

Practice Test 2, Units 1 to 4

Name: _____

Date: _____

$$g = 10 \text{ m/s}^2$$

Part A. Multiple Choice

- Which of the following quantities is a scalar?
 - Displacement
 - Velocity
 - Speed
 - Acceleration
- An ant walks 8.0 m east, then 14 m west, then 3.0 m east, all along one straight line. What is its resultant displacement?
 - 3.0 m west
 - 3.0 m east
 - 19 m west
 - 25 m east
- Two trucks travel side by side along a straight highway, both moving north at 25 m/s relative to the ground. In the reference frame of one truck, the other truck
 - moves north at 25 m/s
 - is at rest
 - moves south at 25 m/s
 - moves north at 50 m/s
- A book lies at rest on a level table. Which forces appear on a correct free-body diagram for the book?
 - The gravitational force on the book only
 - The gravitational force on the book and the normal force from the table
 - The gravitational force on the book, the normal force from the table, and the force the book exerts on the table
 - The gravitational force on the book, the normal force from the table, and a force of inertia
- A space probe coasts far from any star or planet with its engine shut off, so that no appreciable force acts on it. The probe
 - slows down gradually and then stops
 - keeps moving at the same velocity
 - speeds up, since nothing holds it back
 - keeps its speed but gradually curves
- The gravitational field strength at the surface of a certain moon is 1.6 N/kg. What is the magnitude of the gravitational force exerted on a 50 kg astronaut standing on that moon?
 - 31 N
 - 160 N
 - 80 N
 - 500 N
- A 0.50 kg ball moves at 8.0 m/s. What is its translational kinetic energy?
 - 2.0 J
 - 4.0 J
 - 16 J
 - 32 J

8. A spring is compressed a distance x from its natural length. Later the same spring is stretched the same distance x . The energy stored in the stretched spring compared with the compressed spring is
- A. twice as large
 - B. the same
 - C. half as large
 - D. zero, because a stretch and a compression are opposite
9. A motor delivers a steady power of 250 W for 20 s. How much work does it do?
- A. 5000 J
 - B. 12.5 J
 - C. 270 J
 - D. 500 J
10. A cart on a straight track reverses its direction of travel, and its speed afterward is the same as it was before. Which of these changes?
- A. its kinetic energy
 - B. its mass
 - C. its momentum
 - D. the magnitude of its momentum
11. A car starts from rest and accelerates uniformly along a straight road, reaching 24 m/s after traveling 48 m. How long does this take?
- A. 2.0 s
 - B. 6.0 s
 - C. 8.0 s
 - D. 4.0 s
12. A velocity against time graph for an object on a straight line is a straight line that starts at +8.0 m/s at $t = 0$ and crosses the time axis at $t = 4.0$ s. At $t = 4.0$ s the object
- A. has returned to the position it started from
 - B. is momentarily at rest and is about to reverse direction
 - C. has zero acceleration
 - D. is at its farthest point from the start and is still moving forward
13. A ball is thrown horizontally at 15 m/s from the top of a cliff 20 m high and lands on level ground below. How far from the base of the cliff does it land?
- A. 30 m
 - B. 20 m
 - C. 15 m
 - D. 60 m
14. A uniform plank of mass 8.0 kg and length 4.0 m lies along the x -axis with its left end at $x = 0$. A 2.0 kg block sits on the plank at $x = 4.0$ m. The center of mass of plank and block together is at
- A. $x = 3.0$ m
 - B. $x = 2.0$ m
 - C. $x = 2.5$ m
 - D. $x = 2.4$ m

15. Two freight cars are coupled to each other and pulled along level track by a locomotive. Taking the two cars together as the system, the force in the coupling that joins the two cars is
- A. an external force on the system, equal in size to the pull of the locomotive
 - B. an external force on the system, smaller than the pull of the locomotive
 - C. an internal force, which cannot change the motion of the center of mass
 - D. an internal force, which reduces the acceleration of the center of mass
16. Block A rests on top of block B, and block B rests on a table. Which two forces form a Newton's third law pair?
- A. The pull of the Earth on A, and the upward push of B on A
 - B. The downward push of A on B, and the upward push of B on A
 - C. The pull of the Earth on B, and the upward push of the table on B
 - D. The upward push of B on A, and the upward push of the table on B
17. A ball falls freely toward the Earth. Which statement about the gravitational forces in this interaction is correct?
- A. The ball pulls on the Earth with a force equal in size to the pull of the Earth on the ball
 - B. The Earth pulls on the ball far harder than the ball pulls on the Earth, because the Earth has far more mass
 - C. The two pulls act on the same object and cancel, so the ball has no net force
 - D. The ball exerts no gravitational pull on the Earth
18. A passenger stands in a bus that brakes suddenly, and the passenger moves toward the front of the bus. The best explanation is that
- A. a force directed toward the front of the bus acts on the passenger while the brakes are applied
 - B. the floor of the bus pushes the passenger toward the front
 - C. the passenger keeps moving forward while the bus slows down
 - D. the inertia of the passenger creates a forward force on the passenger
19. A 4.0 kg block on a level frictionless surface is acted on by two horizontal forces: 12 N north and 16 N east. What is the magnitude of its acceleration?
- A. 7.0 m/s^2
 - B. 1.0 m/s^2
 - C. 3.0 m/s^2
 - D. 5.0 m/s^2
20. A 20 kg crate is dragged at constant velocity across a level floor by a horizontal force of 60 N. What is the coefficient of kinetic friction between the crate and the floor?
- A. 0.30
 - B. 0.15
 - C. 0.60
 - D. 3.0
21. Two identical ideal springs are joined end to end and hung from a ceiling, and an object hangs at rest from the lower end. Compared with the stretch of a single spring carrying the same object, the total stretch of the pair is
- A. the same
 - B. half as large
 - C. twice as large
 - D. four times as large

22. An ideal spring is pushed in by 1.0 cm, and then by 4.0 cm, each measured from its natural length. Compared with the first case, the spring force and the stored energy are
- A. 4 times as large and 4 times as large
 - B. 16 times as large and 4 times as large
 - C. 4 times as large and 8 times as large
 - D. 4 times as large and 16 times as large
23. A puck slides in a circle on a level, frictionless table, held in its path by a string tied to a peg at the center. The string suddenly breaks. After the break the puck
- A. slides directly away from the peg, along the line from the peg through the puck
 - B. slides in a straight line, along the tangent to the circle
 - C. keeps moving in a circle of larger radius
 - D. slows down and stops, since nothing pulls on it any more
24. A 4.0 kg object carries a momentum of magnitude 12 kg·m/s. What is its kinetic energy?
- A. 6.0 J
 - B. 24 J
 - C. 18 J
 - D. 36 J
25. A 4.0 kg box is lifted from a table 0.80 m above the floor to a shelf 2.3 m above the floor. Use $g = 10 \text{ m/s}^2$. By how much does the gravitational potential energy of the box and Earth system rise?
- A. 32 J
 - B. 60 J
 - C. 92 J
 - D. 124 J
26. A crane lifts a 200 kg crate at a steady speed of 0.50 m/s. Use $g = 10 \text{ m/s}^2$. What power does the crane deliver to the crate?
- A. 100 W
 - B. 400 W
 - C. 2000 W
 - D. 1000 W
27. A 0.80 kg ball starts at rest. The net force on it rises in a straight line from zero to 12 N over 0.20 s, then falls in a straight line back to zero over the next 0.20 s. How fast is the ball then moving?
- A. 3.0 m/s
 - B. 1.5 m/s
 - C. 6.0 m/s
 - D. 2.4 m/s
28. A cart rolls along a level track and slows steadily because of friction from the track. For which choice of system is the total momentum constant?
- A. the cart alone, because no collision takes place
 - B. the cart alone, because friction is internal to it
 - C. the cart together with the track and the Earth
 - D. neither one, because momentum is constant only in a collision

29. A 60 kg student stands at rest on a frictionless frozen pond and throws a 2.0 kg ball east at 9.0 m/s. What is the speed of the student afterward?
- A. 0.15 m/s
 - B. 3.0 m/s
 - C. 0.27 m/s
 - D. 0.30 m/s
30. A ball is dropped onto a floor and rebounds to a height lower than the one it was dropped from. The collision between the ball and the floor was
- A. elastic, because the ball bounced
 - B. inelastic, because kinetic energy was lost
 - C. perfectly inelastic, because the ball touched the floor
 - D. elastic, because the momentum of the ball reversed
31. An object moves along a straight line with constant acceleration. Over a certain interval its average velocity is +6 m/s. Which statement must be true?
- A. Its velocity is +6 m/s at the middle instant of the interval
 - B. Its velocity is +6 m/s at the point halfway along the displacement covered
 - C. Its velocity is +6 m/s at every instant of the interval
 - D. Its acceleration is zero over the interval
32. A ball has been thrown and is moving upward and to the right through the air. Air resistance is negligible. A correct free-body diagram for the ball shows
- A. two forces: gravity downward and a force upward along the direction of motion
 - B. two forces: gravity downward and a normal force upward
 - C. three forces: gravity, the throwing force, and a force of air resistance
 - D. one force, directed downward
33. An astronaut inside a spacecraft in a circular orbit around the Earth floats, with no sensation of weight. Which statement about the forces on the astronaut is correct?
- A. The gravitational force on the astronaut is zero at that altitude
 - B. The normal force on the astronaut is zero and the gravitational force is not
 - C. Both the gravitational force and the normal force on the astronaut are zero
 - D. A centrifugal force on the astronaut balances the gravitational force exactly
34. A block slides down a ramp inclined at 37° . The coefficient of kinetic friction is 0.25. Take $\sin 37^\circ = 0.60$ and $\cos 37^\circ = 0.80$. The magnitude of its acceleration is
- A. 2.0 m/s^2
 - B. 6.0 m/s^2
 - C. 8.0 m/s^2
 - D. 4.0 m/s^2
35. A 0.20 kg ball on the end of a string is swung in a vertical circle of radius 0.50 m. At the lowest point of the circle its speed is 4.0 m/s. What is the magnitude of the tension in the string there?
- A. 8.4 N
 - B. 6.4 N
 - C. 4.4 N
 - D. 2.0 N

36. An elevator starts from rest and accelerates upward. A passenger stands on its floor. The work done on the passenger by the normal force from the floor is
- A. zero, because that force is perpendicular to the force of gravity
 - B. zero, because the passenger does not move relative to the floor
 - C. positive, because that force and the displacement both point upward
 - D. negative, because the passenger pushes down on the floor just as hard
37. A 0.20 kg ball is launched from the ground at 20 m/s at 60° above the horizontal. Use $g = 10 \text{ m/s}^2$ and ignore air resistance. What is its kinetic energy at the highest point of its flight?
- A. 0 J
 - B. 10 J
 - C. 30 J
 - D. 40 J
38. Puck A has mass 2.0 kg and slides east at 3.0 m/s. Puck B has mass 4.0 kg and slides north at 2.0 m/s. What is the magnitude of the total momentum of the system?
- A. 10 kg·m/s
 - B. 14 kg·m/s
 - C. 2.0 kg·m/s
 - D. 6.4 kg·m/s
39. A crate is dragged across a level floor at a steady speed. Its free body diagram shows F_{app} forward, F_f backward, F_N up and F_g down. Over a 3.0 s interval the impulse delivered to the crate is
- A. zero, because the four forces add to zero
 - B. forward, equal to F_{app} times 3.0 s
 - C. backward, equal to F_f times 3.0 s
 - D. downward, equal to F_g times 3.0 s
40. A 1.0 kg lump of clay moving at 6.0 m/s strikes a 2.0 kg block at rest on a level floor and sticks to it. The pair slides 0.40 m and stops. Use $g = 10 \text{ m/s}^2$. What is the coefficient of kinetic friction?
- A. 0.25
 - B. 1.5
 - C. 0.50
 - D. 0.75
41. A velocity against time graph for an object on a straight line is a straight line from -10 m/s at $t = 0$ to $+6.0 \text{ m/s}$ at $t = 8.0 \text{ s}$. Over this interval, the magnitude of the displacement and the distance traveled are
- A. 34 m and 16 m
 - B. 16 m and 16 m
 - C. 16 m and 34 m
 - D. 25 m and 34 m
42. A river 40 m wide flows due east at 3.0 m/s. A swimmer whose speed relative to the water is 5.0 m/s needs to land at the point directly north across the river. How long does the crossing take?
- A. 8.0 s
 - B. 5.0 s
 - C. 13 s
 - D. 10 s

43. A truck moves at constant velocity along a straight, level road. A ball is launched straight up from the flat bed of the truck. Air resistance is negligible. The ball lands
- A. behind the launch point on the road, because the truck moves forward while the ball is in the air
 - B. ahead of the launch point on the road
 - C. back in the truck bed, at the spot it left from
 - D. in the truck bed, but behind the spot it left from
44. A firework shell is launched and follows a parabolic path. At the highest point of the path it bursts into many fragments. Air resistance is negligible. After the burst, the center of mass of the fragments
- A. continues along the original parabolic path
 - B. falls straight down from the point of the burst
 - C. stops moving, because the fragments fly off in all directions
 - D. follows a path that depends on how the fragments were thrown by the burst
45. A 60 kg person stands on a bathroom scale inside an elevator, and the scale reads 480 N. Which statement about the elevator is correct?
- A. Its acceleration is 2.0 m/s^2 downward, with the direction of travel unknown
 - B. It is moving downward at a steady 2.0 m/s
 - C. It must be moving downward and gaining speed at a rate of 2.0 m/s^2
 - D. Its acceleration is 2.0 m/s^2 upward, with the direction of travel unknown
46. A 50 kg crate is lifted from rest by a cable and accelerates upward at 2.0 m/s^2 through a height of 4.0 m. Use $g = 10 \text{ m/s}^2$. How much work does the cable do on the crate?
- A. 400 J
 - B. 2000 J
 - C. 1600 J
 - D. 2400 J
47. Two rough ramps have the same height and the same coefficient of friction, but the second has the gentler slope. Identical boxes are released from rest at the top of each. At the bottom, the box on the gentler ramp is
- A. moving faster, because the normal force on it is smaller
 - B. moving at the same speed, because the two heights are equal
 - C. moving faster, because it is in contact with the ramp for a longer time
 - D. moving slower, because friction acts on it over a longer path
48. Two carts on a level frictionless track have a total momentum of zero. Cart A has mass 1.0 kg and cart B has mass 3.0 kg. The total kinetic energy of the system is 24 J. What is the speed of cart A?
- A. 4.9 m/s
 - B. 6.0 m/s
 - C. 6.9 m/s
 - D. 12 m/s
49. Two blocks of different mass are held at rest on a frictionless table with a compressed spring between them. The spring is released and pushes them apart. Which statement about the two blocks is correct?
- A. The impulses match in size, and so do the two kinetic energies
 - B. The impulses match in size, and the lighter block takes more energy
 - C. The lighter block takes the larger impulse and the larger energy
 - D. The impulses and the speeds both match, because one spring pushed them

50. A spring of force constant 600 N/m , compressed 0.20 m , is released against a 1.5 kg cart on a frictionless track. The cart then strikes a 0.50 kg cart at rest and the two stick together. Their common speed is

- A. 4.0 m/s
- B. 3.5 m/s
- C. 3.0 m/s
- D. 1.5 m/s

Part B. Reasoning

1. A student says that the speedometer of a car reports the velocity of the car. Correct the student, and give an example to prove your point.
2. State what the arrows on a free body diagram stand for, and name three things that must never be drawn on one.
3. A skydiver with an open parachute descends at a steady 55 m/s, and a student says the skydiver cannot be in equilibrium while moving. Correct the student, and give an example to prove your point.
4. A student pushes on a parked car with a force of 400 N and the car does not move. State the work done on the car by the push and justify the answer.
5. A student says that an object with a negative acceleration must be slowing down. Correct the student, and give an example to prove your point.
6. A passenger on a train moving at a steady 30 m/s drops a ball, and it lands at the passenger's feet. Describe the path of the ball as seen from the ground, and name one quantity the two frames agree about.
7. A thin uniform metal ring lies flat on a table. State where the center of mass of the ring is, and explain how a point with no matter at it can be the center of mass.
8. A 2000 kg truck collides with a 1000 kg car and the car is damaged far more, so a student concludes that the truck exerted the larger force. Correct the student, and give an example to prove your point.
9. Explain why static friction can take many different values on the same two surfaces while kinetic friction cannot, and state what limits the static value.
10. An ideal spring pulls back with 6.0 N when it is stretched 3.0 cm from its natural length. State the force when it is stretched 9.0 cm, and state which way the spring force points in each case.
11. A spring is compressed twice as far as before. State what happens to the elastic potential energy stored, and explain why it is not simply doubled.
12. A crane is rated at 3000 W. Explain what that rating limits, and use it to compare the fastest steady lift of a 1500 N load with that of a 3000 N load.
13. A cart on a straight level track has a velocity against time graph that is a single straight line running from +4.0 m/s at $t = 0$ to -4.0 m/s at $t = 4.0$ s. Describe the net force on the cart, and explain what is happening at $t = 2.0$ s.
14. A ball on a light string is swung in a vertical circle of fixed radius. Explain why its speed at the top is less than at the bottom, and why the tension at the top is less as well.
15. A 0.20 kg ball is dropped and bounces off the floor. Name the forces acting on the ball during the contact, and explain how their impulse turns downward motion into upward motion.
16. A firework shell is launched at an angle and bursts into many pieces at the top of its flight. Describe the motion of the center of mass of the pieces after the burst, and explain why the burst does not change it.
17. A projectile is launched from level ground at 45° , and a student says that at the highest point all of its kinetic energy has become gravitational potential energy. Explain what is wrong, and state the fraction of the launch kinetic energy that is still kinetic at the top.
18. An astronaut floats inside a space station in a low orbit, and a student says this happens because there is no gravity there and asks for the distance at which gravity reaches zero. Explain what is wrong with the question, and give the real reason the astronaut floats.
19. A compressed spring between a 1.0 kg block and a 3.0 kg block is released on frictionless ice, with both blocks starting at rest. Compare the magnitudes of their momenta and of their kinetic energies afterward, and explain why the two comparisons differ.
20. A block is released from rest at the top of a rough ramp, and a student asks for the release height at which mechanical energy will be conserved during the slide. Explain what is wrong with the question.

Part C. Problems

1. A motorcycle travels along a straight level road. Its velocity increases steadily from 6.0 m/s to 24 m/s over a time interval of 6.0 s.
 - (a) Derive an expression for the average acceleration in terms of the initial velocity, the final velocity and the time interval, then calculate its value.
 - (b) Calculate the displacement of the motorcycle during the 6.0 s.
 - (c) Calculate the displacement during only the first 2.0 s of that interval.
2. A 40 kg crate is pulled along a level floor at a constant velocity of 2.0 m/s by a horizontal rope. The tension in the rope is 90 N.
 - (a) Calculate the magnitude of the friction force exerted on the crate by the floor.
 - (b) Calculate the magnitude of the normal force exerted on the crate by the floor.
 - (c) Calculate the coefficient of kinetic friction between the crate and the floor.
3. A 1.2 kg ball moves along a level track at 5.0 m/s.
 - (a) Calculate the kinetic energy of the ball.
 - (b) The ball is later moving at 10 m/s along the same track. Calculate its kinetic energy then.
 - (c) Calculate the net work done on the ball between those two moments.
4. A 4.0 kg ball rolls north along a level floor at 2.5 m/s. Take north as positive.
 - (a) Calculate the momentum of the ball.
 - (b) Calculate the kinetic energy of the ball.
 - (c) A 1.0 kg ball is to carry the same momentum as the 4.0 kg ball. Calculate the speed it must have.
5. A cart moves along a straight track and its velocity is graphed against time. The velocity falls linearly from +8.0 m/s at $t = 0$ to zero at $t = 4.0$ s, and then continues to fall linearly to -6.0 m/s at $t = 7.0$ s.
 - (a) Calculate the acceleration of the cart, and state what feature of the graph you read it from.
 - (b) Calculate the displacement of the cart over the whole 7.0 s.
 - (c) Calculate the total distance the cart travels over the same 7.0 s.
6. A ball is kicked from level ground with a speed of 25 m/s at an angle of 53° above the horizontal. Take $\sin 53^\circ = 0.80$ and $\cos 53^\circ = 0.60$, and ignore air resistance.
 - (a) Derive an expression for the total time of flight in terms of the launch speed v_0 , the launch angle θ and g , then calculate its value.
 - (b) Calculate the horizontal range of the ball.
 - (c) Calculate the maximum height the ball reaches above the ground.
7. A worker pushes a 25 kg crate across a level floor with a force of 150 N directed at 30° below the horizontal. The coefficient of kinetic friction between the crate and the floor is 0.20.
 - (a) Derive an expression for the magnitude of the normal force on the crate in terms of m , the applied force F , the angle θ below the horizontal and g , then calculate its value.
 - (b) Calculate the magnitude of the acceleration of the crate.
 - (c) Calculate the magnitude of the force, directed at the same 30° below the horizontal, that would push the crate at constant velocity.
8. A 0.40 kg ball is tied to one end of a light string of length 0.90 m. The other end is held fixed, and the ball moves in a horizontal circle of radius 0.90 m on a frictionless table at a constant speed of 6.0 m/s.
 - (a) Derive an expression for the magnitude of the tension in the string in terms of m , v and r , then calculate its value.
 - (b) Calculate the period of the motion.
 - (c) The string breaks when the tension exceeds 25 N. Calculate the greatest speed the ball can have on this circle without breaking the string.
9. A 10 kg wagon is pulled 10 m along level ground, starting from rest. The rope carries a force of 40 N at 60° above the horizontal, and a friction force of 12 N acts on the wagon.
 - (a) Calculate the work done on the wagon by the rope.
 - (b) Calculate the work done on the wagon by friction.
 - (c) Calculate the speed of the wagon at the end of the 10 m.

10. A vertical spring of force constant 300 N/m stands on the floor with its lower end fixed. A 0.60 kg ball is placed on top of the spring and pressed down until the spring is compressed 0.20 m, and the ball is held there. The mass of the spring may be ignored.

- (a) Calculate the elastic potential energy stored in the spring.
- (b) The ball is released. Derive an expression for the height it rises above the point of release, in terms of k , x , m and g , then calculate it.
- (c) Calculate the speed of the ball as it passes the natural length of the spring, which is 0.20 m above the point of release.

11. A pump raises water from the bottom of a well to ground level 12 m above, and it delivers 30 kg of water at the top each second. The water arrives moving so slowly that its kinetic energy may be ignored.

- (a) Calculate the energy given to the water each second.
- (b) Calculate the power the pump delivers to the water.
- (c) The pump draws 4500 W of electrical power. Calculate the fraction of that power that reaches the water.

12. A 1500 kg van traveling at 20 m/s along a straight level road is brought to rest by its brakes in 8.0 s. Take the direction of travel as positive.

- (a) Calculate the magnitude of the change in momentum of the van.
- (b) Calculate the magnitude of the average braking force on the van.
- (c) On an icy road the force available is only 1250 N. Calculate how long the van would take to stop from 20 m/s.

13. A river is 80 m wide, and its water flows due east at 1.5 m/s relative to the bank. A swimmer can move at 2.5 m/s relative to the water.

- (a) The swimmer sets out from the south bank pointing due north. Derive an expression for the time to reach the north bank in terms of the width of the river and the speed of the swimmer relative to the water, then calculate its value.
- (b) Calculate how far downstream of the point directly opposite the start the swimmer reaches the north bank.
- (c) The swimmer now wants to land at the point directly opposite the start. Calculate the angle, measured from due north, at which the swimmer must point.

14. A planet has a radius of 3.0×10^6 m, and an object released near its surface falls freely with an acceleration of 6.0 m/s^2 . Use $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$.

- (a) Derive an expression for the mass of the planet in terms of the surface field strength g_p , the planet radius R and G , then calculate its value.
- (b) Calculate the altitude above the surface at which the field strength of this planet has fallen to 1.5 m/s^2 .
- (c) An 80 kg astronaut stands on a bathroom scale inside an elevator resting on the surface of this planet. The elevator then accelerates upward at 2.0 m/s^2 . Calculate the reading on the scale.

15. A 4.0 kg crate is pulled from rest 5.0 m up a ramp inclined at 30° to the horizontal. The rope lies along the ramp and carries a force of 36 N. A friction force of 6.0 N acts on the crate while it slides.

- (a) Derive an expression for the kinetic energy of the crate at the top of the 5.0 m, in terms of the rope force T , the friction force f , the mass m , the quantity g , the distance d along the ramp and the angle θ , then calculate it.
- (b) Calculate the speed of the crate at the top of the 5.0 m.
- (c) At the top the rope is released and the crate slides back down the same 5.0 m. Calculate its speed when it returns to the starting point.

16. A 0.50 kg block slides at 8.0 m/s along a level frictionless surface and strikes a 1.5 kg block at rest. The two stick together. The pair then slides onto a rough level patch where the coefficient of kinetic friction between the blocks and the surface is 0.40.

- (a) Calculate the speed of the pair just after the collision.
- (b) Derive an expression for the distance the pair slides on the rough patch before stopping, in terms of v_f , μ and g , then calculate it.
- (c) Calculate the kinetic energy that was no longer kinetic energy of the blocks immediately after the collision.

17. A 2.0 kg block rests on top of a 6.0 kg block, which rests on a level frictionless floor. The coefficient of static friction between the two blocks is 0.40. A horizontal force is exerted on the lower block, and at first the two blocks move together.

(a) Derive an expression for the greatest acceleration the pair can have while the upper block still moves with the lower one, in terms of μ_s and g , then calculate its value.

(b) Calculate the greatest magnitude of the horizontal force that can be exerted on the lower block while the two blocks still move together.

(c) A horizontal force of 48 N is instead exerted on the lower block, so the blocks slide against each other. The coefficient of kinetic friction between them is 0.30. Calculate the magnitude of the acceleration of the upper block.

18. A 0.50 kg puck sits on a frictionless horizontal table. One end of an ideal spring of force constant 120 N/m and relaxed length 0.40 m is attached to the puck, and the other end is pinned to the table. The puck is set moving in a horizontal circle of radius 0.50 m about the pin at a constant speed.

(a) Derive an expression for the speed of the puck in terms of the force constant k , the relaxed length L_0 , the radius r of the circle and the mass m , then calculate its value.

(b) Calculate the period of the motion.

(c) The puck is now set moving in a circle of radius 0.60 m about the same pin. Calculate its speed.

19. A 0.25 kg ball is released from rest 1.25 m above a hard floor, bounces, and rises to a height of 0.45 m. The ball is in contact with the floor for 0.050 s. Ignore air resistance and take up as positive.

(a) Derive an expression for the magnitude of the change in momentum of the ball during the contact, in terms of m , g , the drop height h_1 and the rebound height h_2 , then calculate it.

(b) Calculate the magnitude of the average force the floor exerts on the ball during the contact.

(c) Calculate the kinetic energy that is no longer kinetic energy of the ball after the bounce.

20. A spring of force constant 400 N/m is compressed 0.25 m against a 1.0 kg cart on a level frictionless track, with the far end of the spring fixed to a wall. The spring is released, the cart leaves it at the natural length, and the cart then strikes a 3.0 kg cart at rest on the same track. The two carts stick together.

(a) Derive an expression for the speed of the 1.0 kg cart as it leaves the spring, in terms of k , x and m_1 , then calculate it.

(b) Calculate the speed of the two carts just after the collision.

(c) Calculate the fraction of the energy originally stored in the spring that is still kinetic energy of the carts after the collision.

AP Physics 1, Equation Sheet

The constants, conventions and equations on this sheet are those the College Board provides on the AP Physics exam reference information.

CONSTANTS AND CONVERSION FACTORS

$$G = 6.67 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2) = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$$

universal gravitational constant

$$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2 = 1.0 \times 10^5 \text{ Pa}$$

one atmosphere of pressure

$$g = 9.8 \text{ m/s}^2$$

magnitude of the acceleration due to gravity at the surface of the Earth

$$g = 9.8 \text{ N/kg}$$

magnitude of the gravitational field strength at the surface of the Earth

CONVENTIONS

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- Air resistance is assumed to be negligible unless otherwise stated.
- Springs and strings are assumed to be ideal unless otherwise stated.
- Fluids are assumed to be ideal, and pipes are assumed to be completely filled by fluid, unless otherwise stated.

PREFIXES

Factor	Prefix	Symbol
10^{12}	tera	<i>T</i>
10^9	giga	<i>G</i>
10^6	mega	<i>M</i>
10^3	kilo	<i>k</i>
10^{-2}	centi	<i>c</i>
10^{-3}	milli	<i>m</i>
10^{-6}	micro	μ
10^{-9}	nano	<i>n</i>
10^{-12}	pico	<i>p</i>

UNIT SYMBOLS

hertz	Hz
newton	N
joule	J
pascal	Pa
kilogram	kg
second	s
meter	m
watt	W

TRIGONOMETRIC FUNCTIONS AT COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin \theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos \theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan \theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

GEOMETRY AND TRIGONOMETRY

Rectangle

$$A = bh$$

Triangle

$$A = \frac{1}{2}bh$$

Circle

$$A = \pi r^2$$

$$C = 2\pi r$$

$$s = r\theta$$

Rectangular solid

$$V = \ell wh$$

Cylinder

$$V = \pi r^2 \ell$$

$$S = 2\pi r \ell + 2\pi r^2$$

Sphere

$$V = \frac{4}{3}\pi r^3$$

$$S = 4\pi r^2$$

Right triangle

$$a^2 + b^2 = c^2$$

$$\sin \theta = a/c$$

$$\cos \theta = b/c$$

$$\tan \theta = a/b$$

KINEMATICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

CENTER OF MASS

$$\vec{x}_{\text{cm}} = \frac{\sum m_i \vec{x}_i}{\sum m_i}$$

$$\vec{v}_{\text{cm}} = \frac{\sum \vec{p}_i}{\sum m_i} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$$

FORCE AND TRANSLATIONAL DYNAMICS

$$\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}} = \frac{\vec{F}_{\text{net}}}{m_{\text{sys}}}$$

$$\vec{F}_{\text{net}} = \frac{\Delta \vec{p}}{\Delta t} = m \frac{\Delta \vec{v}}{\Delta t} = m \vec{a}$$

$$|\vec{F}_g| = G \frac{m_1 m_2}{r^2}$$

$$|\vec{F}_f| \leq |\mu \vec{F}_N|$$

$$\vec{F}_s = -k \Delta \vec{x}$$

$$a_c = \frac{v^2}{r}$$

WORK, ENERGY AND POWER

$$K = \frac{1}{2}mv^2$$

$$W = F_{\parallel} d = F d \cos \theta$$

$$\Delta K = \sum W_i = \sum F_{\parallel, i} d_i$$

$$U_s = \frac{1}{2}k(\Delta x)^2$$

$$U_G = -\frac{Gm_1m_2}{r}$$

$$\Delta U_g = mg\Delta y$$

$$P_{\text{avg}} = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t}$$

$$P_{\text{inst}} = F_{\parallel}v = Fv \cos \theta$$

LINEAR MOMENTUM

$$\vec{p} = m\vec{v}$$

$$\vec{J} = \vec{F}_{\text{avg}}\Delta t = \Delta\vec{p}$$

TORQUE AND ROTATIONAL DYNAMICS

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$v = r\omega$$

$$a_T = r\alpha$$

$$\tau = r_{\perp}F = rF \sin \theta$$

$$I = \sum m_i r_i^2$$

$$I' = I_{\text{cm}} + Md^2$$

$$\alpha_{\text{sys}} = \frac{\Sigma \tau}{I_{\text{sys}}} = \frac{\tau_{\text{net}}}{I_{\text{sys}}}$$

ENERGY AND MOMENTUM OF ROTATING SYSTEMS

$$K = \frac{1}{2}I\omega^2$$

$$W = \tau\Delta\theta$$

$$L = I\omega$$

$$L = rmv \sin \theta$$

$$\Delta L = \tau\Delta t$$

$$\Delta x_{\text{cm}} = r\Delta\theta$$

OSCILLATIONS

$$T = \frac{1}{f}$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$x = A \cos(2\pi ft)$$

$$x = A \sin(2\pi ft)$$

FLUIDS

$$\rho = \frac{m}{V}$$

$$P = \frac{F_{\perp}}{A}$$

$$P = P_0 + \rho gh$$

$$P_{\text{gauge}} = \rho gh$$

$$F_b = \rho Vg$$

$$A_1 v_1 = A_2 v_2$$

$$P_1 + \rho gy_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho gy_2 + \frac{1}{2}\rho v_2^2$$

WHAT THE LETTERS MEAN

<i>a</i>	acceleration
<i>A</i>	amplitude or area
<i>d</i>	distance
<i>E</i>	energy
<i>f</i>	frequency
<i>F</i>	force
<i>h</i>	height
<i>I</i>	rotational inertia
<i>J</i>	impulse
<i>k</i>	spring constant
<i>K</i>	kinetic energy
<i>ℓ</i>	length
<i>L</i>	angular momentum
<i>m</i>	mass
<i>M</i>	mass
<i>p</i>	momentum
<i>P</i>	power or pressure
<i>r</i>	radius or distance
<i>t</i>	time
<i>T</i>	period
<i>U</i>	potential energy
<i>v</i>	velocity or speed
<i>V</i>	volume
<i>W</i>	work
<i>x</i>	position
<i>y</i>	vertical position
<i>α</i>	angular acceleration
<i>θ</i>	angle or angular position
<i>μ</i>	coefficient of friction
<i>ρ</i>	density
<i>τ</i>	torque
<i>ω</i>	angular speed