THE TWENTY-SECOND ANNUAL SLAPT PHYSICS CONTEST
SOUTHERN ILLINOIS UNIVERSITY EDWARDSVILLE
APRIL 21, 2007

MECHANICS TEST

g = 9.8 m/s/s

Please answer the following questions on the supplied answer sheet. You may write on this test booklet and keep it for your records. Only the answer sheets will be scored

1. Which one of the following is *not* a vector quantity?
   (a) acceleration
   (b) displacement
   (c) instantaneous velocity
   (d) average speed
   (e) average velocity

Questions 2 and 3 pertain to the situation described below:

Peter noticed a bug crawling along a meter stick and decided to record the bug's position in five-second intervals. After the bug crawled off the meter stick, Peter created the table shown.

time (s)	position (cm)
0.00	49.6
5.00	39.2
10.0	42.5
15.0	41.0
20.0	65.7

2. What is the displacement of the bug between $t = 0.00$ s and $t = 20.0$ s?
   (a) +39.9 cm (c) +65.7 cm (e) +16.1 cm
   (b) –39.9 cm (d) –16.1 cm

3. What is the total distance that the bug traveled between $t = 0.00$ s and $t = 20.0$ s? Assume the bug only changed directions at the end of a five-second interval.
   (a) 39.9 cm (c) 16.1 cm (e) 26.5 cm
   (b) 65.7 cm (d) 47.1 cm

4. A bus leaves New York City, takes a non-direct route and arrives in St. Louis, Missouri 23 hours, 16 minutes later. If the distance between the two cities is 1250 km, what is the magnitude of the bus' average velocity?
   (a) 37.2 km/h (c) 46.0 km/h (e) 58.1 km/h
   (b) 41.4 km/h (d) 53.7 km/h

5. A baseball is hit upward and travels along a parabolic arc before it strikes the ground. Which one of the following statements is necessarily true?
   (a) The acceleration of the ball decreases as the ball moves upward.
   (b) The velocity of the ball is zero m/s when the ball is at the highest point in the arc.
   (c) The acceleration of the ball is zero m/s^2 when the ball is at the highest point in the arc.
   (d) The *x*-component of the velocity of the ball is the same throughout the ball's flight.
   (e) The velocity of the ball is a maximum when the ball is at the highest point in the arc.

6. In which one of the following situations does the car have a westward acceleration?
   (a) The car travels westward at constant speed.
   (b) The car travels eastward and speeds up.
   (c) The car travels westward and slows down.
   (d) The car travels eastward and slows down.

7. Complete the following statement: An inertial reference frame is one in which
   (a) Newton's first law of motion is valid.
   (b) the inertias of objects within the frame are zero.
   (c) the frame is accelerating.
   (d) the acceleration due to gravity is greater than zero m/s^2.
   (e) Newton's third law of motion is not valid.

8. A train approaches a small town with a constant velocity of +28.6 m/s. The operator applies the brake, reducing the train's velocity to +11.4 m/s. If the average acceleration of the train during braking is –1.35 m/s^2, for what elapsed time does the operator apply the brake?

(a) 8.44 s (c) 3.38 s (e) 10.4 s
(b) 12.7 s (d) 5.92 s

9. Which one of the following statements must be true if the expression $x = v_0 t + \frac{1}{2}at^2$ is to be used?

(a) x is constant. (c) t is constant. (e) Both v_0 and t are constant.
(b) v is constant. (d) a is constant.

10 Two cars travel along a level highway in the same direction. It is observed that the distance between the cars is *increasing*. Which one of the following statements concerning this situation is *necessarily* true?

(a) The velocity of each car is increasing.
(b) At least one of the cars has a *non-zero* acceleration.
(c) The leading car has the greater acceleration.
(d) The trailing car has the smaller acceleration.
(e) Both cars could be accelerating at the same rate.

11. A car starts from rest and accelerates at a constant rate in a straight line. In the *first* second the car covers a distance of 2.0 meters. How much *additional* distance will the car cover during the *second* second of its motion?

(a) 2.0 m (c) 6.0 m (e) 13 m
(b) 4.0 m (d) 8.0 m

12. An eagle is flying due east at 8.9 m/s carrying a gopher in its talons. The gopher manages to break free at a height of 12 m. What is the magnitude of the gopher's velocity as it reaches the ground? Note: effects of air resistance are not included in this calculation.

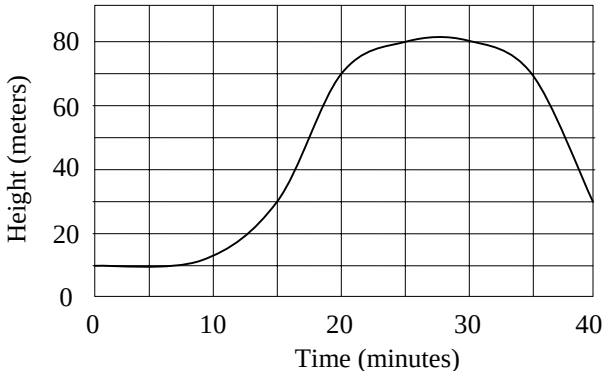
(a) 22 m/s (c) 11 m/s (e) 8.9 m/s
(b) 18 m/s (d) 9.8 m/s

13. A rock is dropped from rest from a height h above the ground. It falls and hits the ground with a speed of 11 m/s. From what height should the rock be dropped so that its speed on hitting the ground is 22 m/s? Neglect air resistance.

(a) 1.4h (c) 3.0h (e) 0.71h
(b) 2.0h (d) 4.0h

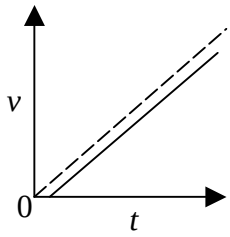
14. The graph shows the height versus time of an object. Estimate the instantaneous velocity, in m/s, of the object at time t = 15 min.

(a) 0.90 m/s
(b) 0.70 m/s
(c) 0.50 m/s
(d) 0.30 m/s
(e) 0.10 m/s



15. If the same object were released in air, the magnitude of its acceleration would begin at the free-fall value, but it would decrease continuously to zero as the object continued to fall.

For which one of the choices given does the solid line best represent the speed of the object as a function of time when it is dropped from rest in air? *Note:* The dashed line shows the free-fall under vacuum graph for comparison.

(a)


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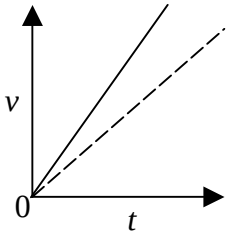

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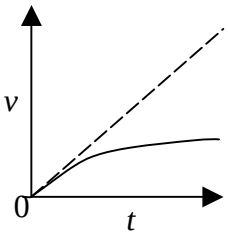

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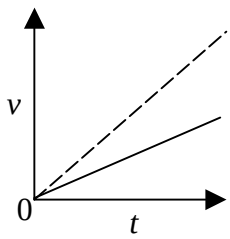
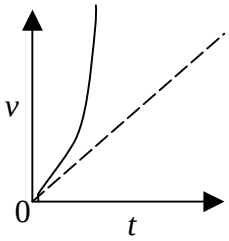
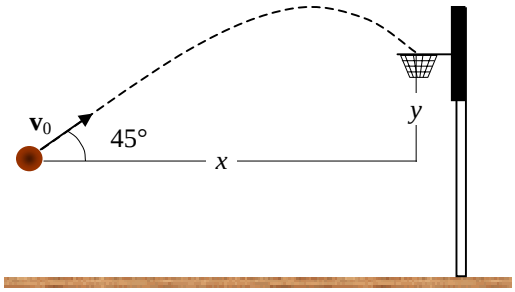


(d)


16. A basketball is launched with an initial speed of 8.0 m/s and follows the trajectory shown. The ball enters the basket 0.96 s after it is launched. What are the distances *x* and *y*? **Note**: *The drawing is not to scale.*

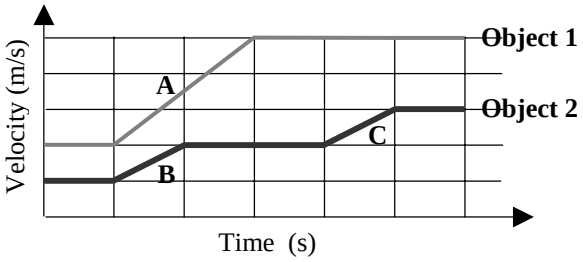


	x	*y*
(a)	5.4 m	0.73 m
(b)	7.7 m	0.91 m
(c)	5.4 m	0.91 m
(d)	5.7 m	0.73 m
(e)	5.4 m	5.4 m

17. A boat that can travel at 4.0 km/h in still water crosses a river with a current of 2.0 km/h. At what angle must the boat be pointed upstream (that is, relative to its actual path) to go straight across the river?

(a) 27° (c) 60° (e) 90°
(b) 30° (d) 63°

18. The graph shows the velocities of two objects of equal mass as a function of time. Net forces $\mathbf{F}_A$, $\mathbf{F}_B$, and $\mathbf{F}_C$ acted on the objects during intervals A, B, and C, respectively. Which one of the following choices is the correct relationship between the magnitudes of the net forces?



(a) $F_B = F_C > F_A$ (c) $F_A > F_B = F_C$ (e) $F_A > F_B > F_C$
(b) $F_C > F_B > F_A$ (d) $F_A = F_B = F_C$

19. Two forces act on a 16-kg object. The first force has a magnitude of 68 N and is directed 24° north of east. The second force is 32 N, 48° north of west. What is the acceleration of the object resulting from the action of these two forces?

(a) 1.6 m/s^2, 5.5° north of east
(b) 1.9 m/s^2, 18° north of west
(c) 2.4 m/s^2, 34° north of east
(d) 3.6 m/s^2, 5.5° north of west
(e) 4.1 m/s^2, 52° north of east

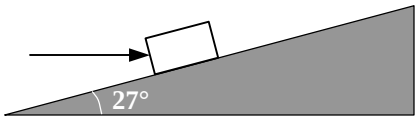
20. An astronaut orbits the earth in a space capsule whose height above the earth is equal to the earth's radius. How does the weight of the astronaut in the capsule compare to her weight on the earth?

(a) Her weight is equal to her weight on earth.
(b) Her weight is equal to one-fourth her weight on earth.
(c) Her weight is equal to one-half of her weight on earth.
(d) Her weight is equal to one-third of her weight on earth.
(e) Her weight is equal to zero.

21.. An apple crate with a weight of 225 N accelerates along a *frictionless* surface as the crate is pulled with a force of 14.5 N as shown in the drawing. What is the horizontal acceleration of the crate?

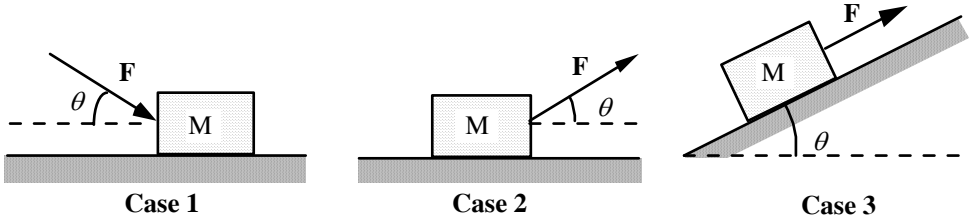
(a) 1.40 m/s^2
(b) 0.427 m/s^2
(c) 1.29 m/s^2
(d) 0.597 m/s^2
(e) 0.644 m/s^2

22. A 250-N force is directed horizontally as shown to push a 29-kg box up an inclined plane at a constant speed. Determine the magnitude of the normal force, F_N, and the coefficient of kinetic friction, μ_k.



	F_N	μ_k
(a)	330 N	0.31
(b)	310 N	0.33
(c)	250 N	0.27
(d)	290 N	0.30
(e)	370 N	0.26

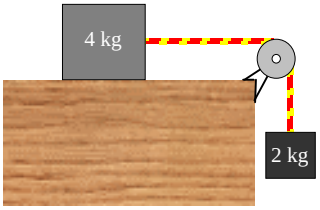
23. Note the following situations:



In which case will the magnitude of the normal force on the block be equal to ($Mg + F \sin \theta$)?

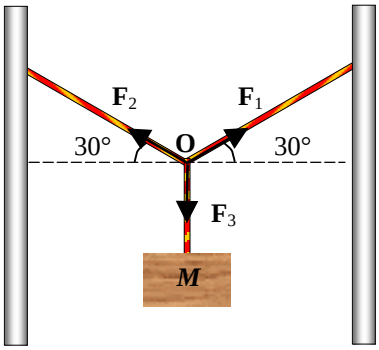
(a) case *1* only
(b) case *2* only
(c) both cases *1* and *2*
(d) both cases *2* and *3*
(e) cases *1*, *2*, and *3*

24. A 4-kg block is connected by means of a *massless* rope to a 2-kg block as shown in the figure. Complete the following statement: If the 4-kg block is to begin sliding, the coefficient of static friction between the 4-kg block and the surface must be



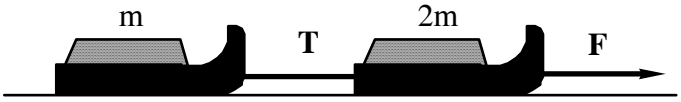
(a) less than zero.
(b) greater than 2.
(c) greater than 1, but less than 2.
(d) greater than 0.5, but less than 1.
(e) less than 0.5, but greater than zero.

25. A block of mass M is hung by ropes as shown. The system is in equilibrium. The point O represents the knot, the junction of the three ropes. Which of the following statements is true concerning the magnitudes of the three forces in equilibrium?



(a) $F_1 = F_2 = F_3$
(b) $F_2 = 2F_3$
(c) $F_2 < F_3$
(d) $F_1 = F_2 = \frac{F_3}{2}$
(e) $F_1 > F_3$

26. Two sleds are hooked together in tandem as shown in the figure. The front sled is twice as massive as the rear sled.



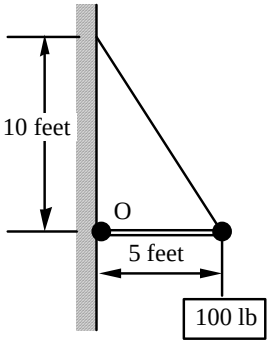
The sleds are pulled along a frictionless surface by an applied force **F**. The tension in the rope between the sleds is **T**. Determine the ratio of the magnitudes of the two forces, $\frac{T}{F}$.

(a) 0.25 (c) 0.50 (e) 2.0
(b) 0.33 (d) 0.67

27. A certain crane can provide a maximum lifting force of 25 000 N. It hoists a 2000-kg load starting at ground level by applying the maximum force for a 2-second interval; then, it applies just sufficient force to keep the load moving upward at constant speed. Approximately how long does it take to raise the load from ground level to a height of 30 m?

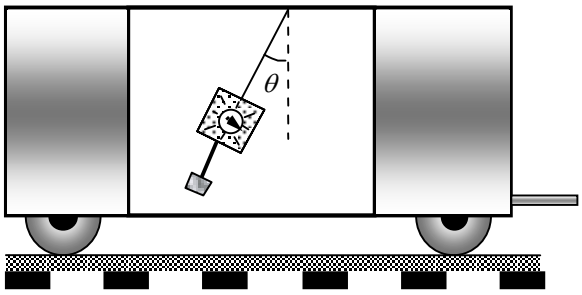
(a) 2 s (c) 7 s (e) 10 s
(b) 5 s (d) 9 s

28. A *massless horizontal strut* is attached to the wall at the hinge O. Which one of the following phrases best describes the force that the hinge pin applies *to the strut* if the weight of the cables is also neglected?



(a) 50 lb, to the right
(b) 100 lb, straight up
(c) 200 lb, to the right
(d) 244 lb, 27° above the strut
(e) 56 lb, to the left

29. A spring scale is fastened to the ceiling of a railway car. When a 1.0-kg block is hung from the scale, it reads 12 N and is oriented as shown in the figure. What is the approximate acceleration of the car as measured by an observer at rest on the ground outside of the car?



(a) 7 m/s^2 to the right
(b) 7 m/s^2 to the left
(c) 12 m/s^2 to the right
(d) 12 m/s^2 to the left
(e) It is impossible to calculate since the angle θ has not been given.

30. Sara puts a box into the trunk of her car. Later, she drives around an unbanked curve that has a radius of 48 m. The speed of the car on the curve is 16 m/s, but the box remains stationary relative to the floor of the trunk. Determine the minimum coefficient of static friction for the box on the floor of the trunk.

(a) 0.42
(b) 0.54
(c) 0.17
(d) 0.33
(e) This cannot be determined without knowing the mass of the box.

Questions 31 and 32 pertain to the following situation.

An airplane flying at 115 m/s due east makes a gradual turn following a circular path to fly south. The turn takes 15 seconds to complete.

31. What is the radius of the curve that the plane follows in making the turn?

(a) 280 m
(b) 350 m
(c) 830 m
(d) 1100 m
(e) 1600 m

32. What is the magnitude of the centripetal acceleration during the turn?

(a) zero m/s^2
(b) 6.9 m/s^2
(c) 8.1 m/s^2
(d) 9.8 m/s^2
(e) 12 m/s^2

33. The kinetic energy of an 1100-kg truck is 4.6×10^5 J. What is the speed of the truck?

(a) 25 m/s
(b) 33 m/s
(c) 29 m/s
(d) 17 m/s
(e) 21 m/s

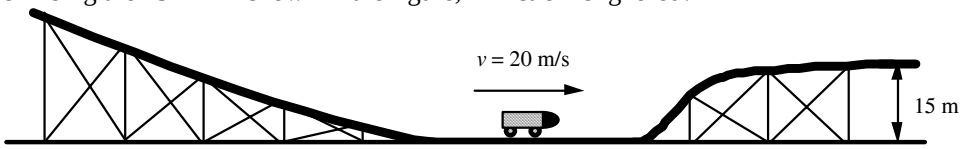
34. A 10.0-g bullet traveling horizontally at 755 m/s strikes a stationary target and stops after penetrating 14.5 cm into the target. What is the average force of the target on the bullet?

(a) 1.97×10^4 N
(b) 2.07×10^5 N
(c) 6.26×10^3 N
(d) 3.13×10^4 N
(e) 3.93×10^4 N

35. A helicopter (m = 1250 kg) is cruising at a speed of 25.0 m/s at an altitude of 185 m. What is the total mechanical energy of the helicopter?

(a) 3.91×10^5 J
(b) 2.66×10^6 J
(c) 2.27×10^6 J
(d) 6.18×10^5 J
(e) 1.88×10^6 J

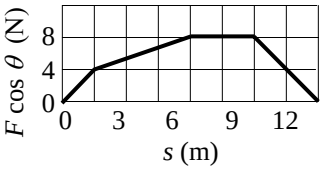
36. A roller-coaster car is moving at 20 m/s along a straight horizontal track. What will its speed be after climbing the 15-m hill shown in the figure, if friction is ignored?



(a) 17 m/s
(b) 7 m/s
(c) 5 m/s
(d) 10 m/s
(e) 14 m/s

37. A 51-kg woman runs up a flight of stairs in 5.0 s. Her net upward displacement is 5.0 m. Approximately, what average power did the woman exert while she was running?
(a) 5.0 kW
(b) 1.0 kW
(c) 0.75 kW
(d) 0.50 kW
(e) 0.25 kW

38. The force component acting on an object along the displacement varies with the displacement s as shown in the graph. Determine the work done on the object as it travels from $s = 0.0$ to 12 m.



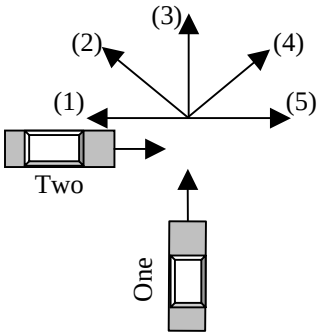
(a) 48 J
(b) 66 J
(c) 72 J
(d) 57 J
(e) 81 J

39. While a car is stopped at a traffic light in a storm, raindrops strike the roof of the car. The area of the roof is 5.0 m^2. Each raindrop has a mass of 3.7×10^{-4} kg and speed of 2.5 m/s before impact and is at rest after the impact. If, on average at a given time, 150 raindrops strike each square meter, what is the impulse of the rain striking the car?
(a) 0.69 N · s
(b) 0.046 N · s
(c) 0.14 N · s
(d) 11 N · s
(e) 21 N · s

40. A stationary bomb explodes in space breaking into a number of small fragments. At the location of the explosion, the net force due to gravity is zero newtons. Which one of the following statements concerning this event is true?
(a) Kinetic energy is conserved in this process.
(b) The fragments must have equal kinetic energies.
(c) The sum of the kinetic energies of the fragments must be zero.
(d) The vector sum of the linear momenta of the fragments must be zero.
(e) The velocity of any one fragment must be equal to the velocity of any other fragment.

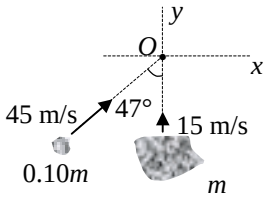
41. A sled of mass m is coasting on the icy surface of a frozen river. While it is passing under a bridge, a package of equal mass m is dropped straight down and lands on the sled (without causing any damage). The sled plus the added load then continue along the original line of motion. How does the kinetic energy of the sled + load compare with the original kinetic energy of the sled?
(a) It is 1/4 the original kinetic energy of the sled.
(b) It is 1/2 the original kinetic energy of the sled.
(c) It is 3/4 the original kinetic energy of the sled.
(d) It is the same as the original kinetic energy of the sled.
(e) It is twice the original kinetic energy of the sled.

42. Car One is traveling due north and Car Two is traveling due east. After the collision shown, Car One rebounds in the due south direction. Which of the numbered arrows is the only one that can represent the final direction of Car Two?



(a) 1
(b) 2
(c) 3
(d) 4
(e) 5

43. Two asteroids are drifting in space with trajectories shown. Assuming the collision at point *O* between them is completely inelastic, at what angle from its original direction is the larger asteroid deflected?

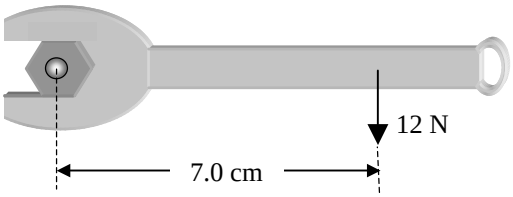


(a) 80° above the +*x* axis
(b) 69° above the +*x* axis
(c) 42° above the +*x* axis
(d) 47° above the +*x* axis
(e) 90° above the +*x* axis

44. During the spin-dry cycle of a washing machine, the motor slows from 95 rad/s to 30 rad/s while the turning the drum through an angle of 402 radians. What is the magnitude of the angular acceleration of the motor?

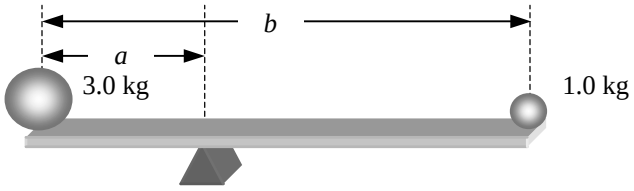
(a) 64 rad/s^2
(b) 32 rad/s^2
(c) 10 rad/s^2
(d) 20 rad/s^2
(e) 1.0 rad/s^2

45. A wrench is used to tighten a nut as shown in the figure. A 12-N force is applied 7.0 cm from the axis of rotation. What is the torque due to the applied force?



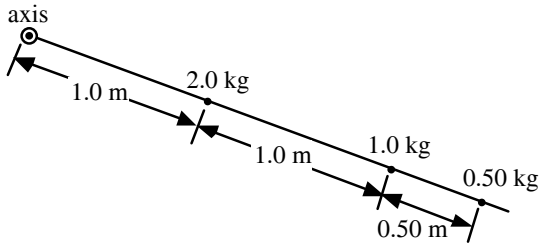
(a) 0.58 N · m
(b) 0.84 N · m
(c) 1.71 N · m
(d) 14 N · m
(e) 58 N · m

46. A 3.0-kg ball and a 1.0-kg ball are placed at opposite ends of a *massless* beam so that the system is in equilibrium as shown. **Note**: *The drawing is not drawn to scale.* What is the ratio of the lengths, *b*/*a*?



(a) 2.0
(b) 2.5
(c) 3.0
(d) 4.0
(e) 5.0

47. Three objects are attached to a *massless* rigid rod that has an axis of rotation as shown. Assuming all of the mass of each object is located at the point shown for each, calculate the moment of inertia of this system.



(a) 1.3 kg · m^2
(b) 3.1 kg · m^2
(c) 5.3 kg · m^2
(d) 7.2 kg · m^2
(e) 9.1 kg · m^2

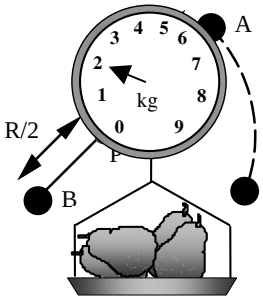
48. A string is wrapped around a pulley of radius 0.10 m and moment of inertia 0.15 kg · m^2. The string is pulled with a force of 12 N. What is the magnitude of the resulting angular acceleration of the pulley?

(a) 18 rad/s^2
(b) 0.13 rad/s^2
(c) 80 rad/s^2
(d) 0.055 rad/s^2
(e) 8.0 rad/s^2

49. What happens when a spinning ice skater draws in her outstretched arms?

(a) Her angular momentum decreases.
(b) Her angular momentum increases.
(c) Her moment of inertia decreases causing her to speed up.
(d) Her moment of inertia decreases causing her to slow down.
(e) The torque that she exerts increases her moment of inertia.

50. In the produce section of a supermarket, five pears are placed on a spring scale. The placement of the pears stretches the spring and causes the dial to move from zero to a reading of 2.0 kg. If the spring constant is 450 N/m, what is the displacement of the spring due to the weight of the pears?



(a) 0.0044 m
(b) 0.0088 m
(c) 0.018 m
(d) 0.044 m
(e) 0.088 m