Physics for Scientists and Engineers, 4e **(Giancoli)**

Chapter 12 Static Equilibrium; Elasticity and Fracture

12.1 Conceptual Questions

1) State the conditions for static equilibrium.
Answer: (1) The net force acting on the object must be zero.
(2) The net torque acting on the object must be zero.
Diff: 1 Page Ref: Sec. 12-1

2) If the net force on an object is zero, does the net torque on the object also have to be zero?
Answer: No. For example, the object might be subjected to two equal and opposite forces that are not along the same straight line. This would produce a torque, but the net force would be zero.
Diff: 1 Page Ref: Sec. 12-1

3) If the net torque on an object is zero, does the the net force on the object also have to be zero?
Answer: No. If the sum of the forces on an object are not zero, then the CM of the object will accelerate in the direction of the net force. If the sum of the torques on the object are zero, then the object has no angular acceleration.
Diff: 2 Page Ref: Sec. 12-1

4) An object in static equilibrium, if left undisturbed, will undergo no translational or rotational acceleration. However, if the object is displaced slightly, three outcomes are possible. List and explain each of these outcomes.
Answer: 1. Stable equilibrium: the object returns to its original position
2. Unstable equilibrium: the object moves even farther from it original position
3. Neutral equilibrium: the object remains in its new position
Diff: 2 Page Ref: Sec. 12-3

5) If you stand with your back towards a wall and your heels touching the wall, you cannot lean over to touch your toes. Why?
Answer: As you bend over your center of gravity moves forward and eventually is beyond the area of the floor in touch with your feet. This does not happen when you do it away from the wall because part of your body moves back and the center of mass remains over your feet.
Diff: 2 Page Ref: Sec. 12-3

6) Tightrope walkers often employ a long pole to help them retain their balance. What advantage is there to using a very flexible pole so that the ends droop?
Answer: The drooping of the pole lowers the center of mass of the walker-pole system, making it less unstable. In fact, if the center is below the rope the system becomes stable.
Diff: 2 Page Ref: Sec. 12-3

7) Compare and contrast tensile stress, compressive stress, and shear stress.
Answer: Tensile stress results from forces pulling outward at opposite ends of a material, stretching the material.
compressive stress is the exact opposite of tensile stress. Instead of being stretched, the material is compressed: the forces act inwardly on the object.
An object under shear stress has equal and opposite forces applied parallel to its opposite faces.
Diff: 1 Page Ref: Sec. 12-4

8) If an object is in equilibrium, the net torque about any arbitrary axis must be zero.
Answer: TRUE
Diff: 1 Page Ref: Sec. 12-1

9) An object whose center of gravity is below its point of support, will be in neutral equilibrium.
Answer: FALSE
Diff: 1 Page Ref: Sec. 12-3

10) An object whose center of gravity is above its base of support will be stable if a vertical line projected downward from the center of gravity falls within the base of support.
Answer: TRUE
Diff: 1 Page Ref: Sec. 12-3

11) An object whose center of gravity is above its base of support will be unstable if a vertical line projected downward from the center of gravity falls outside of the base of support.
Answer: TRUE
Diff: 1 Page Ref: Sec. 12-3

12) If an object is stretched beyond its elastic limit, it does not return to its original length upon removal of the external force.
Answer: TRUE
Diff: 1 Page Ref: Sec. 12-4

13) The maximum elongation of a typical metal is reached at the breaking point.
Answer: TRUE
Diff: 1 Page Ref: Sec. 12-4

14) The maximum force that can be applied without breaking a material is called the breaking force.
Answer: FALSE
Diff: 1 Page Ref: Sec. 12-4

15) Several forces act on an object at rest. It is known that the sum of the forces acting on the object is zero. Which statement is necessarily true?
A) The object will remain stationary.
B) The object's center of mass may move in such a way that the object will roll without slipping.
C) The object's center of mass will not move, but the object may begin to rotate.
D) The object's center of mass may accelerate and the object may begin to rotate.
E) The object's center of mass may accelerate, but the object will remain in the same orientation.
Answer: C
Diff: 1 Page Ref: Sec. 12-1

FIGURE 12-1

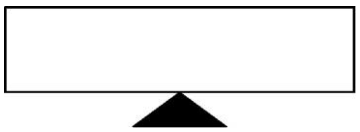
16) A massive uniform beam is supported in equilibrium by two fulcrums as shown in Fig. 12-1. Which fulcrum applied the greater magnitude force to the beam?
A) the right fulcrum
B) the left fulcrum
C) The answer depends on the length of the beam.
D) The answer depends on the mass of the beam.
E) Both fulcrums apply the same force.
Answer: A
Diff: 1 Page Ref: Sec. 12-2

17) A heavy boy and a lightweight girl are balanced on a massless seesaw. If they both move forward so that they are one-half their original distance from the pivot point, what will happen to the seesaw?
A) It is impossible to say without knowing the masses.
B) It is impossible to say without knowing the distances.
C) The side the boy is sitting on will tilt downward.
D) Nothing, the seesaw will still be balanced.
E) The side the girl is sitting on will tilt downward.
Answer: D
Diff: 2 Page Ref: Sec. 12-2

18) A sphere hanging freely from a cord is in
A) stable equilibrium.
B) unstable equilibrium.
C) neutral equilibrium.
D) positive equilibrium.
E) negative equilibrium.
Answer: A
Diff: 1 Page Ref: Sec. 12-3

19) A cone balanced on its small end is in
A) stable equilibrium.
B) unstable equilibrium.
C) neutral equilibrium.
D) positive equilibrium.
E) negative equilibrium.
Answer: B
Diff: 1 Page Ref: Sec. 12-3

FIGURE 12-2



20) A thick uniform beam is balanced on a pivot as shown in Fig. 12-2 where it is in equilibrium. Which type of equilibrium is this and why is it of that type?
A) Stable. When the beam tilts slightly to one side, the center of mass moves to the same side resulting in torque that will cause rotational acceleration in the opposite direction of the slight displacement.
B) Unstable. When the beam tilts slightly to one side, the center of mass moves to the same side resulting in torque that will cause further rotation in that direction.
C) The type of stability depends on the mass and length of the beam. Until those values are known, the stability cannot be evaluated.
D) Neutral. A tilt of the beam does not change the torque that is acting on the body and the total torque will remain zero as it is in equilibrium.
E) Stable. All equilibria are stable when a single support is below the center of mass. The equilibria are only unstable or neutral when the support is under one corner of the object.
Answer: B
Diff: 1 Page Ref: Sec. 12-3

21) The region from the origin to the elastic limit on an applied force versus elongation graph for a typical metal under tension is referred to as the
A) elastic region.
B) proportional region.
C) plastic region.
D) ultimate strength region.
E) breaking region.
Answer: A
Diff: 1 Page Ref: Sec. 12-4

22) If an object is stretched beyond the elastic limit, it enters the _____ on an applied force versus elongation graph for a typical metal.
A) elastic region
B) proportional region
C) plastic region
D) ultimate strength region
E) breaking region
Answer: C
Diff: 1 Page Ref: Sec. 12-4

23) The maximum elongation of a typical metal is reached at the
A) proportional limit.
B) elastic limit.
C) inelastic limit.
D) breaking point.
E) ultimate strength.
Answer: D
Diff: 1 Page Ref: Sec. 12-4

24) Stress is
A) the strain per unit length.
B) the same as force.
C) the ratio of the change in length to the original length.
D) applied force per cross-sectional area.
E) the ratio of elastic modulus to strain.
Answer: D
Diff: 1 Page Ref: Sec. 12-4

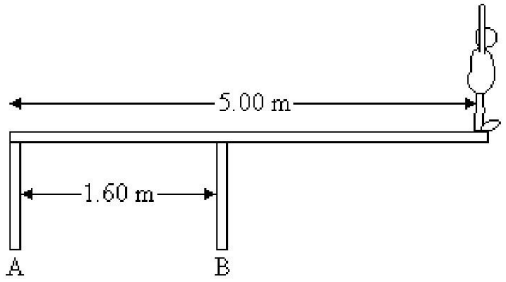
25) Strain is
A) the ratio of the change in length to the original length.
B) the stress per unit area.
C) the same as force.
D) the applied force per cross-sectional area.
E) the ratio of stress to elastic modulus.
Answer: A
Diff: 1 Page Ref: Sec. 12-4

26) The horizontal component of the buttressing force at the base of a pointed arch is
A) less than that of a rounded arch.
B) equal to that of a rounded arch.
C) greater than that of a rounded arch.
D) zero in magnitude.
Answer: A
Diff: 1 Page Ref: Sec. 12-7

12.2 Quantitative Problems

1) A light board, 10 m long, is supported by two sawhorses, one at one edge of the board and a second at the midpoint. A 40-N weight is placed between the two sawhorses, 3.0 m from the edge and 2.0 m from the center. What forces are exerted by the sawhorses on the board?
Answer: 16 N at the end and 24 N at the midpoint
Diff: 1 Page Ref: Sec. 12-2

FIGURE 12-3

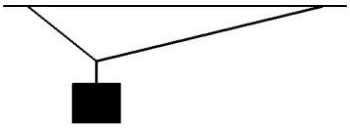


2) An 82.0 kg-diver stands at the edge of a light 5.00-m diving board, which is supported by two pillars 1.60 m apart, as shown in Fig. 12-3.
(a) Find the force exerted by pillar A.
(b) Find the force exerted by pillar B.
Answer: (a) 1.71 kN downwards
(b) 2.51 kN upwards
Diff: 1 Page Ref: Sec. 12-2

FIGURE 12-1

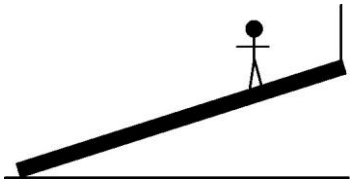
3) A 100-kg, 12.0-m long uniform beam is supported in equilibrium by two fulcrums as shown in Fig. 12-1. The left fulcrum is 1.00 m from the nearer end of the beam and the right fulcrum is 3.00 m from the nearer end of the beam.
   (a) What is the magnitude of the force of the left fulcrum on the beam?
   (b) What is the magnitude of the force of the right fulcrum on the beam?
   Answer: (a) 1.47 kN
   (b) 2.45 kN
   Diff: 2 Page Ref: Sec. 12-2

FIGURE 12-4



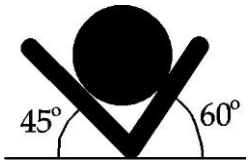
4) A 20.0-kg mass is supported by two strings as shown in Fig. 12-4. The left string is 2.00 m long and the right string is 5.00 m long. The attachment points for the two strings are 6.00 m apart on the ceiling.
   (a) What is the tension in the left side string?
   (b) What is the tension in the right side string?
   Answer: (a) 199 N
   (b) 131 N
   Diff: 2 Page Ref: Sec. 12-2

FIGURE 12-5



5) A 20.0-kg uniform plank is supported by the floor at one end and by a vertical rope at the other as shown in Fig. 12-5. A 50.0-kg mass person stands on the plank a distance three-fourths of the length plank from the end on the floor.
   (a) What is the tension in the rope?
   (b) What is the magnitude of the force of floor on the plank?
   Answer: (a) 466 N
   (b) 220 N
   Diff: 2 Page Ref: Sec. 12-2

FIGURE 12-6



6) A 3.00-kg ball rests in a frictionless groove as shown in Fig. 12-6.
(a) What is the normal force between the left side of the groove and the ball?
(b) What is the normal force between the right side of the groove and the ball?
Answer: (a) 26.4 N
(b) 21.5 N
Diff: 2 Page Ref: Sec. 12-2

7) A 3.00-m long plank of negligible mass has a 30.0-kg mass at one end and a 40.0-kg mass at the other end. How far from the 30.0-kg mass should a fulcrum be placed so that the plank is balanced?
A) 1.71 m B) 1.29 m C) 0.750 m D) 1.50 m E) 2.25 m
Answer: A
Diff: 1 Page Ref: Sec. 12-2

8) A 2.00-m long uniform beam of mass 4.00 kg rests on a fulcrum that is 1.20 m from one end when a 3.00-kg mass rests on that end and a 8.00-kg mass is placed at another location on the beam. How far from the end at which the 3.00-kg mass is placed is the location of the 8.00-kg mass?
A) 1.45 m B) 1.75 m C) 1.35 m D) 1.55 m E) 1.65 m
Answer: B
Diff: 1 Page Ref: Sec. 12-2

9) A non-uniform, 80-g, meter stick balances when the support is placed at the 51.0-cm mark. At what location on the stick should a 5.0-g tack be placed so that the stick will balance at the 50.0 cm mark?
A) 16.0 cm B) 67.0 cm C) 66.0 cm D) 35.0 cm E) 34.0 cm
Answer: E
Diff: 1 Page Ref: Sec. 12-2

10) A meter stick balances at the 50.0-cm mark. If a mass of 50.0 g is placed at the 90.0-cm mark, the stick balances at the 61.3-cm mark. What is the mass of the meter stick?
A) 127 g B) 178 g C) 89.7 g D) 32.6 g E) 73.4 g
Answer: A
Diff: 1 Page Ref: Sec. 12-2

11) A 30.0-kg child sits on one end of a long uniform beam with a mass 20.0 kg and a 40.0-kg child sits on the other end. The beam balances when a fulcrum is placed below the beam a distance 1.10 m from the 30.0-kg child. How long is the beam?
A) 2.12 m B) 1.98 m C) 1.93 m D) 2.07 m E) 2.20 m
Answer: B
Diff: 1 Page Ref: Sec. 12-2

12) A seesaw made of a plank of mass 10.0 kg and length 3.00 m is balanced on a fulcrum 1.00 m from one end of the plank. A 20.0-kg mass rests on the end of the plank nearest the fulcrum. What mass must be on the other end if the plank remains balanced?
A) 6.67 kg B) 7.50 kg C) 10.0 kg D) -10.0 kg E) 5.00 kg
Answer: B
Diff: 1 Page Ref: Sec. 12-2

13) Two children are carrying a 2.00-m long uniform level board with a mass 5.00 kg, each supporting one end of the board. A 1.00-kg book is resting on the board a distance 1.20 m from one end of the board. What is the force applied by the child that is closer to the book to support the board?

A) 29.4 N downward
B) 58.9 N upward
C) 29.4 N upward
D) 30.4 N upward
E) 3.10 N upward

Answer: D
Diff: 1 Page Ref: Sec. 12-2

14) Two people are lifting a 2.0-m wide, 80-kg, office desk by the ends. One side is heavier than the other, and it is found that the person exerting the larger force is exerting a vertical force of 500 N. How far from that person is the center of mass of the desk?

A) 0.73 m B) 1.3 m C) 1.4 m D) 0.58 m E) 1.0 m

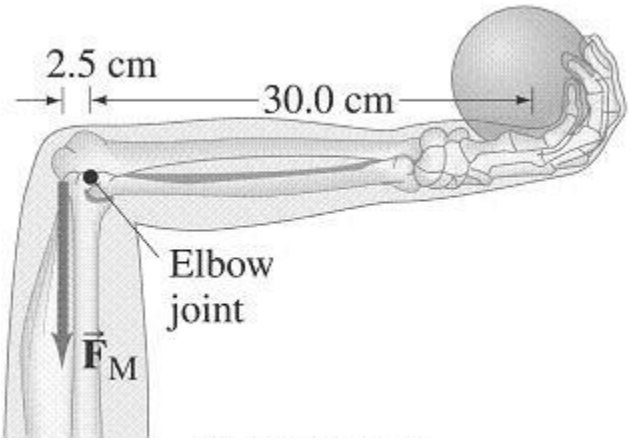
Answer: A
Diff: 1 Page Ref: Sec. 12-2

15) A 25-kg wooden sign 3.0-m long by 2.2-m high is supported by two nails along its left edge, one at the bottom of the sign and the other at the top. The nails are on the same vertical line. Find the horizontal component of the force exerted by the upper nail.

A) 250 N B) 120 N C) 360 N D) 170 N E) 280 N

Answer: D
Diff: 1 Page Ref: Sec. 12-2

FIGURE 12-7



16) Assuming the lower arm has a mass of 2.8 kg and its CG is 12 cm from the elbow-joint pivot, how much force must the extensor muscle in the upper arm exert on the lower arm to hold a 7.5 kg shot put (Fig. 12-7)?

A) 100 N B) 500 N C) 750 N D) 1000 N E) 1500 N

Answer: D
Diff: 2 Page Ref: Sec. 12-2

17) A uniform beam with a mass of 120 kg and a length of 5.0 m rests on two supports, one at the left edge and one 3.0 m from the left edge. How close to the right edge can a 68-kg person walk along the beam without causing it to tip over?

A) 1.6 m B) 1.8 m C) 0.88 m D) 1.5 m E) 0.50 m

Answer: A
Diff: 2 Page Ref: Sec. 12-2

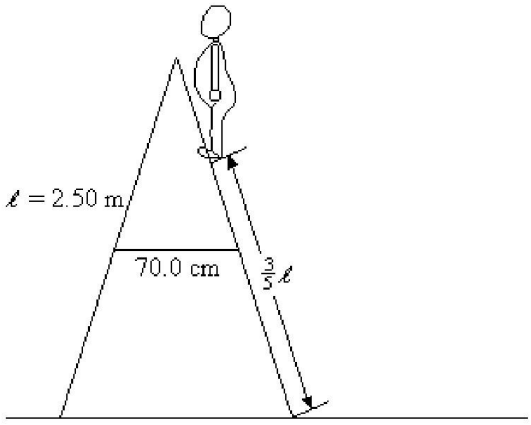
18) A 5.0-m long, 12-kg, ladder rests against a smooth vertical wall with the bottom of the ladder 3.0 m from the wall. The coefficient of static friction between the floor and the ladder is 0.28. What distance, measured along the ladder from the bottom, can a 60-kg person climb before the ladder starts to slip?

A) 4.0 m B) 3.7 m C) 1.7 m D) 1.3 m E) 3.3 m

Answer: C

Diff: 2 Page Ref: Sec. 12-2

FIGURE 12-8



19) A stepladder consists of two halves, hinged at the top, and connected by a tie rod which keeps the two halves from spreading apart. In this particular instance, the two halves are 2.50 m long, the tie rod is connected to the center of each half and is 70.0 cm long. An 800-N person stands 3/5 of the way up the stepladder, as shown in Figure 12-8. Neglecting the weight of the ladder, and assuming that the ladder is resting on a smooth floor, what is the tension in the tie rod? Note: to solve this problem you must "cut" the ladder in half and consider the equilibrium of forces and torques acting on each half of the ladder.

A) 140 N B) 240 N C) 280 N D) 360 N E) 560 N

Answer: A

Diff: 3 Page Ref: Sec. 12-2

20) Two identical ladders are 3.0 m long and weigh 600 N each. They are connected by a hinge at the top and are held together by a horizontal rope, 1.0 m above the smooth floor forming a symmetric "A" arrangement. The angle between the ladders is 60° and both ladders have their center of gravity at their midpoint. What is the tension in the rope?

A) 240 N B) 300 N C) 220 N D) 260 N E) 280 N

Answer: E

Diff: 3 Page Ref: Sec. 12-2

21) The Leaning Tower of Pisa is 55 m tall and about 7.0 m in diameter. The top is 4.5 m off center. How much farther can it lean before it becomes unstable?

A) 0.5 m B) 1.5 m C) 2.5 m D) 3.5 m E) 4.5 m

Answer: C

Diff: 2 Page Ref: Sec. 12-3

22) A 120-kg refrigerator, 2.00 m tall and 85.0 cm wide has its center of mass at its geometrical center. You are attempting to slide it along the floor by pushing horizontally on the side of the refrigerator. The coefficient of static friction between the floor and the refrigerator is 0.300. Depending on where you push, the refrigerator may start to tip over before it starts to slide along the floor. What is the highest distance above the floor that you can push the refrigerator so that it won't tip before it begins to slide?

A) 0.710 m B) 1.00 m C) 1.21 m D) 1.42 m E) 1.63 m

Answer: D

Diff: 2 Page Ref: Sec. 12-3

23) A truck is carrying a 120-kg refrigerator, which is 2.20 m tall and 85.0 cm wide has its center of mass at its geometrical center. The refrigerator is facing sideways and a short strip on the bed of the truck keeps the refrigerator from sliding. What is the maximum acceleration that the truck can have before the refrigerator begins to tip over?

A) 1.90 m/s^2 B) 4.17 m/s^2 C) 3.79 m/s^2 D) 7.58 m/s^2 E) 8.34 m/s^2

Answer: C

Diff: 2 Page Ref: Sec. 12-3

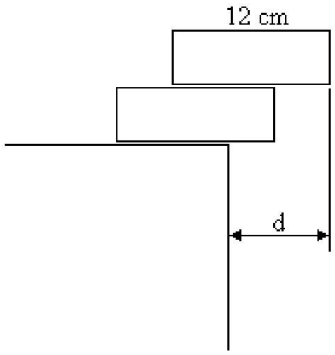
24) The wheelbase on a truck is 2.4 m wide and the truck's center of mass is located along the vertical centerline of the truck and 2.0 m above the bottom of the tires. The truck is going around a banked turn, when it is forced to stop. What is the maximum slope that the bank can have such that the truck will not tip over?

A) 26° B) 31° C) 34° D) 39° E) 21°

Answer: B

Diff: 2 Page Ref: Sec. 12-3

FIGURE 12-9



25) A child is trying to stack two uniform wooden blocks, 12 cm in length, so they will protrude as much as possible over the edge of a table, without tipping over, as shown in Fig. 12-9. What is the maximum possible overhang distance?

A) 5 cm B) 6 cm C) 7 cm D) 8 cm E) 9 cm

Answer: E

Diff: 2 Page Ref: Sec. 12-3

26) What is the maximum length of steel cable that can hang vertically supported from one end of the cable? The Young's modulus of this steel is 2.10×10^{11} N/m^2, the tensile strength of this steel is 7.4×10^8 N/m^2, and the density of this steel is 7.6×10^3 kg/m^2.

A) 9.93 km B) 4.22 km C) 456 m D) 1.75 km E) 24.8 km

Answer: A

Diff: 1 Page Ref: Sec. 12-4

27) A mass of 1000 kg hangs at the end of a steel rod 5.0 m in length. The diameter of the rod is 0.80 cm and Young's modulus for the rod is 210,000 MN/m^2. What is the elongation of the rod?

A) 1.2 cm B) 0.46 cm C) 0.12 cm D) 1.8 cm E) 0.047 cm

Answer: B

Diff: 1 Page Ref: Sec. 12-4

28) A 0.600-mm diameter wire stretches 0.5% of its length when it is stretched with a tension of 20 N. What is the Young's modulus of this wire?

A) 5.66×10^{10} N/m^2

B) 3.54×10^{9} N/m^2

C) 1.41×10^{10} N/m^2

D) 6.43×10^{9} N/m^2

E) 2.78×10^{9} N/m^2

Answer: C

Diff: 1 Page Ref: Sec. 12-4

29) A cable is 100-m long and has a cross-sectional area of 1 mm^2. A 1000-N force is applied to stretch the cable. The elastic modulus for the cable is 1.0×10^{11} N/m^2. How far does it stretch?

A) 0.001 m B) 0.01 m C) 0.10 m D) 1.0 m E) 10 m

Answer: D

Diff: 2 Page Ref: Sec. 12-4

30) A steel lift column in a service station is 4.0 m long and 0.20 m in diameter. Young's modulus for steel is 20×10^{10} N/m^2. By how much does the column shrink when a 5000-kg truck is on it?

A) 4.7×10^{-7} m B) 8.0×10^{-7} m C) 3.2×10^{-6} m D) 7.8×10^{-6} m E) 3.1×10^{-5} m

Answer: E

Diff: 2 Page Ref: Sec. 12-4

31) A steel sphere with a radius of 2.0 m falls off a ship and sinks to a depth where the pressure is 15 MN/m^2. The bulk modulus for steel is 1.6×10^{11} N/m^2. What is the change in the radius of the sphere?

A) 0.021 mm B) 4.2 mm C) 0.42 mm D) 0.19 mm E) 0.063 mm

Answer: E

Diff: 2 Page Ref: Sec. 12-4

32) A shear force of 400 N is applied to one face of an aluminum cube with sides of 30 cm. What is the resulting relative displacement? (The shear modulus for aluminum is 2.5×10^{10} N/m^2)

A) 1.9×10^{-8} m B) 2.6×10^{-8} m C) 4.4×10^{-8} m D) 5.3×10^{-8} m E) 8.2×10^{-8} m

Answer: D

Diff: 2 Page Ref: Sec. 12-4

33) At a depth of about 1030 m in the sea the pressure has increased by 100 atmospheres (to about 10^7 N/m^2). By how much has 1.0 m^3 of water been compressed by this pressure? The bulk modulus of water is 2.3×10^9 N/m^2.

A) 2.3×10^{-3} m^3

B) 3.3×10^{-3} m^3

C) 4.3×10^{-3} m^3

D) 5.3×10^{-3} m^3

E) 6.3×10^{-3} m^3

Answer: C

Diff: 2 Page Ref: Sec. 12-4

34) A brass rod, 4.0 m long and with a cross sectional area of 9.2×10^{-6} m^2 is subjected to a tension of 6.0×10^3 N/m^2. The Young's modulus for brass is 9.0×10^{10} N/m^2, and the Poisson ratio is 0.48. By how much does the volume of the rod change?

A) 6.3×10^{-7} m^3
B) 0.029 m^3
C) 2.7×10^{-7} m^3
D) 4.0×10^{-7} m^3
E) 5.2×10^{-7} m^3

Answer: E
Diff: 3 Page Ref: Sec. 12-4

35) The tensile strength for a certain steel wire is 3000 MN/m^2. What is the maximum load that can be applied to a wire with a diameter of 3.0 mm made of this kind of steel?

A) 64 kN B) 9.0 kN C) 42 kN D) 85 kN E) 21 kN

Answer: E
Diff: 1 Page Ref: Sec. 12-5

36) A 55-cm steel rod has a diameter of 30 cm. The compressive strength of steel is 500×10^6 N/m^2. What is the compression force that would break the rod?

A) 3.5×10^7 N B) 2.4×10^7 N C) 1.4×10^8 N D) 4.7×10^8 N E) 8.9×10^8 N

Answer: A
Diff: 1 Page Ref: Sec. 12-5