CBSE

MECHANICAL PROPERTIES OF SOLIDS WS 1

Class 11 - Physics

Section A

1. A copper cube measures 6.00 cm on each side. The bottom face is held in place by very strong glue to a flat horizontal surface, while a horizontal force F is applied to the upper face parallel to one of the edges. How large must F be to cause the cube to deform by 0.250 mm? (shear modulus of copper = 4.4×10^{10} Pa) **[1]**

   a) 6.4×10^5 N
   b) 6.5×10^5 N
   c) 6.3×10^5 N
   d) 6.6×10^5 N

2. A 4 m long copper wire of cross-sectional area 1.2 cm^2 is stretched by a force of 4.8×10^3 N. Young's modulus for copper is Y = 1.2×10^{11} N/m^2. The increase in length of the wire is **[1]**

   a) 0.48 mm
   b) 0.8 mm
   c) 5.36 mm
   d) 1.32 mm

3. A metallic rod of length l and cross-sectional area A is made of a material of Young's modulus Y. If the rod is elongated by an amount y, then the work done is proportional to **[1]**

   a) y^2
   b) y
   c) $\frac{1}{y}$
   d) $\frac{1}{y^2}$

4. **Assertion (A):** Elastic restoring forces may be conservative. **[1]**
   Reason (R): The value of strain for same stress are different while increasing the load and while decreasing the load.

   a) Both A and R are true and R is the correct explanation of A.
   b) Both A and R are true but R is not the correct explanation of A.
   c) A is true but R is false.
   d) A is false but R is true.

5. **Assertion:** Identical springs of steel and copper are equally stretched. More work will be done on the steel spring. **[1]**
   Reason: Steel is more elastic than copper.

   a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
   b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
   c) Assertion is correct statement but reason is wrong statement.
   d) Assertion is wrong statement but reason is correct statement.

6. **Assertion (A):** The strain produced by a hydraulic pressure is volumetric in nature. **[1]**
   Reason (R): It is a ratio of change in volume (ΔV) of the original volume (V)

   a) Both A and R are true and R is the correct
   b) Both A and R are true but R is not the

explanation of A.

correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

7. **Assertion:** Spring balances show correct readings even after they had been used for a long time interval. **[1]**
Reason: On using for long time, spring balances loose its elastic strength.

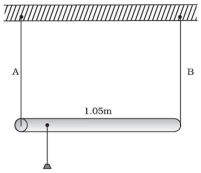
a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

8. A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminum (wire B) of equal lengths as shown in Figure. The cross-sectional areas of wires A and B are 1.0 mm^2 and 2.0 mm^2, respectively. At what point along the rod should a mass m be suspended in order to produce equal strains in both steel and aluminum wires. Take Young's modulus of steel as 200 GPa, for aluminum 70 GPa **[1]**



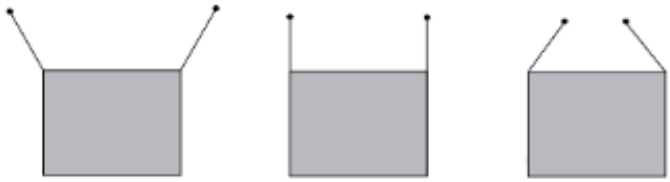
a) 0.42 m from steel wire

b) 0.40 m from steel wire

c) 0.43 m from steel wire

d) 0.44 m from steel wire

9. A rectangular frame is to be suspended symmetrically by two strings of equal length on two supports (Fig.). It can be done in one of the following three ways; **[1]**



The tension in the strings will be

a) least in (b)

b) least in (a)

c) least in (c)

d) the same in all cases

10. What will happen to the potential energy of the atoms of a solid when it is compressed? What happens when a wire is stretched? **[1]**

11. An Indian rubber cube of side 7 cm has one side fixed, while a tangential force equal to the weight of 200 kilogram is applied to the opposite face. Find the shearing strain produced and distance through which the strained side moves. Modulus of rigidity for rubber is 2×10^7 dyne cm^{-2}. **[1]**

12. Write copper, steel, glass and rubber in the order of increasing coefficient of elasticity. **[1]**

13. A 60 kg motor rests on four cylindrical rubber blocks. Each cylinder has a height of 3 cm and a cross-sectional area of 15 cm^2. The shear modulus for this rubber is 2×10^6 Nm^{-2}. If a sideways force of 300 N is applied to the motor, how far will it move sideways? **[1]**

14. If S is the stress and Y is Young's modulus of the material of a wire, what is the energy stored in the wire per unit volume in terms of S and Y? **[1]**

15. The stretching of a coil spring is determined by its shear modulus. Why? **[1]**

16. Two wires made of the same material are subjected to forces in the ratio of 1 : 4. Their lengths are in the ratio 8 : 1 and diameter in the ratio 2 : 1. Find the ratio of their extensions. **[1]**

17. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Find the elastic energy stored in the wire. **[1]**

18. A wire stretches by a certain amount under a load. If the load and radius both are increased to four times, find the stretch caused in the wire. **[1]**

Section B

19. A material having Poisson's ratio 0.2. A load is applied on it, due to which it suffers the longitudinal strain 3.0 $\times 10^{-3}$, then find out the percentage change in its volume. **[2]**

20. A truck is pulling a car out of a ditch by means of a steel cable that is 9.1 m long and has a radius of 5 mm. When the car just begins to move, the tension in the cable is 800 N. How much has the cable stretched? (Young's modulus for steel is 2×10^{11} N.m^{-2}) **[2]**

21. The breaking stress for metal is 7.8×10^9 Nm^{-2}. Calculate the maximum length of the wire made of this metal which may be suspended without breaking. The density of the metal = 7.8×10^3 kg m^{-3}. Take g = 10 N kg^{-1}. **[2]**

22. Calculate the increase in energy of a brass bar of length 0.2 m and cross-sectional area 1 cm^2 when compressed with a load of 5 kg weight along its length. Young's modulus of brass = 1.0×10^{11} Nm^{-2} and g = 9.8 ms^{-2}. **[2]**

23. A cube of aluminium of each side 4 cm is subjected to a tangential (shearing) force. The top face of the cube is sheared through 0.012 cm with respect to the bottom face. Find **[2]**

    i. shearing strain

    ii. shearing stress and shearing force. Given $\eta = 2.08 \times 10^{11}$ dyne cm^{-2}.

24. The compressibility of water is 4×10^{-5} per unit atmospheric pressure. What will be the decrease in volume of 100 cm^3 of water under pressure of 100 atmosphere? **[2]**

25. A steel wire of length 2.0 m is stretched through 2.0 mm. The cross-sectional area of the wire is 4.0 mm^2. Calculate the elastic potential energy stored in the wire in the stretched condition. Young's modulus of steel is 2.0×10^{11} Nm^{-2}. **[2]**

26. A steel rod ($Y = 2 \times 10^{11}$ Nm^{-2}; and $\alpha = 10^{-50}$ C^{-1}) of length 1 m and area of cross-section 1 cm^2 is heated from 0°C to 200°C, without being allowed to extend or bend. What is the tension produced in the rod? **[2]**

27. A solid ball 300 cm in diameter is submerged in a lake at such a depth that the pressure exerted by water is 1.00 kgf cm^{-2}. Find the change in volume of the ball at this depth. κ for material of the ball = 1.00×10^{13} dyne cm^{-2}. **[2]**

28. A rubber string 10 m long is suspended from rigid support at its one end. Calculate the extension in the string due to its own weight. The density of rubber is 1.5×10^3 kg m^{-3} and Young's modulus for the rubber is 5 × 106 Nm^{-2}. Take g = 10 N kg^{-1}. **[2]**

29. Two wires A and B are of the same material. Their lengths are in the ratio 1:2 and the diameters in the ratio 2:1. If they are pulled by the same force, then what will be the ratio of their increase in lengths? **[2]**

30. A steel wire of uniform cross-section of 1 mm^2 is heated to 70°C and stretched by tying its two ends rigidly. Calculate the change in the tension of the wire when the temperature falls from 70° C to 35° C. Coefficient of linear expansion of steel is 1.1×10^{-5} $^oC^{-1}$ and Young's modulus is 2.0×10^{11} Nm^{-2}. **[2]**

31. A square lead slab of side 50 cm and thickness 10 cm is subject to a shearing force (on its narrow face) of 9.0 × **[2]**

10^4 N. The lower edge is riveted to the floor. How much will the upper edge be displaced?

32. A cable is replaced by another of the same length and material but of twice the diameter, **[2]**

    i. How does this affect its elongation under a given load?

    ii. How many times will be the maximum load it can now support without exceeding the elastic limit?

33. Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 6.9×10^7 Pa? Assume that each rivet is to carry one quarter of the load. **[2]**

34. A silica glass rod has a diameter of 1 cm and is 10 cm long. The ultimate strength of glass is 50×10^6 Nm^{-2}. Estimate the largest mass that can be hung from it without breaking it. Take g = 10 N kg^{-1}. **[2]**

35. Four identical hollow cylindrical columns of mild steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 cm and 40 cm respectively. Assuming the load distribution to be uniform, calculate the compressional strain of each column. The Young's modulus of steel is 2.0×10^{11} Pa. **[2]**

36. A wire of length 2.5 m has a percentage strain of 0.012% under a tensile force. Determine the extension in the wire. **[2]**

37. Calculate the value of stress in a wire of steel having a radius of 2 mm of 10 kN of force is applied on it. **[2]**

38. A wire is cut to half its original length. **[2]**

    i. How would it affect the elongation under a given load?

    ii. How does it affect the maximum load it can support without exceeding the elastic limit?

39. Determine the Poisson's ratio of the material of a wire whose volume remains constant under an external normal stress. **[2]**

40. A structural steel rod has a radius of 10 mm and a length of 1.0 m. A 100 kN force stretches it along its length. Calculate **[2]**

    a. stress

    b. elongation, and

    c. strain on the rod

    Young's Modulus, of structural steel is 2.0×10^{11}N m^{-2}

41. The average depth of Indian Ocean is about 3000 m. Calculate the fractional compression, $\frac{\Delta V}{V}$, of water at the bottom of the ocean, given that the bulk modulus of water is 2.2×10^9 Nm^{-2}. (Take g = 10 ms^{-2}) **[2]**

42. Two wires of same length and material but of different radii are suspended from a rigid support. Both carry the same load. Will the stress, strain and extension in them be same or different? **[2]**

43. Find the stress to be applied to a steel wire to stretch it by 0.025% of its original length. Y for steel is 9×10^{10} Nm^{-2}. **[2]**

44. A 40 kg boy whose leg bones are 4 cm^2 in area and 50 cm long falls through a height of 50 cm without breaking his leg bones. If the bones can stand stress of 0.9×10^8 Nm^{-2}, calculate Young's modulus for the material of the bone. Take g = 10 ms^{-2}. **[2]**

45. Two parallel steel wires A and B are fixed to rigid support at the upper ends and subjected to the same load at the lower ends. The lengths of the wires are in the ratio 4 : 5 and their radii are in the ratio 4 : 3. The increase in the length of wire A is 1 mm. Calculate the increase in the length of the wire B. **[2]**

46. What do you mean by normal stress? Name any two types. **[2]**

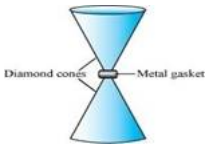
47. A steel wire of 4.0 m is stretched through 2.0 mm The cross-sectional area of the wire is 2.0 mm^2. If Young's **[2]**

modulus of steel is 2.0×10^{11} Nm^{-2}, find

i. the energy density of the wire and

ii. the elastic potential energy stored in the wire.

48. Anvils made of single crystals of diamond, with the shape as shown in figure, are used to investigate behaviour of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.50 mm, and the wide ends are subjected to a compressional force of 50,000 N. What is the pressure at the tip of the anvil? **[2]**



Section C

49. Explain the following: **[3]**

i. Concrete beams used in large buildings have greater depth than breadths.

ii. Load bearing bars are generally made in I-section.

iii. Pillar with distributed ends is preferred over a pillar with rounded ends.

50. A copper wire of 2.2 m length and a steel wire of length 1.6 m, both of diameter 3.0 mm are connected end to end. When stretched by a load, the net elongation is found to be 0.70 mm. Obtain the load applied. **[3]**

51. Briefly apply your knowledge of elasticity in the working of a crane used for lifting and moving heavy loads. Illustrate by some rough calculations. **[3]**

52. Define stress and strain and derive their units. What is Hooke's law? Write its one limitation. **[3]**

53. In a physics department, a Foucault pendulum consists of a 130 kg steel ball which swings at the end of a 8.0 m long steel cable having the diameter of 3.0 mm. If the ball was first hung from the cable, then determine how much did the cable stretch? **[3]**

54. A uniform heavy rod of weight W, cross-sectional area A and length l is hanging from a fixed support. Young's modulus of the material of the rod is Y. Neglecting the lateral contraction, find the elongation produced in the rod. **[3]**

55. Two strips of metal are riveted together at their ends by four rivets, each of diameter 6 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 6.9×10^7 Pa? Assume that each rivet is to carry one-quarter of the load. **[3]**

56. Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 2.3×10^9 Pa? Assume that each rivet is to carry one-quarter of the load. **[3]**

Section D

57. **State True or False:** **[4]**

(a) Stress is a vector quantity. **[1]**

(b) A metal rod of Young's modulus Y has a length L and area of cross-section A. The work done in stretching the rod by amount ΔL is $\frac{YA(\Delta L)^2}{2L}$. **[1]**

(c) Any metallic part of the machinery is never subjected to stress beyond the elastic limit of the material. **[1]**

(d) Identical springs of steel and copper are equally stretched. Equal amount of work is done on both springs. **[1]**

58. **Fill in the blanks:** **[4]**

(a) The stress required to double the length of a wire of Young's modulus Y is equal to _____. **[1]**

(b) A force acting on a body, instead of producing a change in its state of rest or of uniform motion, **[1]**

produces a change in the shape of the body, such a force is called _____.

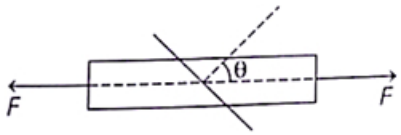
(c) The value of Young's modulus for a perfectly rigid body is _____. **[1]**

(d) If a body is subjected to a uniform force from all sides, then the corresponding stress is called _____. **[1]**

Section E

Question No. 59 to 63 are based on the given text. Read the text carefully and answer the questions: **[5]**

When a bar of cross-section A is subjected to equal and opposite tensile forces at its ends, then a restoring force equal to the applied force normal to its cross-section comes into existence. This restoring force per unit area of cross-section is known as tensile stress. While when the deforming force acts tangentially to the surface, then this tangential force applied per unit area of cross-section is known as tangential stress. consider a plane section of the bar whose normal makes an angle θ with the axis of the bar.



59. Which of the following property of the bar does not change due to this force?

a) Size
b) Shape
c) Area
d) Volume

60. What is the tensile stress on this plane?

a) (F/A) $\sec^2\theta$
b) (F/A) $\cos^2\theta$
c) (F/A) $\tan\theta$
d) (F/A)

61. What is the shearing stress on this plane?

a) $\frac{F}{4A^2}$
b) $\frac{F}{A}\cos 2\theta$
c) $\frac{F}{2A}\sin 2\theta$
d) $\frac{F}{2A}\cos^2\theta$

62. For what value of θ is the tensile stress maximum?

a) 30^o
b) 0^o
c) 45^o
d) 90^o

63. For what value of θ is the shearing stress maximum?

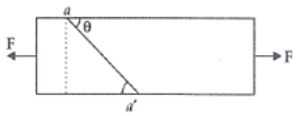
a) 90^o
b) 60^o
c) 45^o
d) 30^o

64. A steel wire of length 4.7 m and cross-sectional area $3.0 \times 10^{-5}\mathrm{m}^2$ stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area of $4.0 \times 10^{-5}\mathrm{m}^2$ under a given load. What is the ratio of the Young's modulus of steel to that of copper? **[5]**

65. Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7.0×10^6 Pa. **[5]**

66. Consider a long steel bar under a tensile stress due to forces $\vec{F}$ acting at the edges along the length of the bar (Figure). Consider a plane making an angle θ with the length. What are the tensile and shearing stresses on this **[5]**

plane?



i. For what angle is the tensile stress a maximum?

ii. For what angle is the shearing stress a maximum?

67. A rubber string 10m long is suspended from a rigid support at its one end. Calculate the extension in the string due to its own weight. The density of rubber is 1.5×10^3 kg/m^3 and Young's modulus for the rubber is 5×10^6 N/m^2. The breaking stress for a metal is 7.8×10^9 N/m^2. **[5]**

68. a. A steel wire of mass μ per unit length with a circular cross-section has a radius of 0.1 cm. The wire is of length 10 m when measured lying horizontal, and hangs from a hook on the wall. A mass of 25 kg is hung from the free end of the wire. Assuming the wire to be uniform and lateral strains << longitudinal strains, find the extension in the length of the wire. The density of steel is 7860 kg m^{-3} (Young's modulus Y = 2×10^{11} Nm^{-2}). **[5]**

b. If the yield strength of steel is 2.5×10^8 Nm^{-2}, what is the maximum weight that can be hung at the lower end of the wire?

69. Derive an expression for the elastic potential energy stored in a stretched wire under stress. Define the terms elastic after effect and elastic fatigue. **[5]**