The Project Physics Course

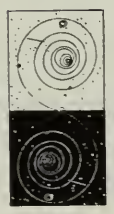
Tests 1

Concepts of Motion

The Project Physics Course

Tests

UNIT 1 Concepts of Motion



A Component of the
Project Physics Course

Distributed by
Holt, Rinehart and Winston, Inc.
New York-Toronto

This publication is one of the many instructional materials developed for the Project Physics Course. These materials include Texts, Handbooks, Teacher Resource Books, Readers, Programmed Instruction Booklets, Film Loops, Transparencies, 16mm films and laboratory equipment. Development of the course has profited from the help of many colleagues listed in the text units.

Directors of Harvard Project Physics

Gerald Holton, Department of Physics, Harvard University
F. James Rutherford, Chairman of the Department of Science Education, New York University, New York
Fletcher G. Watson, Harvard Graduate School of Education

Picture Credit

Cover photo: F. Miller, LIFE MAGAZINE, © Time, Inc.

ISBN: 0-03-084815-6
3456789 039 9876543

TEST A

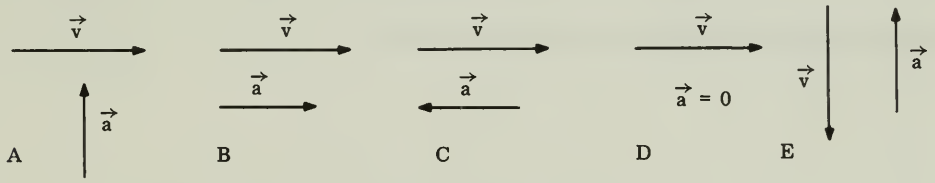
Directions

This test consists of fifteen multiple-choice questions and six problem-and-essay questions, divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

The numerical values of some physical constants and equations that may be useful in the test are given on the last page of this booklet.

1. The arrows show the direction of the velocity and acceleration vectors for a car at five separate instants of time.

   Which diagram applies to the car while it is turning a corner?



2. Several cars are racing on an oval track. Which of the following statements is correct for every racing car after it completes exactly one lap of a race?

   A. Its acceleration is the same as when it crossed the starting line.
   B. Its speed is the same as when it crossed the starting line.
   C. Its displacement from the starting line is zero.
   D. Its acceleration has not changed since it crossed the starting line.
   E. Its velocity has not changed since it crossed the starting line.

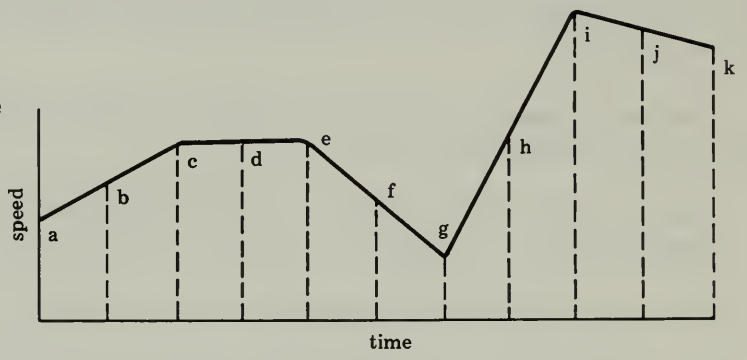
3. ALL EXCEPT ONE of the following require the application of a net force. Which one is the exception?

   A. to change an object from a state of rest to state of motion
   B. to maintain an object in motion at a constant velocity
   C. to change an object's speed without changing its direction of motion
   D. to maintain an object in uniform circular motion
   E. to change an object's direction of motion without changing its speed

4. Which one of the following statements correctly describes a satellite orbiting about the earth?

   A. The acceleration and velocity of the satellite are in roughly the same direction.
   B. There is no force acting on the satellite.
   C. The velocity of the satellite is constant.
   D. The satellite must fall back to earth when its fuel is gone.
   E. The satellite is always accelerating toward the earth.

Questions 5 and 6 refer to the graph at the right.



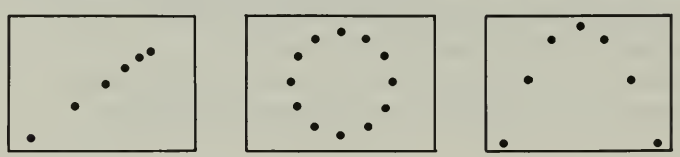
5. The magnitude of the acceleration is greatest in the time interval

   A. a to c.
   B. c to e.
   C. e to g.
   D. g to i.
   E. i to k.

6. The speed is greatest at the time corresponding to point

   A. c.
   B. g.
   C. h.
   D. i.
   E. k.

7. The following are diagrams which represent stroboscopic photographs of a ball. The strobe rate is constant and is the same for all three pictures.



Which of the photographs could be produced with a stationary ball and a moving camera?

   A. None
   B. 1 only
   C. 2 only
   D. 1 and 2 only
   E. 1, 2 and 3

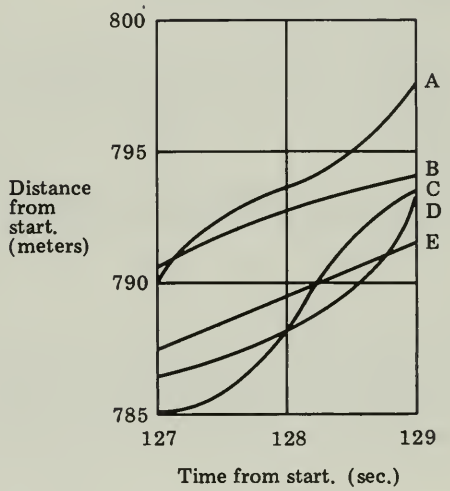
Questions 8 and 9 refer to the graph at the right and statement below. The graph shows the positions of five sprinters near the end of an 800-meter race.

8. The average speed of sprinter C in the time period 127 second to 129 second from the start was approximately

   A. 4 m/sec.
   B. 6.5 m/sec.
   C. 8 m/sec.
   D. 9 m/sec.
   E. 13 m/sec.

9. Which sprinter runs with uniform speed during the time period shown?

   A. sprinter A
   B. sprinter B
   C. sprinter C
   D. sprinter D
   E. sprinter E



10. A golf ball is hit toward the pin from a point on the same level as the pin and 110 yards away. It strikes the ground near the pin. Assuming that air resistance had no effect on the ball's path, what is the best estimate of the location at which it reached the highest point in its path?

    A. within 30 yards of where it was hit
    B. about halfway to the pin
    C. approximately two-thirds of the way to the pin
    D. almost directly over the pin
    E. no estimate is possible. The data are not sufficient for a decision.

Questions 11 and 12 refer to the following, which is a hypothetical report submitted by an astronaut about a space maneuver intended to link two capsules:

"At 5:01:00 A.M. we activated Rocket Z-4 for 10 seconds. (1) The thrust gauge showed that the rocket produced a force of 77 newtons. (2) Accordingly, we estimated a velocity toward the target vehicle of 4 meters/second. (3) We expected to touch the target vehicle in 300 seconds, at 5:06:10. (4) Actually, we touched at 5:06:28." (5)

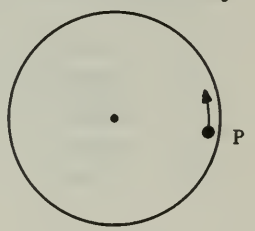
11. Which of the sentences above gives the result of a computation done by the astronaut that involved the use of Newton's second law?

A. 1 only B. 2 only C. 3 only D. 4 only E. 2, 3 and 4 only

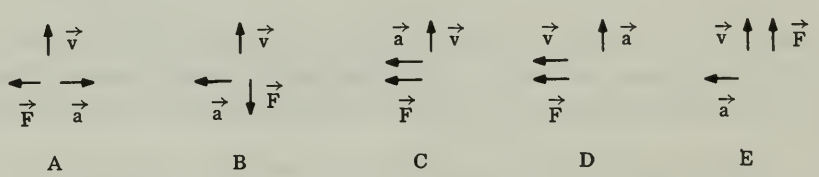
12. Which of the sentences above describes how the astronaut changed conditions to perform the maneuver?

A. 1 only B. 4 only C. 5 only D. 1 and 4 only E. 1 and 5 only

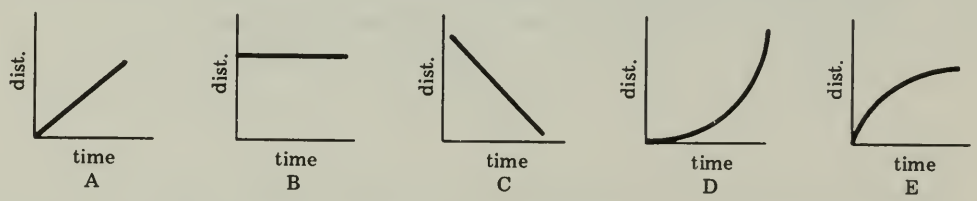
13. A child is riding on a merry-go-round, as shown at the right. When he is at point P, which set of vectors shows the direction of his velocity $\vec{v}$, his acceleration $\vec{a}$ and the centripetal force $\vec{F}$ acting on him?



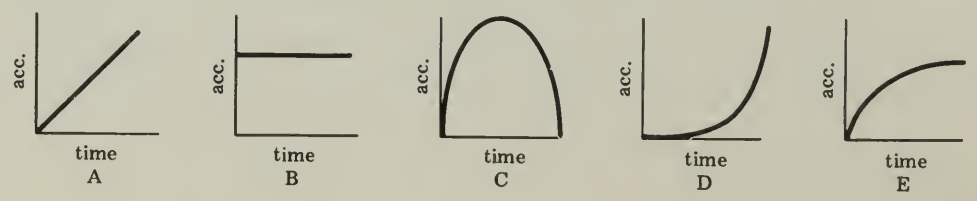
A. set A
B. set B
C. set C
D. set D
E. set E



14. A steel ball rolls down an inclined plane. Which graph best represents how the distance traveled changes with time?



15. A propeller rotates with constant rate. If we consider the two ends of the propeller, which graph best represents how the magnitude of their acceleration changes with time?

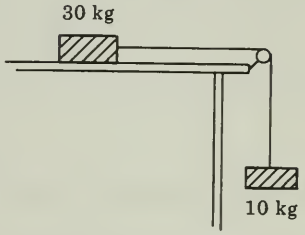


PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following four questions.

1. A 30-kilogram block lies on a frictionless table, and is connected to a 10-kilogram block by a rope passing over a frictionless pulley, as shown in the diagram.

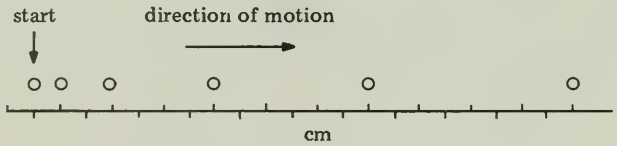


   a) What is the acceleration of the 10-kilogram block?

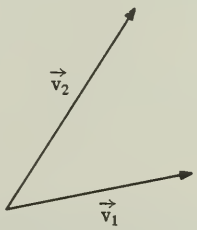
   b) What is the acceleration of the 30-kilogram block?

2. A car accelerates away from a stoplight. Use this example of a moving object to explain the difference between average speed and instantaneous speed.

3. The diagram below illustrates the motion of a ball as if it were recorded by a camera whose shutter remained open and whose only source of light was a stroboscopic lamp flashing 10 times per second. On this diagram 1.0 centimeter represents 1.0 centimeter in the laboratory. What was the acceleration of the ball?



4. Find $\Delta\vec{v}$, where $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

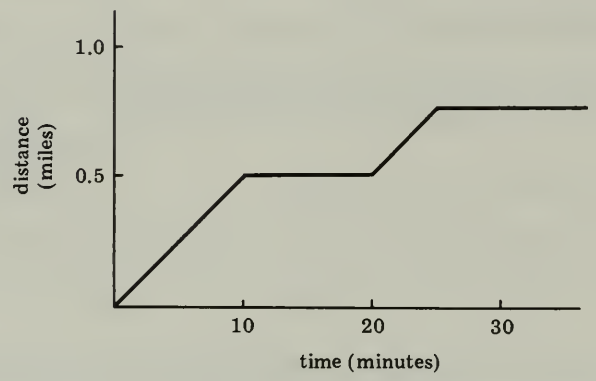


Group Two

Answer ONE of the following two questions.

5. Galileo held that the proper language with which to describe nature is mathematics. How is our understanding of natural phenomena aided by describing what we observe in mathematical terms?

6. A man goes for a walk. Write a description of his motion that includes numerical values of time, distance and speed, based on the information contained in the graph below.

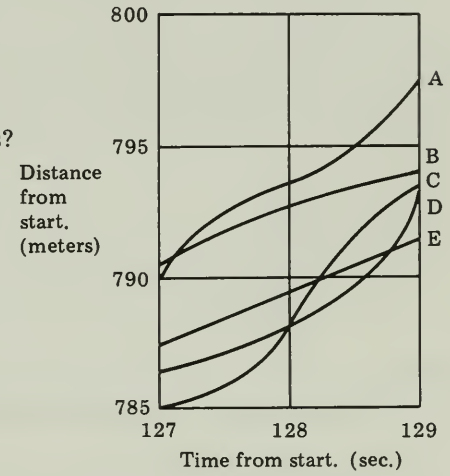


Directions

This test consists of fifteen multiple-choice questions and six problem-and-essay questions, divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

The numerical values of some physical constants and equations that may be useful in the test are given on the last page of this booklet.

Questions 1 and 2 refer to the figure at right, which shows the positions of five runners near the end of an 800-meter race.



1. Which sprinter was ahead after exactly 127 seconds?

   A. sprinter A
   B. sprinter B
   C. sprinter C
   D. sprinter D
   E. sprinter E

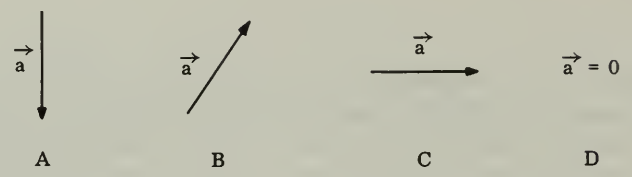
2. With what average speed did E run in the interval 127 to 129 seconds?

   A. 1 m/sec
   B. 2 m/sec
   C. 4 m/sec
   D. 5 m/sec
   E. 11 m/sec

3. Which of the following four statements describes the motion of a bullet that has been fired by a supersonic jet fighter plane flying parallel to the ground? (Neglect air resistance.)

   A. uniform straight-line motion
   B. uniformly accelerated straight-line motion
   C. circular motion
   D. projectile motion

4. Which of the following four diagrams represents the acceleration of a golf ball the instant after it leaves the face of a golf club?



5. An ice skater gives a sudden push to a sled that sends it sliding away from him. Consider the following statements (assume friction is negligible).

   1. The force exerted on the sled by the skater is equal in magnitude to the force exerted on the skater by the sled.
   2. During the push the acceleration of the skater is equal in magnitude to the acceleration of the sled.
   3. The skater will accelerate for the same length of time as the sled.

   Which of the statements is true if the skater and the sled have the same mass?

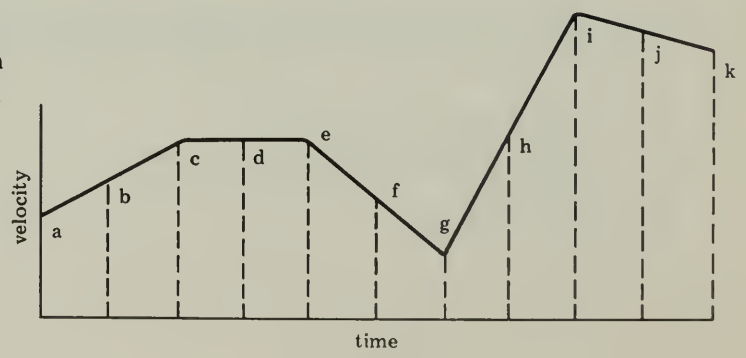
   A. 1 only
   B. 2 only
   C. 3 only
   D. 2 and 3 only
   E. 1, 2 and 3

6. A child is riding on a merry-go-round that is rotating at a constant rate. The child has

   A. constant velocity.
   B. constant acceleration.
   C. constant speed.
   D. constant acceleration and speed
   E. constant velocity, acceleration and speed

7. In the graph at the right, the magnitude of the acceleration is greatest in the time interval

   A. a to c.
   B. c to e.
   C. e to g.
   D. g to i.
   E. i to k.



8. ALL EXCEPT ONE of the following require a net unbalanced force. Which is the exception?

   A. to set into motion an object which is initially at rest
   B. to maintain an object in a state of constant velocity
   C. to maintain an object in a state of uniform circular motion
   D. to stop a moving object
   E. to change an object's direction of motion while keeping its speed constant

9. The distance d traveled by an object is given by the equation $d = \frac{1}{2} at^2$, when the object

   A. is moving in a circle.
   B. has a constant velocity.
   C. starts from rest and accelerates uniformly.
   D. is thrown upward.
   E. is thrown downward.

10. This test paper is sitting at rest on your desk. Which of the following statements best describes this situation?

    A. There are no forces acting on your paper.
    B. Your paper is at rest in any coordinate system.
    C. Your paper exerts no force on the desk.
    D. There are many forces acting on your paper, but they balance each other.

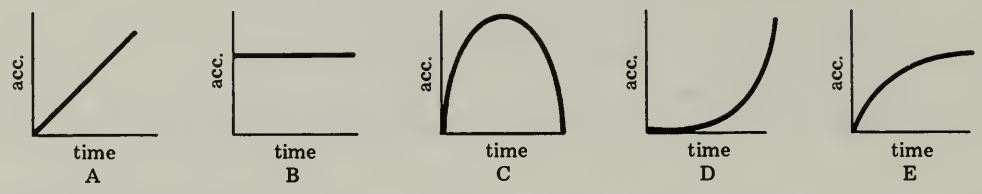
11. A satellite is in orbit around the earth. In the absence of air friction, which of the following statements is necessarily true?

    A. The acceleration and velocity of the satellite are in approximately the same direction.
    B. There is no force acting on the satellite.
    C. The velocity of the satellite is constant.
    D. The satellite must fall back to earth when its fuel is gone.
    E. The satellite always accelerates towards the earth.

12. If you must choose between two hypotheses, which of the following is the best reason for selecting hypothesis 1 rather than hypothesis 2?

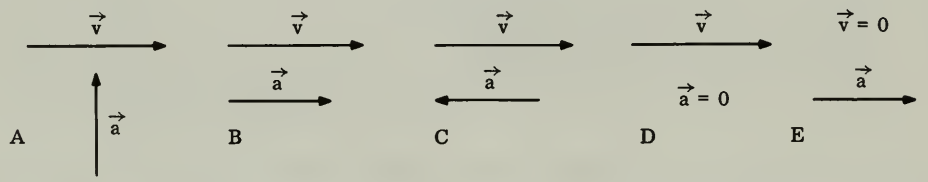
    A. Hypothesis 1 is more in agreement with the observed facts.
    B. Hypothesis 1 contains more mathematics.
    C. Hypothesis 1 is newer.
    D. Hypothesis 1 is more easily understood.
    E. Several people think hypothesis 1 is more likely to be correct.

13. A rock is thrown into the air. Which graph represents how the magnitude of its acceleration changes with time while it is in the air? (Neglect air resistance.)



14. A propeller blade rotates at a constant rate. Which graph best represents how the magnitude of the force on one tip of the propeller changes with time?

15. In the diagrams shown below, arrows show the direction of the velocity and acceleration vectors for a car at five separate instants of time. Which diagram represents the car starting from rest?



PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following four questions.

1. Upon observing a rolling object, you obtained the following values for d/t^2, where d is the distance rolled and t the elapsed time.

d/t^2
0.00185
0.00183
0.00192
0.00182
0.00187
0.00182

Do these data justify the conclusion that d/t^2 is a constant? Explain.

2. Consider the motion of a flare dropped from an airplane flying at constant velocity. Describe this motion as seen by observers in the airplane and on the ground.

3. What is the difference between the concepts "weight" and "mass"?

4. An object resting on a level frictionless surface on the earth is subjected to a horizontal force equal to its weight. What is the magnitude of its acceleration?

Group Two

Answer ONE of the following two questions.

5. Joe and Louis are arguing about uniform acceleration. Joe says that acceleration means "the longer you go, the faster you go." Louis states that acceleration means "the farther you go, the faster you go."

   a) Present their points of view in terms of an equation or equations.
   b) Who is right and why?

6. Galileo approached scientific problems in ways different from Aristotle and the Scholastics. Two of these differences are listed below. Select one and explain why you think it was important to the development of physics.

   a) insistence that experiment and observation must be quantitative, not just qualitative.
   b) abstraction from real situations to idealized ones that show the laws of nature in their simplest form.

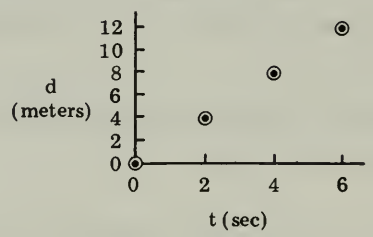
Directions

Answer ALL forty multiple-choice questions by marking the letter corresponding to the one best answer.

The numerical values of some physical constants and equations that may be useful in the test are given on the last page of this booket.

1. An experiment yielded the data given in the table and graph below.

t (seconds)	d (meters)
0	0
2	4
4	8
6	12



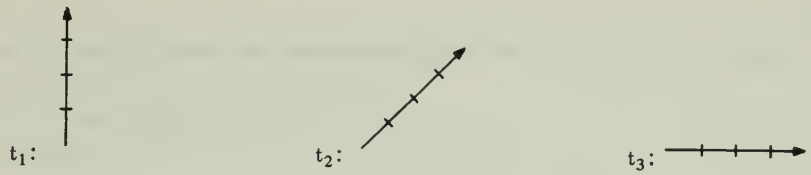
If these data are expressed as an equation, d = kt, the value of k is

A. 1 m/sec.
B. 1 sec/m.
C. 2 m/sec.
D. 2 sec/m.
E. 0.5 m/sec.

2. Referring to his work, Newton wrote, "If I have seen further than others, it is because I have stood on the shoulders of giants." Who of the following was one of the "giants" whose work on motion immediately preceded Newton's?

A. Fermi
B. Galileo
C. Simplicio
D. Aristotle

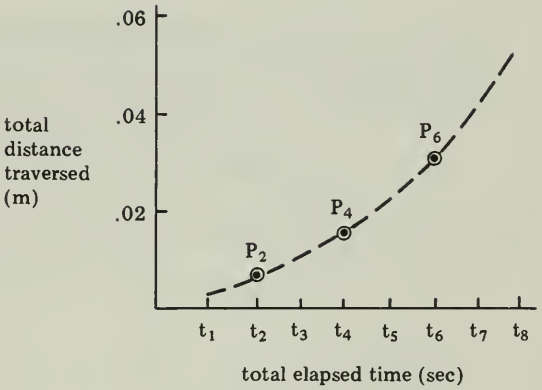
3. The arrows drawn below represent the velocity vectors of a Boeing 707 jet at three successive times.



We may conclude that the jet was

A. changing direction.
B. speeding up.
C. slowing down.
D. maintaining a constant velocity.

Questions 4 and 5 refer to the following statement and graph: The graph at the right shows the relationship between the time and the total distance traversed by a glider moving on a nearly frictionless air track. Points P_2, P_4 and P_6 represent the experimental measurements. The dotted curve is a smooth curve drawn through these points.



4. If the values of the total distance traversed at times t_5, t_6 and t_8 are arranged in order of uncertainty with the most *uncertain* value of distance first, the order is

A. t_5, t_6, t_8.
B. t_8, t_6, t_5.
C. t_5, t_8, t_6.
D. t_6, t_5, t_8.
E. t_8, t_5, t_6.

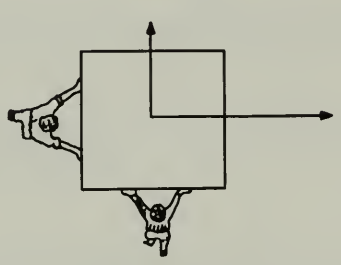
5. The slope of the curve at t_4 represents the

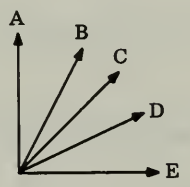
A. total distance traversed.
B. instantaneous speed.
C. acceleration.
D. rates of change of speed.
E. average speed.

TEST C

6. Two men push on a box resting on a smooth level floor as indicated in the diagram below. The lengths of the arrows are drawn proportional to the magnitude of the force each man exerts on the box.

   In the diagram below, which arrow indicates the direction in which the box will start to move?





7. A satellite is in a circular orbit around a planet. The satellite's period of revolution T, and the radius of the orbit R are known. Which of the following equations must you use to compute its acceleration?

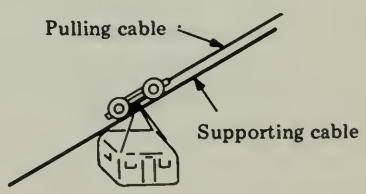
   A. $d = \frac{1}{2} aT^2$ only.
   B. $v = \frac{2\pi R}{T}$ and $v = aT$.
   C. $v = \frac{2\pi R}{T}$ and $a = \frac{v^2}{R}$
   D. $d = \frac{1}{2} aT$ and $a = \frac{v^2}{R}$
   E. $v = aT$ and $a \frac{v^2}{R}$

8. A man pushes a puck on a frictionless horizontal surface with a force of 10 newtons. The resulting acceleration is 4.0 meters/second^2. What is the mass of the puck?

   A. 0.4 kg
   B. 2.5 kg
   C. 4.0 kg
   D. 10 kg
   E. 40 kg

9. The diagram at right shows a cable car supported by an overhead cable and pulled uphill by a second cable. Which of the following forces is zero when the cable car moves with constant velocity?

   A. net unbalanced force on the car and carriage
   B. frictional force on the wheels of the carriage
   C. force of gravity on the car and carriage
   D. force exerted by supporting cables
   E. force exerted by the cable that pulls the car upward



10. In ALL EXCEPT ONE of the following situations, an object is being accelerated. Which one is the exception?

    A. The object changes direction without changing speed.
    B. The object changes speed without changing direction.
    C. The object maintains speed and direction.
    D. The object maintains uniform circular motion.
    E. The object moves in the trajectory of a projectile.

Questions 11 and 12 refer to the following situation.

During a planned maneuver in space flight, a free-floating astronaut pushes a free-floating instrument package. The mass of the astronaut is greater than that of the instrument package.

11. The force exerted by the astronaut on the instrument package

    A. is equal to the force exerted by the package on the astronaut.
    B. is greater than the force exerted by the package on the astronaut.
    C. is less than the force exerted by the package on the astronaut.
    D. is equal to zero.
    E. may be greater than, less than, or equal to the force exerted by the package on the astronaut; one cannot tell with the information given here.

12. During the push

    A. the magnitude of the acceleration of the astronaut is greater than that of the instrument package.
    B. the magnitude of the acceleration of the astronaut is smaller than that of the instrument package.
    C. neither astronaut nor instrument package is accelerated.
    D. the accelerations of each are equal in magnitude but opposite in direction.
    E. the accelerations of each are equal in magnitude and in the same direction.

13. In *Two New Sciences* Salviati, speaking for Galileo, defines "a motion to be uniformly accelerated, when starting from rest it acquires during equal time intervals, equal increments of speed." This definition is important because it

    A. convinces Simplicio, the spokesman for Aristotelian physics.
    B. corresponds closely to the way real objects fall near the surface of the earth.
    C. explains the cause of acceleration of falling objects.
    D. is correct regardless of the air resistance of falling objects.
    E. is the only definition that can be tested by experiment.

14. ALL EXCEPT ONE of the following statements would be operational definitions of one second of time. Which one is the exception?

One second is

A. a little more time than there is between the pulsebeats of most people.
B. the shortest unit of time.
C. 1/86,400 of the time it takes the earth to make one rotation about its axis.
D. the length of a time interval a little shorter than it takes a student to answer this question.

Questions 15 and 16 refer to the following statement.

Scientists on the imaginary planet Q have defined a unit of length, the "lar," to be the distance between two mountain peaks on the surface of the planet. The unit of time on the planet Q is called the "tik" and is defined as the average interval between pulsebeats of the king.

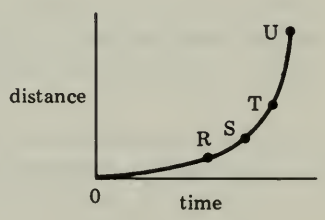
15. What units would express acceleration on planet Q if acceleration were defined as it is on earth?

A. lar/tik
B. lar/sec
C. lar^2/sec
D. tik/lar^2
E. lar/tik^2

16. If the distance between the cities Zytropolis and Elany on planet Q is 20 lars, what would your average speed be if you made the trip in 100 tiks?

A. 0.2 lars/tik
B. 0.1 tiks/lar
C. 5 tiks/lar
D. 5 lars/tik
E. 100 tiks/lar

17. The graph at the right represents the distance traveled by an automobile as a function of time. The instantaneous speed at the time corresponding to point S is best approximated by the slope of a straight line drawn between points



A. S and T.
B. O and S.
C. R and S.
D. R and T.
E. R and U.

18. A subway car is at rest in a subway station. A boy sitting in the car flips a dime into the air; the dime hits the floor. Later, when the car is moving over a straight, level section of track at a high, constant speed, he flips the dime again in exactly the same way. Where does the dime hit the floor?

A. at the same spot on the floor as before.
B. ahead of where it hit before.
C. behind where it hit before.

Questions 19 and 20 refer to the following statements concerning Galileo's work with balls rolling down inclined planes. This work led to the acceptance of the idea that falling objects accelerate uniformly. The quotations are from *Two New Sciences.*

1. If speed during fall increases with time, $\frac{d}{t^2}$ is constant.

2. "We took a piece of wooden scantling, about 12 cubits long, half a cubit wide, and three finger breadths thick. In its top edge we cut a straight channel."

3. "Having raised the scantling in a sloping position by raising one end some one or two cubits above the other, we let the ball roll down the channel."

4. "We always found that the distances traversed were to each other as the squares of the times."

5. Since for a rolling ball $\frac{d}{t^2}$ is constant, $\frac{d}{t^2}$ is constant for a falling ball also.

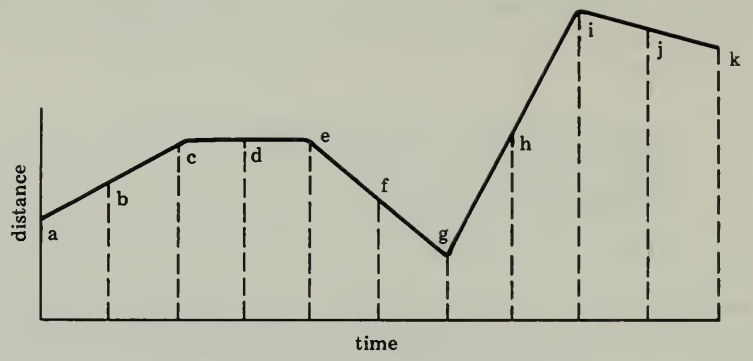
19. Which of the statements are assumptions made by Galileo?

A. 1 only
B. 4 only
C. 5 only
D. 1 and 4 only
E. 4 and 5 only

20. Which statement presents experimental results?

A. 1 only
B. 4 only
C. 5 only
D. 2 and 3 only
E. 1 and 5 only

Questions 21 and 22 refer to the following graph.



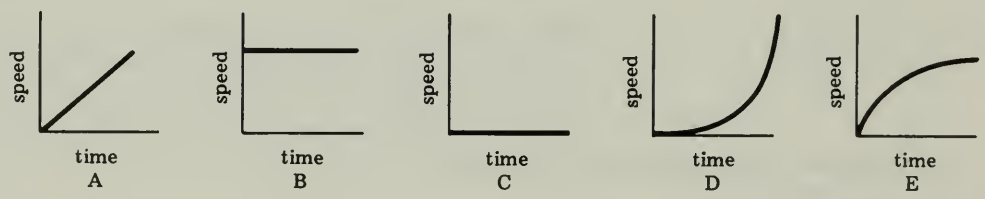
21. The greatest distance is traveled between the times corresponding to points

A. a and c.
B. c and e.
C. e and g.
D. g and i.
E. i and k.

22. v is greatest between times corresponding to points

A. a and k.
B. c and e.
C. e and g.
D. g and i.
E. i and k.

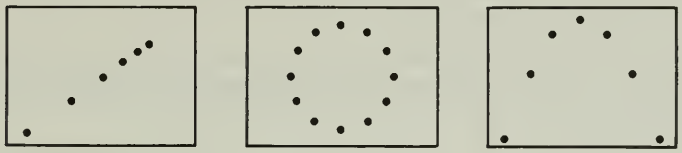
23. A cart, initially at rest, is pulled with a constant, unbalanced force. Which graph best represents how the speed of the cart changes with time?



A. graph A
B. graph B
C. graph C
D. graph D
E. graph E

TEST C

For questions 24 and 25 use the following figures which represent stroboscopic photographs of a moving ball. The strobe rate is constant and is the same for all three "photographs."



24. Which of the "photographs" could have been produced with the camera in motion and the ball fixed in position?

A. none
B. 1 only
C. 2 only
D. 1 and 2 only
E. 1, 2 and 3

25. If the camera is fixed in position, which of the "pictures" show a ball being acted upon by a net unbalanced force?

A. 1 only
B. 3 only
C. 1 and 3 only
D. 2 and 3 only
E. 1, 2 and 3

26. Which of the following increases with time if an object moves with uniform velocity?

A. instantaneous velocity
B. average velocity
C. acceleration
D. direction
E. displacement

27. A sprinter reaches top speed 3 seconds after the start of a race. In those 3 seconds, he moves 18 meters. Assume that he accelerates uniformly. What is his acceleration?

A. 2 meters/sec^2
B. 3 meters/sec^2
C. 4 meters/sec^2
D. 7 meters/sec^2
E. 18 meters/sec^2

Questions 28 and 29 refer to the following statement and table:

Main Street in Centerville is crossed by streets called 1st St., 2nd St., 3rd St. ... 46th St. Blocks between the numbered streets are equally long.

Five cars are traveling along Main Street, and their locations are recorded at five-minute invervals, as shown in the following table:

	10:00 a.m.	10:05 a.m.	10:10 a.m.	10:15 a.m.
car A	25th	30th	35th	40th
car B	30th	25th	15th	10th
car C	1st	2nd	5th	10th
car D	9th	10th	20th	38th
car E	35th	33rd	23rd	20th

28. Which car traveled with the greatest average speed during the period described?

A. car A
B. car B
C. car C
D. car D
E. car E

29. Assuming that all cars started from rest at 10:00 a.m., which car could have traveled with uniform acceleration during the entire period described?

A. car A
B. car B
C. car C
D. car D
E. car E

Use one of the following statements to describe the motion mentioned in questions 30 and 31:

A. straight-line motion at uniform speed
B. uniformly accelerated straight-line motion
C. circular motion
D. projectile motion

30. the motion of a shirt in a washing machine in the middle of the "spin-dry" cycle

31. the motion of a bicyclist seen from a passing car when each is moving with constant speed on a straight, horizontal road

32. ALL EXCEPT ONE of the following conditions must apply if one is to use the equation $d = \frac{1}{2} at^2$. Which one is the exception?

A. The motion must be free fall.
B. The acceleration must be constant in magnitude.
C. The initial velocity of the body must be zero.
D. Displacement must be measured from the point where motion begins.
E. Acceleration must be constant in direction.

33. An 80-kilogram fireman slides down a pole in a fire station. His grip on the pole causes a frictional force of 240 newtons opposing his fall. What is the approximate value of his acceleration toward the floor below?

A. 13 m/sec^2
B. 10 m/sec^2
C. 8 m/sec^2
D. 7 m/sec^2
E. zero

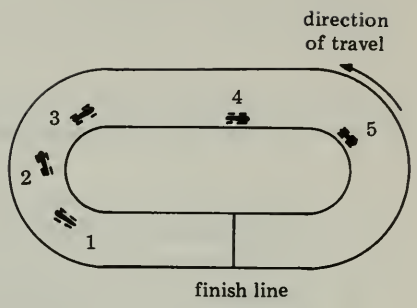
34. Two barrels roll off the deck of a barge and describe identical paths from the edge of the deck to the water. Which of the following conclusions is necessarily true?

A. Both have the same mass.
B. Both have the same weight.
C. Both moved with the same velocity at the instant they fell overboard.
D. Both were pushed with the same force across the deck before they fell overboard.
E. They were chained together.

35. Aristotle's scientific beliefs were different from Galileo's. Which one of the following statements would be in agreement with those of Aristotle?

A. Mathematics has no important place in scientific thought.
B. An object on earth will move at a constant speed if there are no unbalanced forces acting on it.
C. Different objects near the surface of the earth fall freely with the same acceleration.
D. Objects on the earth and heavenly bodies obey the same basic laws of motion.

36. Just before the end of a 25-lap auto race, the five leading cars moving in a counter-clockwise direction are in the positions shown in the diagram. Which of the following statements is necessarily true?

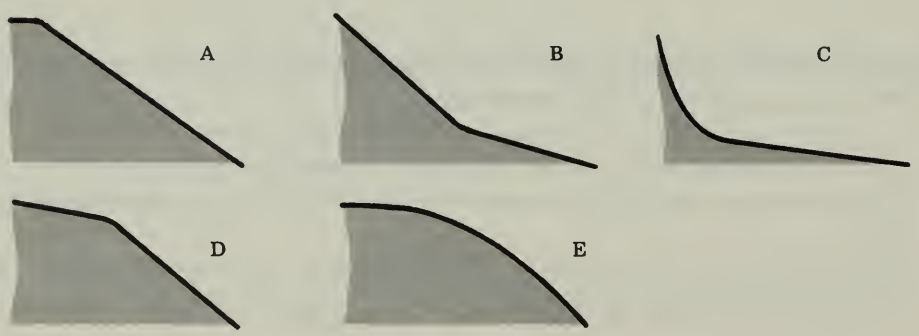


A. Car 5 is traveling with the smallest speed.
B. Car 2 can cross the finish line without changing velocity.
C. Car 4 can cross the finish line without changing speed.
D. Car 1 will finish first.
E. All 5 cars are traveling with the same velocity.

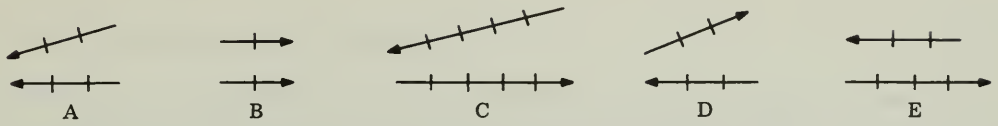
37. Measurements made on a ball rolling down a hill of unknown shape provided the following data:

Time	Instantaneous Speed
0 sec	0 m/sec
1	6
2	12
3	18
4	20
5	22
6	24

Which of the following diagrams could represent the shape of the hill?

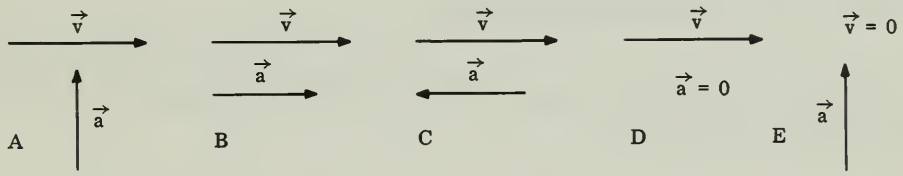


38. Which of the following pairs of vectors has the resultant of largest magnitude?



A. pair A
B. pair B
C. pair C
D. pair D
E. pair E

39. The arrows in the diagrams below show the directions of the velocity and acceleration vectors that apply to a car at five separate instants of time.



ALL EXCEPT ONE of the diagrams above show an instant at which the velocity is changing. Which is the exception?

A. diagram A
B. diagram B
C. diagram C
D. diagram D
E. diagram E

40. A satellite is in a circular orbit around the earth. Which of the following statements must be true?

1. The speed is constant.
2. The velocity is constant.
3. The period is constant.

A. 1 only
B. 2 only
C. 1 and 3 only
D. 2 and 3 only
E. 1, 2 and 3

TEST D

Directions

This test consists of eight questions in two groups. Answer only FOUR of the five questions in Group One, and only TWO of the three questions in Group Two. Spend about 5 minutes on each of the questions from Group One, and 10 minutes on each of the questions from Group Two.

The numerical values of some physical constants and equations that may be useful in the test are given on the last page of this booklet.

Group One

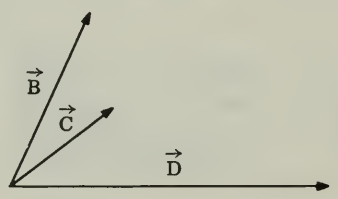
Answer FOUR of the five questions in this group.

1. A satellite is in a circular orbit. Describe the force acting on the satellite, the satellite's acceleration, its velocity and its speed.

2. At time zero, a boy mounted a bicycle and rode off, accelerating uniformly at 2 meters/second^2 for 3 seconds. He continued at constant speed for an additional 5 seconds and then stopped abruptly. Plot the boy's motion on a speed-versus-time graph.

3. List three experimental techniques now available for the study of motion that were not available to Galileo in 1632.

4. Find $\vec{A}$, where $\vec{A} = \vec{B} + \vec{C} + \vec{D}$.



5. To an Aristotelian, it seems clear that a force is necessary to maintain uniform motion. Comment on this statement from the point of view of a Newtonian.

Group Two

Answer TWO of the three questions in this group.

6. An airplane is flying horizontally over the ocean at a speed of 200 meters/second and at an altitude of 2000 meters. The pilot drops a flare. (Neglect air resistance.)

   a) How many seconds after release does the flare hit the water?
   b) At what distance from point P, directly under the point of release, does the flare strike the water?

7. Acceleration is the rate of change of speed. Instantaneous acceleration is the slope of a speed-time graph at a point. Suppose we call the rate of change of acceleration *surge.*

   a) What is the algebraic expression defining average surge?
   b) What are the units of surge?
   c) How can we calculate instantaneous surge?

8. In *Two New Sciences,* Galileo uses the character Salviati to present his own views concerning free fall. At one point in the discussion Salviati states:

   If then we take two bodies whose natural speeds are different, it is clear that on uniting the two, the more rapid one will be partly retarded by the slower, and the slower will be somewhat hastened by the swifter. ... But if this is true, and if a large stone moves with a speed of, say, eight while a smaller moves with a speed of four, then when they are united, the system will move with a speed of less than eight; but the two stones when tied together make a stone larger than that which before moved with a speed of eight. Since the heavier body moves with less speed than the lighter .... you see how, from the premise that the heavier body moves more rapidly than the lighter one, I infer that the heavier body moves more slowly.

   Salviati based the preceding argument on several assumptions that are not necessarily valid.

   a) State one of these assumptions.
   b) Consider that this assumption is not valid. Propose a more appropriate assumption.
   c) Based on your assumption, what conclusions can be drawn regarding the rate of fall of the two stones that are tied together?