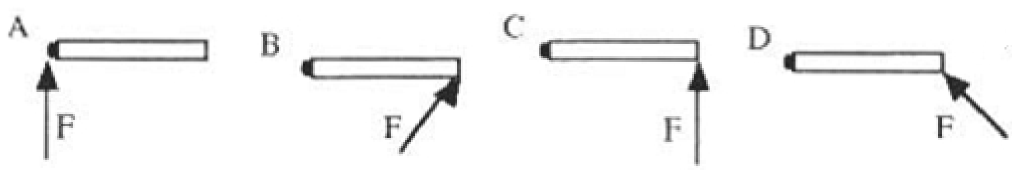
AP Physics Multiple Choice Practice – Torque

1. A uniform meterstick of mass 0.20 kg is pivoted at the 40 cm mark. Where should one hang a mass of 0.50 kg to balance the stick?
(A) 16 cm (B) 36 cm (C) 44 cm (D) 46 cm

2. A uniform meterstick is balanced at its midpoint with several forces applied as shown below. If the stick is in equilibrium, the magnitude of the force X in newtons (N) is
(A) 50 N (B) 100 N (C) 200 N (D) 300 N

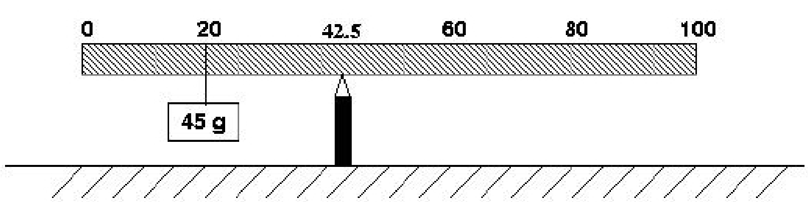


3. A door (seen from above in the figures below) has hinges on the left hand side. Which force produces the largest torque? The magnitudes of all forces are equal.



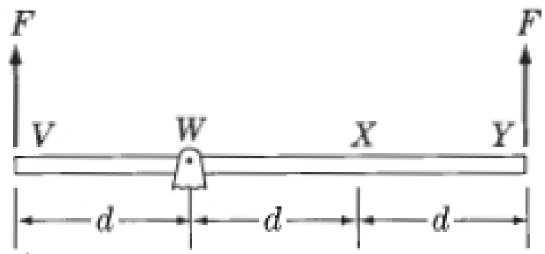
4. A meterstick is supported at each side by a spring scale. A heavy mass is then hung on the meterstick so that the spring scale on the left hand side reads four times the value of the spring scale on the right hand side. If the mass of the meterstick is negligible compared to the hanging mass, how far from the right hand side is the large mass hanging.
(A) 25 cm (B) 67 cm (C) 75 cm (D) 80 cm

5. A uniform meter stick has a 45.0 *g* mass placed at the 20 *cm* mark as shown in the figure. If a pivot is placed at the 42.5 *cm* mark and the meter stick remains horizontal in static equilibrium, what is the mass of the meter stick?



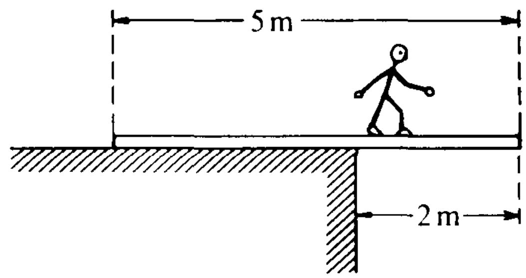
(A) 45.0 *g* (B) 72.0 *g* (C) 120.0 *g* (D) 135.0 *g*

6. A massless rigid rod of length $3d$ is pivoted at a fixed point W, and two forces each of magnitude F are applied vertically upward as shown. A third vertical force of magnitude F may be applied, either upward or downward, at one of the labeled points. With the proper choice of direction at each point, the rod can be in equilibrium if the third force of magnitude F is applied at point

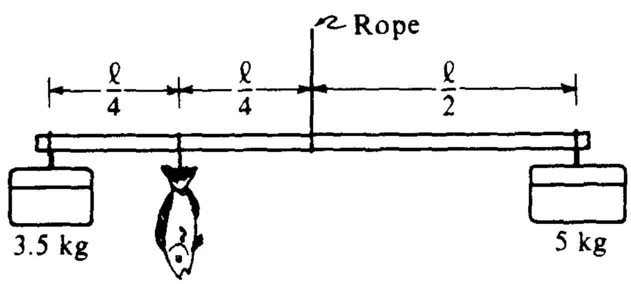


(A) Y only (B) V or X only (C) V or Y only (D) V, W, or X

7. A 5-meter uniform plank of mass 100 kilograms rests on the top of a building with 2 meters extended over the edge as shown. How far can a 50-kilogram person venture past the edge of the building on the plank before the plank just begins to tip?
(A) 0.5 m (B) 1 m (C) 1.5 m (D) 2 m

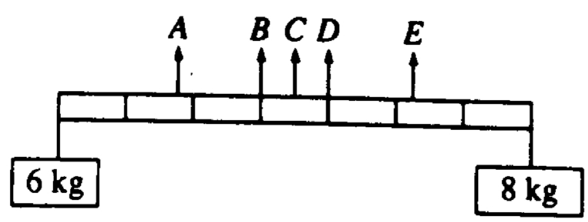


8. To weigh a fish, a person hangs a tackle box of mass 3.5 kilograms and a cooler of mass 5 kilograms from the ends of a uniform rigid pole that is suspended by a rope attached to its center. The system balances when the fish hangs at a point 1/4 of the rod's length from the tackle box. What is the mass of the fish?

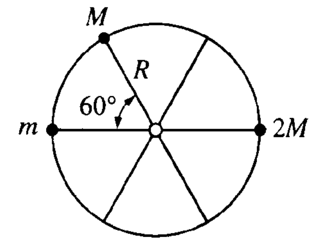


(A) 1.5 kg (B) 2 kg (C) 3 kg (D) 6 kg

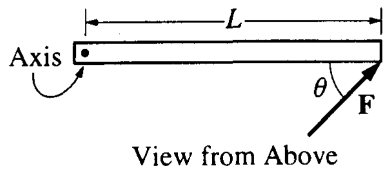
9. Two objects, of masses 6 and 8 kilograms, are hung from the ends of a stick that is 70 cm long and has marks every 10 cm, as shown. If the mass of the stick is negligible, at which of the points indicated should a cord be attached if the stick is to remain horizontal when suspended from the cord?
(A) A (B) B (C) C (D) D



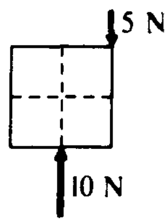
10. A wheel of radius R and negligible mass is mounted on a horizontal frictionless axle so that the wheel is in a vertical plane. Three small objects having masses m, M, and $2M$, respectively, are mounted on the rim of the wheel, as shown. If the system is in static equilibrium, what is the value of m in terms of M?
(A) $M/2$ (B) M (C) $3M/2$ (D) $5M/2$



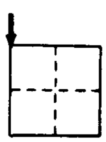
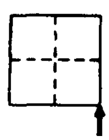
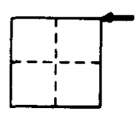
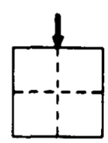
11. A rod on a horizontal tabletop is pivoted at one end and is free to rotate without friction about a vertical axis, as shown. A force **F** is applied at the other end, at an angle θ to the rod. If **F** were to be applied perpendicular to the rod, at what distance from the axis should it be applied in order to produce the same torque?

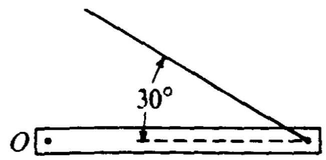


(A) L sin θ (B) L cos θ (C) L (D) L tan θ

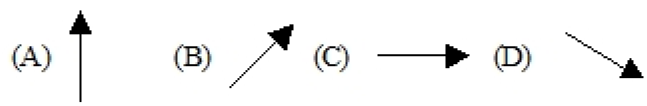


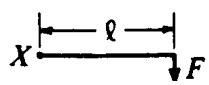
12. A square piece of plywood on a horizontal tabletop is subjected to the two horizontal forces shown. Where should a third force of magnitude 5 newtons be applied to put the piece of plywood into equilibrium?

(A)

(B)

(C)

(D)


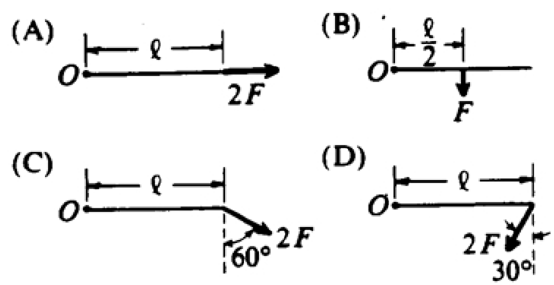


13. A uniform rigid bar of weight W is supported in a horizontal orientation as shown by a rope that makes a 30° angle with the horizontal. The force exerted on the bar at point O, where it is pivoted, is best represented by a vector whose direction is which of the following?

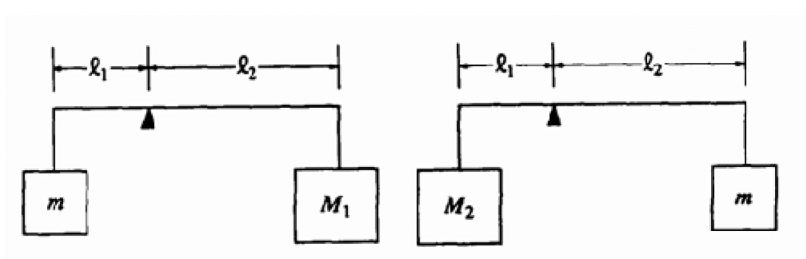




14. In which of the following diagrams is the torque about point O equal in magnitude to the torque about point X in the diagram? (All forces lie in the plane of the paper.)



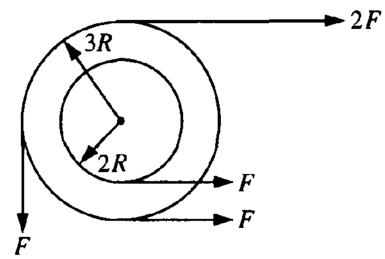
15. A rod of length L and of negligible mass is pivoted at a point that is off-center with lengths shown in the figure below. The figures show two cases in which masses are suspended from the ends of the rod. In each case the unknown mass m is balanced by a known mass, M_1 or M_2, so that the rod remains horizontal. What is the value of m in terms of the known masses?



(A) $\sqrt{M_1 M_2}$ (B) $\frac{1}{2}(M_1 + M_2)$ (C) $M_1 M_2$ (D) $\frac{1}{2}M_1M_2$

16. A system of two wheels fixed to each other is free to rotate about a frictionless axis through the common center of the wheels and perpendicular to the page. Four forces are exerted tangentially to the rims of the wheels, as shown. The magnitude of the net torque on the system about the axis is

(A) zero (B) 2FR (C) 5FR (D) 14FR



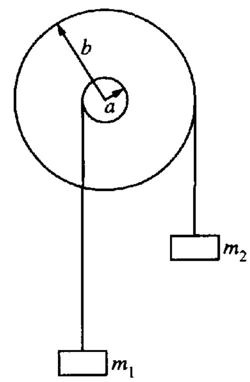
17. For the wheel-and-axle system shown, which of the following expresses the condition required for the system to be in static equilibrium?

(A) $m_1 = m_2$

(B) $am_1 = bm_2$

(C) $am_2 = bm_1$

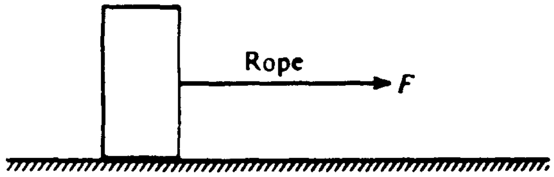
(D) $a^2m_1 = b^2m_2$



18. A meterstick of negligible mass is placed on a fulcrum at the 0.60 m mark, with a 2.0 kg mass hung at the 0 m mark and a 1.0 kg mass hung at the 1.0 m mark. The meterstick is released from rest in a horizontal position. Immediately after release, the magnitude of the net torque on the meterstick about the fulcrum is most nearly

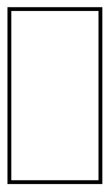
(A) 2.0 N•m (B) 8.0 N•m (C) 10 N•m (D) 16 N•m

AP Physics Free Response Practice – Torque

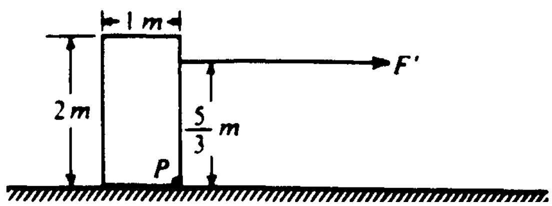


1983B1. A box of uniform density weighing 100 newtons moves in a straight line with constant speed along a horizontal surface. The coefficient of sliding friction is 0.4 and a rope exerts a force F in the direction of motion as shown above.

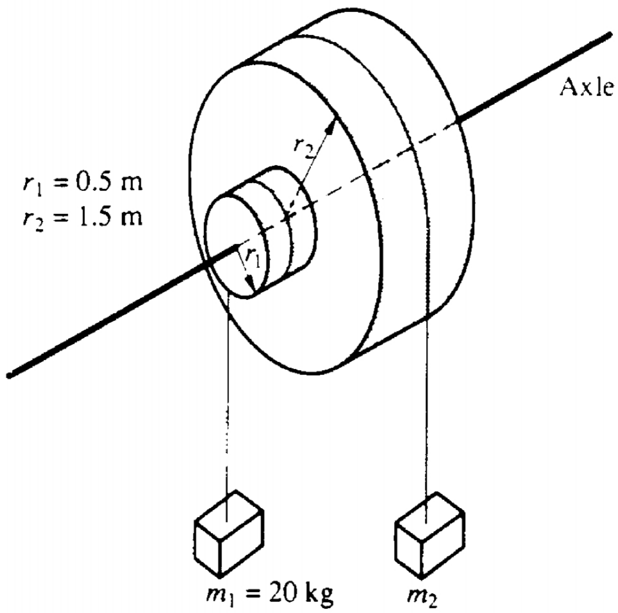
a. On the diagram below, draw and identify all the forces on the box.



b. Calculate the force F exerted by the rope that keeps the box moving with constant speed.

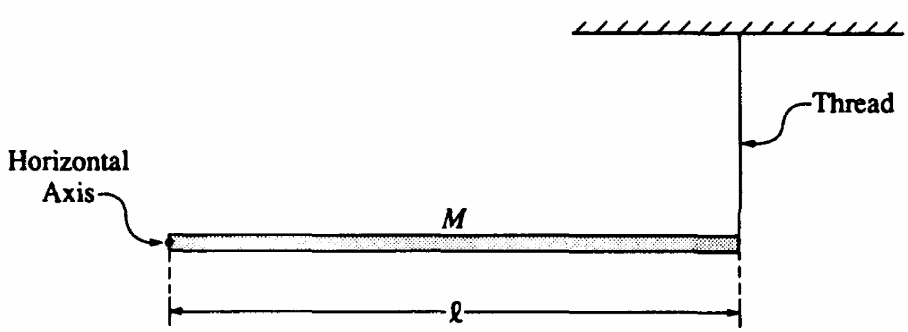


c. A horizontal force F', applied at a height 5/3 meters above the surface as shown in the diagram above, is just sufficient to cause the box to begin to tip forward about an axis through point P. The box is 1 meter wide and 2 meters high. Calculate the force F'.



C1991M2. Two masses. m_1 and m_2, are connected by light cables to the perimeters of two cylinders of radii r_1 and r_2, respectively, as shown in the diagram above with $r_1 = 0.5$ meter, $r_2 = 1.5$ meters, and $m_1 = 20$ kilograms.

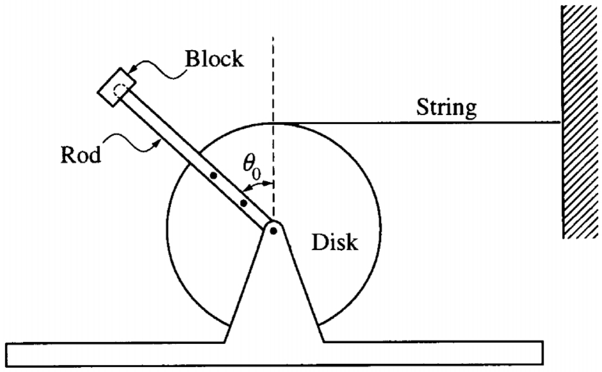
a. Determine m_2 such that the system will remain in equilibrium.



C1993M3. A long, uniform rod of mass M and length *l* is supported at the left end by a horizontal axis into the page and perpendicular to the rod, as shown above. The right end is connected to the ceiling by a thin vertical thread so that the rod is horizontal. Express the answers to all parts of this question in terms of M, L and g.

a. Determine the magnitude and direction of the force exerted on the rod by the axis.

b. If the breaking strength of the thread is 2Mg, determine the maximum distance, r, measured from the hinge axis, that a box of mass 4M could be placed without breaking the thread

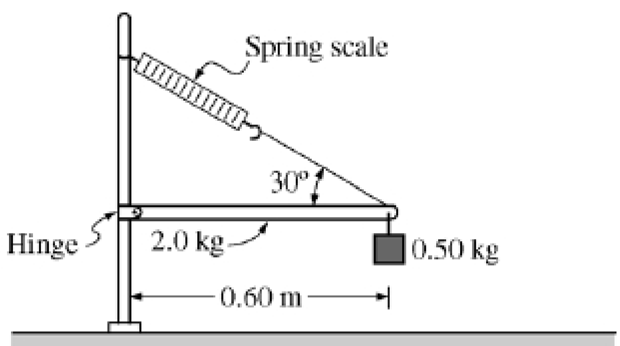


C1999M3. As shown above, a uniform disk is mounted to an axle and is free to rotate without friction. A thin uniform rod is rigidly attached to the disk. A block is attached to the end of the rod. Properties of the rod, and block are as follows.

Rod: mass = m, length = 2R
Block: mass = 2m
Disk: radius = R

The system is held in equilibrium with the rod at an angle θ_o to the vertical, as shown above, by a horizontal string of negligible mass with one end attached to the disk and the other to a wall. Determine the tension in the string in terms of m, θ_o, and g.

C2008M2.

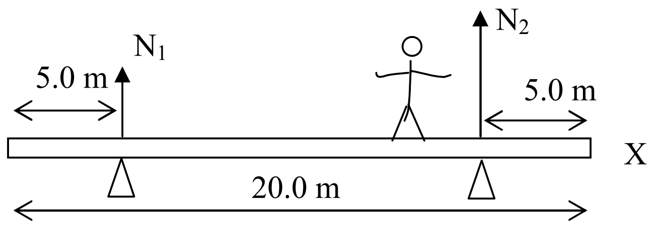


The horizontal uniform rod shown above has length 0.60 m and mass 2.0 kg. The left end of the rod is attached to a vertical support by a frictionless hinge that allows the rod to swing up or down. The right end of the rod is supported by a cord that makes an angle of 30° with the rod. A spring scale of negligible mass measures the tension in the cord. A 0.50 kg block is also attached to the right end of the rod.
(a) On the diagram below, draw and label vectors to represent all the forces acting on the rod. Show each force vector originating at its point of application.

(b) Calculate the reading on the spring scale.
(c) Calculate the magnitude of the force exerted by the hinge on the rod

Supplemental Problem

The diagram below shows a beam of length 20.0 m and mass 40.0 kg resting on two supports placed at 5.0 m from each end.



A person of mass 50.0 kg stands on the beam between the supports. The reaction forces at the supports are shown.

(a) State the value of $N_1 + N_2$

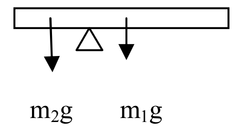
(b) The person now moves toward the X end of the beam to the position where the beam just begins to tip and reaction force N_1 becomes zero as the beam starts to leave the left support. Determine the distance of the girl from the end X when the beam is about to tip.

ANSWERS - AP Physics Multiple Choice Practice – Torque

Solution — Answer

1. Mass of stick m_1=0.20 kg at midpoint, Total length L=1.0 m, Pivot at 0.40 m, attached mass m_2=0.50 kg. — B

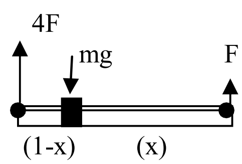
   Applying rotational equilibrium $\tau_{net}=0$
   $(m_1 g) \bullet r_1 = (m_2 g) \bullet r_2$
   (0.2) (0.1 m) = (0.5)(x)
   x = 0.04 m (measured away from 40 cm mark)
   → gives a position on the stick of 36 cm



2. As above, apply rotational equilibrium — A
   + (300) (30cm) – X (20 cm) – (200) (40 cm) = 0

3. Torque = $(Fr)_\perp$ Choices A and E make zero torque, Of the remaining choices, each has moment arm = r but choice C has the full value of F to create torque (perpendicular) while the others would only use a component of F to make less torque — C

4. Applying rotational equilibrium, using location of unknown mass as pivot … — D



   4F (1 – x) = (F) (x)
   4F = 5Fx
   x = 4/5 = 0.80 m measured from right side

5. Applying rotational equilibrium ("g" cancels on each side) — D
   $(m_1 g) \bullet r_1 = (m_2 g) \bullet r_2$
   (45) (22.5 cm) = (m) (7.5 cm) → m = 135 g

6. On the left of the pivot τ=Fd, on the right side of the pivot τ = F(2d). So we either have to add 1(Fd) to the left side to balance out the torque or remove 1(Fd) on the right side to balance out torque. Putting an upwards force on the left side at V gives (2Fd) on the left to balance torques, or putting a downwards force on the right side at X give a total of Fd on the right also causing a balance — B

7. Apply rotational equilibrium using the corner of the building as the pivot point. Weight of plank (acting at midpoint) provides torque on left and weight of man provides torque on right. — B
   $(m_1 g) \bullet r_1 = (m_2 g) \bullet r_2$
   (100 kg) (0.5m) = (50 kg) (r) → r = 1m

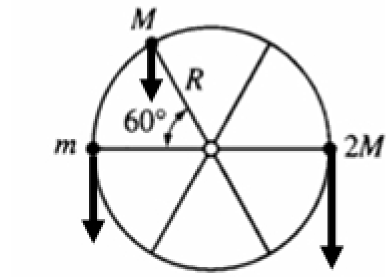
8. Apply rotational equilibrium using the rope as the pivot point. — C
   (3.5)(9.8)(L/2) + m(9.8)(L/4) – (5)(9.8)(L/2) = 0 → m = 3 kg

9. To balance the torques on each side, we obviously need to be closer to the heavier mass. — D
   Trying point D as a pivot point we have:
   $(m_1 g) \bullet r_1$?=? $(m_2 g) \bullet r_2$
   (6kg) (40 cm) ?=? (8kg) (30 cm) and we see it works.

10. Applying rotational equilibrium at the center pivot we get: C

$+mg(R) + Mg(R\cos 60°) – 2Mg(R) = 0.$

Using $\cos 60° = ½$ we arrive at the answer $3M/2$



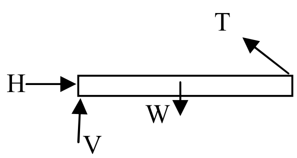
11. Finding the torque in the current configuration we have: A

$(F\sin\theta)(L) = FL \sin \theta.$

To get the same torque with F applied perpendicular we would have to change the L to get $F (L\sin\theta)$

12. To balance the forces (Fnet=0) the answer must be A or D, to prevent rotation, obviously A would be needed. A

13. FBD B



Since the rope is at an angle it has x and y components of force.
Therefore, H would have to exist to counteract Tx.
Based on $\tau_{net} = 0$ requirement, V also would have to exist to balance W if we were to chose a pivot point at the right end of the bar

14. In the given diagram the torque is = FL. C

Finding the torque of all the choices reveals C as correct.

$(2F\sin 60°)(L) = 2F ½ L = FL$

15. Applying rotational equilibrium to each diagram gives A

DIAGRAM 1: $(mg)(L_1) = (M_1g)(L_2)$

$L_1 = M_1(L_2) /m$

(sub this L_1) into the Diagram 2 eqn, and solve.

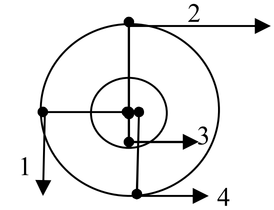
DIAGRAM 2: $(M_2g)(L_1) = mg(L_2)$

$M_2 (L_1) = m (L_2)$

16. Find the torques of each using proper signs and add up. B

$+ (1) – (2) + (3) + (4)$

$+F(3R) – (2F)(3R) + F(2R) +F(3R) = 2FR$



17. Simply apply rotational equilibrium B

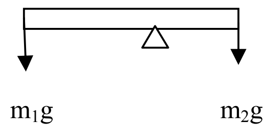
$(m_1g) \bullet r_1 = (m_2g) \bullet r_2$

$m_1a = m_2b$

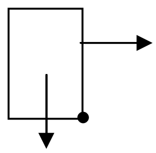
18. Question says meterstick has no mass, so ignore that force. Pivot placed at 0.60 m. Based on the applied masses, this meterstick would have a net torque and rotate. Find the net Torque as follows B

$\tau_{net} = + (m_1g) \bullet r_1 - (m_2g) \bullet r_2$

$+ (2)(10\ m/s^2)(0.6\ m) - (1)(10\ m/s^2)(0.4\ m)$



1983B1.
a) FBD. F_n pointing up, F_g pointing down, f_k applied to base of box pointing left
b) Constant speed → a=0.
Fnet = 0 F – fk = 0 F – uFn = 0 F – (0.4)(100)=0 F = 40 N
c) The force F' occurs at the limit point of tipping which is when the torque trying to tip it (caused by F') is equal to the torque trying to stop it from tipping (from the weight) using the tipping pivot point of the bottom right corner of the box.



(F')(5/3 m) = Fg (0.5m)
(F') (5/3) = (100)(0.5)
F' = 30 N

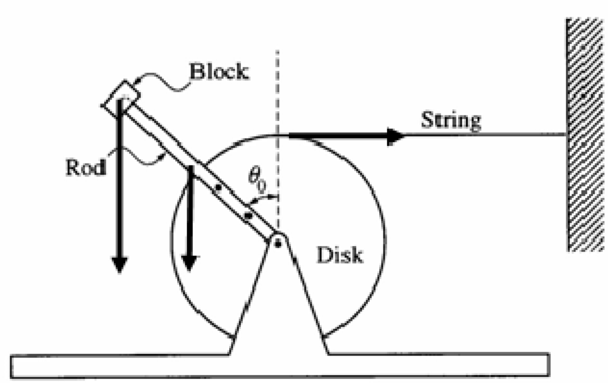
C1991M2.
Apply rotational equilibrium with the center as the pivot
$(m_1g) \bullet r_1 = (m_2g) \bullet r_2$ $(20)(9.8)(0.5) = m_2(9.8)(1.5)$ $m_2 = 6.67$ kg

C1993M3
(a) There is no H support force at the hinge since there are no other horizontal forces acting, so there is only vertical support for V. The tension in the thread T acts upwards and the weight of the rod acts at the midpoint. Apply rotational equilibrium using the hinge axis as the pivot:
$+(T)(L) – (Mg)(L/2) = 0$ $T = Mg/2$

Then using Fnet(y) = 0 $V + T – Mg = 0$ $V + Mg/2 – Mg = 0$ $V = Mg / 2$

(b) Apply rotational equilibrium using the hinge axis as the pivot and "r" as the unknown distance of the box
Thread torque – Box torque - Rod Torque= 0
$(2Mg)(L) – (4Mg)(r) – (Mg)(L/2) = 0$
$2L – 4r – L/2 = 0$ $r = 3/8\ L$

C1999M3



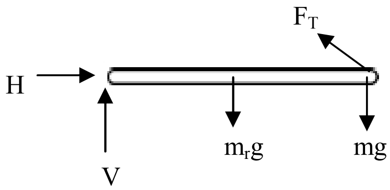
Apply rotational equilibrium using the center of the disk as the pivot

$(m_bg)(2R\sin\theta_o) + (m_rg)(R\sin\theta_o) – T(R) = 0$
$(2mg)(2R\sin\theta_o) + (mg)(R\sin\theta_o) – T(R) = 0$

$T = 5mg(\sin\theta_o)$

C2008M2

a) FBD



b) Apply rotational equilibrium using the hinge as the pivot

$+(F_T\sin30)(0.6) - (mg)(0.6) - (m_rg)(0.3) = 0$

$+(F_T\sin30)(0.6) - (0.5)(9.8)(0.6) - (2)(9.8)(0.3)=0$ $\quad F_T = 29.4$ N

c) Apply Fnet(x), Fnet(y) = 0 to find H and V $\quad$ V=9.8N, H=25.46N

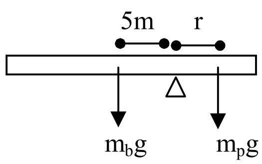
combining H and V $\quad F_{hinge} = 27.28$ N

Supplemental

(a) Simple application of Fnet(y) = 0 $\quad N_1 + N_2 - m_bg - m_pg = 0$

$N_1 + N_2 = (40)(9.8) + (50)(9.8) \quad = 882$ N

(b)



Apply rotational equilibrium

$(m_bg) \bullet r_1 = (m_pg) \bullet r_2$

(40) (5m) = (50) (r) $\quad$ r = 4m from hinge

➔ 1 m from point X