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**1. The efficiency of a compressor can be defined as:**

- a. Minimum work input / Actual work input
- b. Outlet total pressure – Inlet total pressure
- c. Volume flow rate x Total pressure difference
- d. Minimum work input/ Actual work input
- e. Mass x (speed of light)<sup>2</sup>

**2. The term fan is used for machines:**

- a. converting energy of a flowing liquid into useful energy
- b. that increase the pressure of a flowing liquid
- c. imparting a substantial rise in pressure to a flowing gas
- d. imparting only a small increase in pressure to a flowing gas
- e. converting energy of a flowing gas into useful energy

**3. Cavitation is:**

- a. the head increase of an operating machine
- b. the boiling of a liquid at normal temperature when the static pressure is made sufficiently low
- c. the condensation of a vapor at the saturation temperature
- d. the performance of an airfoil in compressible conditions
- e. the vortices formed in a flowing liquid

**4. The following parameters define the forces acting on an airfoil:**

- a. Lift and drag
- b. Pressure and temperature
- c. Thrust and friction
- d. Traction and torsion
- e. Upwind and downwind

**5. An impeller blade geometry can be defined by the following parameters:**

- a. Lift, drag, wake
- b. Leading edge, trailing edge, camber
- c. Inflow, outflow, throughflow

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- d. Casing, inlet duct, volute
- e. Thickness, blockage, slip factor

### **6. Why are electric hybrid architectures more common in combination with SI engines than with CI engines, for passenger cars applications?**

- a. Due to the Diesel Gate Accident the CI engine is no more used as a solution for passenger cars
- b. The SI engine is cheaper and less efficient than the CI engine
- c. The SI engine is cheaper but more efficient than the CI engine, especially at part load
- d. The CI engine after-treatment system is not compatible with on-off stages typical of hybrid operation
- e. None of the others

### **7. What signals do you need to measure to certify the engine power output according to ISO standards?**

- a. Engine speed, crankshaft output torque, ambient pressure, temperature and humidity
- b. Engine power, ambient pressure, temperature and humidity
- c. Engine speed, crankshaft output torque, ambient pressure and temperature
- d. Engine speed, crankshaft output torque, fuel mass flow, ambient pressure, temperature and humidity
- e. None of the others

### **8. Why should a downsized engine be more efficient?**

- a. Because the mechanical efficiency is higher, and it is operated at higher load
- b. Because the pumping losses are lower, and it is operated at lower load
- c. Because it is turbocharged, and it is operated at higher load
- d. Because it is lighter, and the pumping losses are lower
- e. None of the others

### **9. The conversion of a spark-ignition engine from Port-Fuel Injection (PFI) to Direct Injection (DI) leads to:**

- a. Increased mixture temperature at the end of the compression stroke
- b. Longer combustion duration period and lower resistance to engine knock
- c. Reduced Particulate Matter (PM) and NO<sub>x</sub> formation
- d. The possibility to use fuel stratification strategies for optimal combustion development
- e. None of the others

### **10. The application of a heat recovery system to a turbogas energy system leads to:**

- a. An increase of the overall fuel consumption
- b. An increase of the exhaust gas temperature
- c. A reduction of the air inlet temperature to the combustion chamber
- d. An increase of the system efficiency for the same output power

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e. None of the others

**11. Heat transfer on a surface exposed to ambient air**

- a. occurs by thermal conduction
- b. occurs by convection
- c. occurs by a combination of convection and radiation
- d. is always negligible
- e. depends mostly on ambient pressure

**12. A finned tube heat exchanger is usually exploited to**

- a. decrease the pressure of a fluid
- b. melt a solid substance
- c. exchange heat between two gases
- d. exchange heat between two liquids
- e. exchange heat between a liquid and a gas

**13. The coefficient of performance of a refrigeration system**

- a. has a value between 0 and 100%
- b. is the ratio of actual value of the cooling heat rate and its maximum theoretical value
- c. is affected by efficiency of the pump installed in the refrigerant circuit
- d. is generally increased by increasing the size of heat exchangers
- e. is independent of the operating conditions

**14. The speed of sound in a perfect gas**

- a. depends on its absolute temperature
- b. is proportional to the Mach number
- c. is always higher than 330 m/s
- d. is always higher than 1000 km/h
- e. is always lower than 1000 km/h

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**15. Measuring on a Pitot tube a differential pressure of 200 Pa in air with density  $1 \text{ kg/m}^3$  can be translated into an air velocity**

- a. higher than 1000 km/h
- b. practically negligible
- c. around 200 m/s
- d. around 20 m/s
- e. around 2 m/s

**16. In the International System of Quantities, the coherent unit for pressure is:**

- a. bar
- b. Newton
- c. Pascal
- d. Joule
- e.  $\text{N/cm}^2$

**17. Using a U tube manometer, a differential pressure of 1 kPa correspond to:**

- a. about 98 mm of water head
- b. about 102 mm of water head
- c. about 49 mm of water head
- d. about 980 mm of water head
- e. about 1020 mm of water head

**18. How is specific heat measured?**

- a. J/kg
- b.  $\text{J/kg} \cdot \text{K}$
- c.  $\text{J}/(\text{kg} \cdot \text{K})$
- d.  $\text{J} \cdot \text{kg}/\text{K}$
- e.  $\text{J} \cdot \text{kg} \cdot \text{K}$

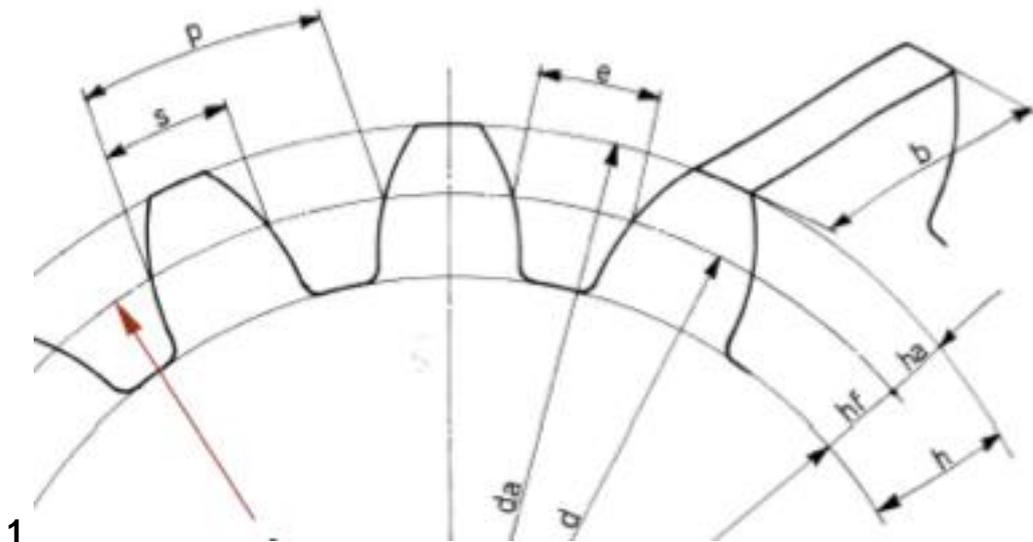
**19. Comparing Thermocouples to Resistance Temperature Detectors, in general, Thermocouples:**

- a. measure higher temperatures, are more accurate and more expensive;
- b. measure lower temperatures, are more accurate and cheaper;
- c. measure higher temperatures, are less accurate and more expensive;
- d. measure lower temperatures, are more accurate and more expensive;
- e. measure higher temperatures, are less accurate and cheaper;

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**20. The in-cylinder pressure of an internal combustion engine at the test bench is usually measured by means of:**

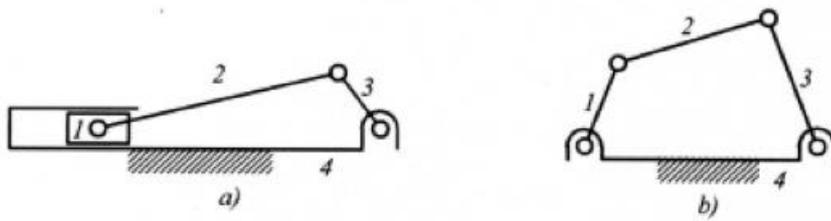
- a. A load cell;
- b. A strain gauge;
- c. An optical-access piston;
- d. An accelerometer;
- e. A piezoelectric detector;



**21. Taking with reference the figure with  $d$  the pitch diameter, which the correct formulation for the module (or modulus) in spur gears**

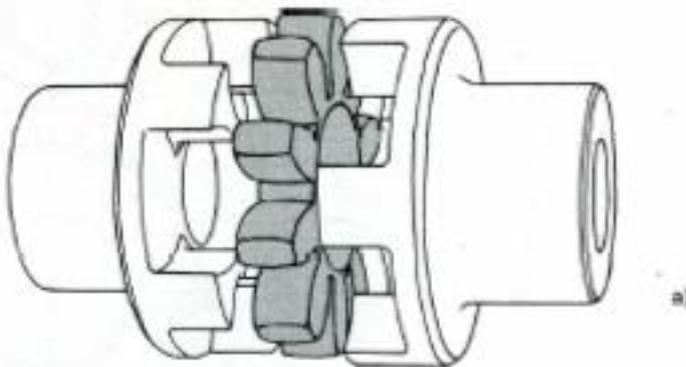
- a.  $p/\pi$
- b.  $\pi/p$
- c.  $2p/\pi$
- d.  $s+e$
- e.  $h$

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22. How many degrees of freedom have the mechanisms depicted in the figure?

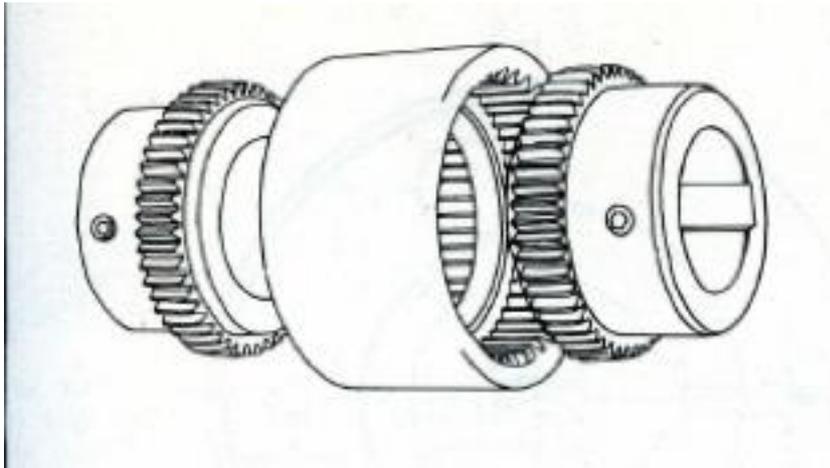
- a. 1
- b. 2
- c. 3
- d. 4
- e. 5



23. Which kinds of misalignments enable the joint in the figure?

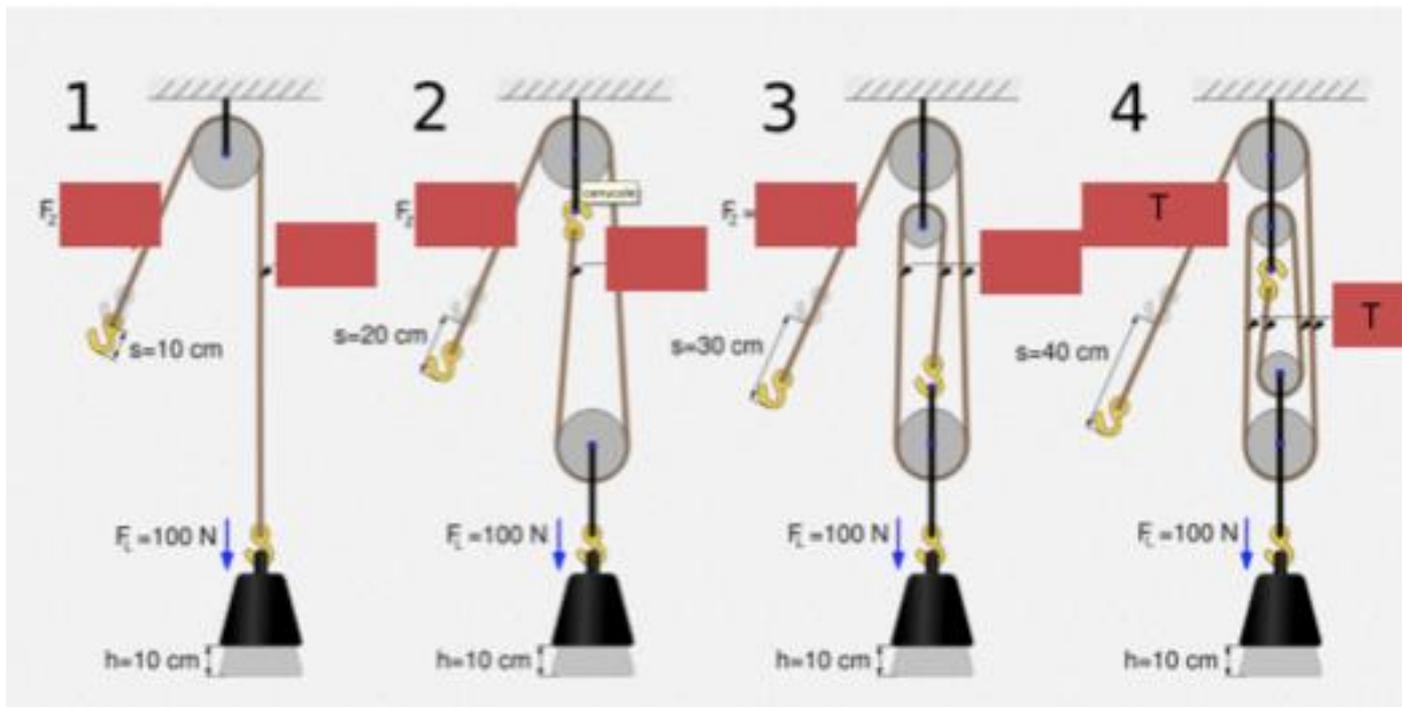
- a. Only radial misalignments
- b. Only axial misalignments
- c. Only angular misalignments
- d. Angular and radial misalignments
- e. Angular, axial and radial misalignments

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24. Which kinds of misalignments enable the joint in the figure?

- a. Only radial misalignments
- b. Only axial misalignments
- c. Only angular misalignments
- d. Angular and radial misalignments
- e. Angular, axial and radial misalignments



25. For mechanisms number 4 in the figures, please write the correct value of T

- a. 25N
- b. 50N

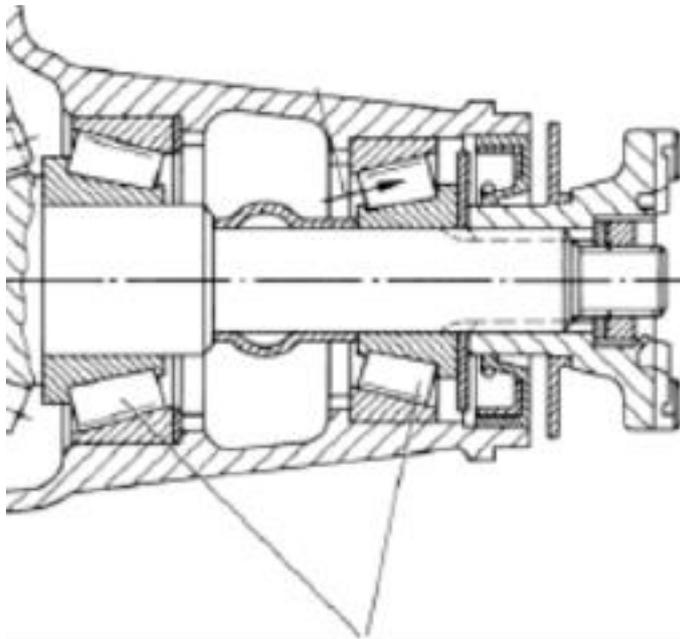
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- c. 75N
- d. 100N
- e. 125N

**26. What is the effect of damping on phase angle at resonance frequency?**

- a. Phase angle increases as damping increases
- b. Damping has no effect on phase angle
- c. Phase angle increases as damping decreases
- d. Phase angle increases of  $\pi/4$  if damping doubles
- e. None of the others

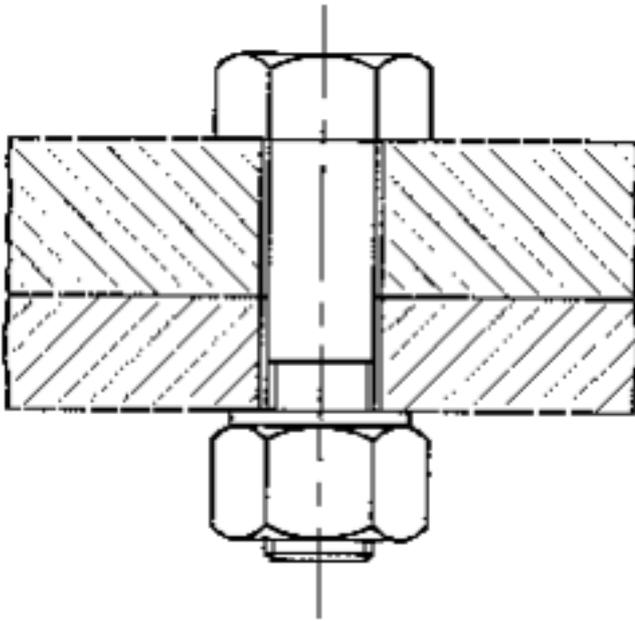
**27. In the figure below, the main shaft of the transmission is rotating on a couple of bearings. The arrangement of the bearings is:**



- a) "O" arrangement
- b) "Tandem" arrangement
- c) "X" arrangement
- d) "Fixed" arrangement
- e) No one of the previous

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28. In the tightening process of a bolt of nominal diameter  $D$  [mm], the simplified relation to easily link the torque tightening  $T$  [Nmm] to the screw preload  $F$  [N] can be expressed as:



- a)  $T = K \times F \times D$ , with  $K$  value  $\sim 0.2$
- b)  $T = F \times D$
- c)  $T = F \times D / 2$
- d)  $T = K \times F$ , with  $K$  value  $\sim 0.2$
- e) No one of the others

29. In the figure below two different types of realization of welded T-joints are represented: on the left, a T-joint with full penetration; on the right, a T-joint with corner welding. Choose the correct sentence:



- a) T-joints with full penetration have higher structural performances than corner-welded T joints
- b) T-joints with full penetration have lower structural performances than corner-welded T joints
- c) The structural performances of the welded joints are the same, independently by the type of realization
- d) T-joints with full penetration cannot be used for structural purposes.

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e) No one of the previous

**30. Which is the main difference between the normal stress  $s$  and the shear stress  $t$  against the strength of metal?**

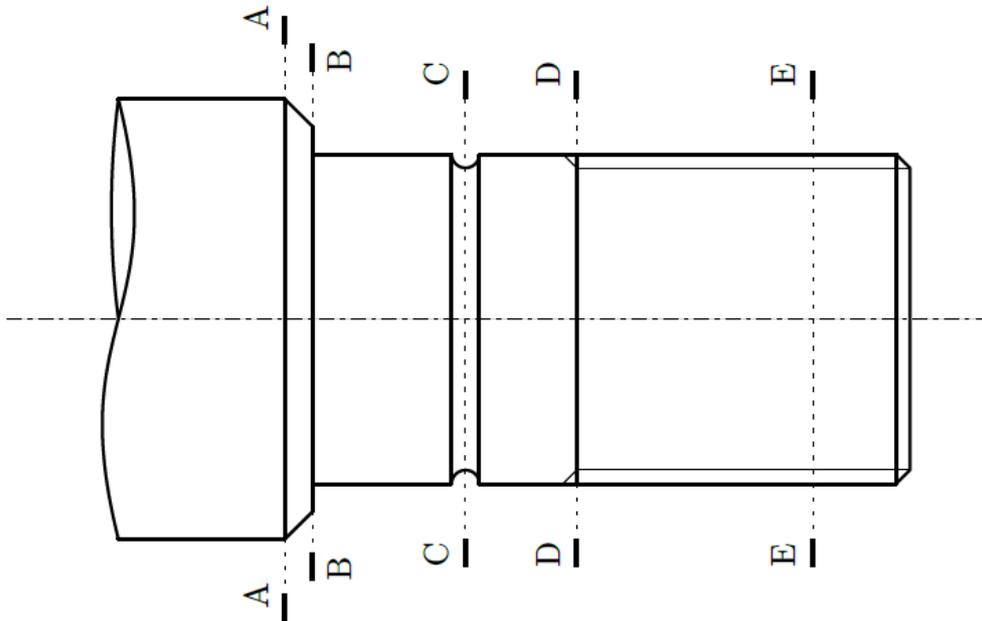
- a) There is no difference.
- b) The shear stress is more dangerous than the normal stress.
- c) The normal stress is more dangerous than the shear stress.
- d) The difference depends on the type of the material.
- e) The difference depends on the temperature of the material.

**31. A fully reversed fatigue cycle is characterized by:**

- A) the mean stress value is positive, the maximum and the minimum stress values are positive and negative, respectively.
- B) the mean stress value is negative, the maximum and the minimum stress values are negative and positive, respectively.
- C) the mean stress value is null, the maximum and the minimum stress values are positive and negative, respectively.
- D) the mean stress value is null, the maximum and the minimum stress values are negative and positive, respectively.
- E) None of them

**32. With reference to the shaft and the sections named from A to E, as shown in Figure:**

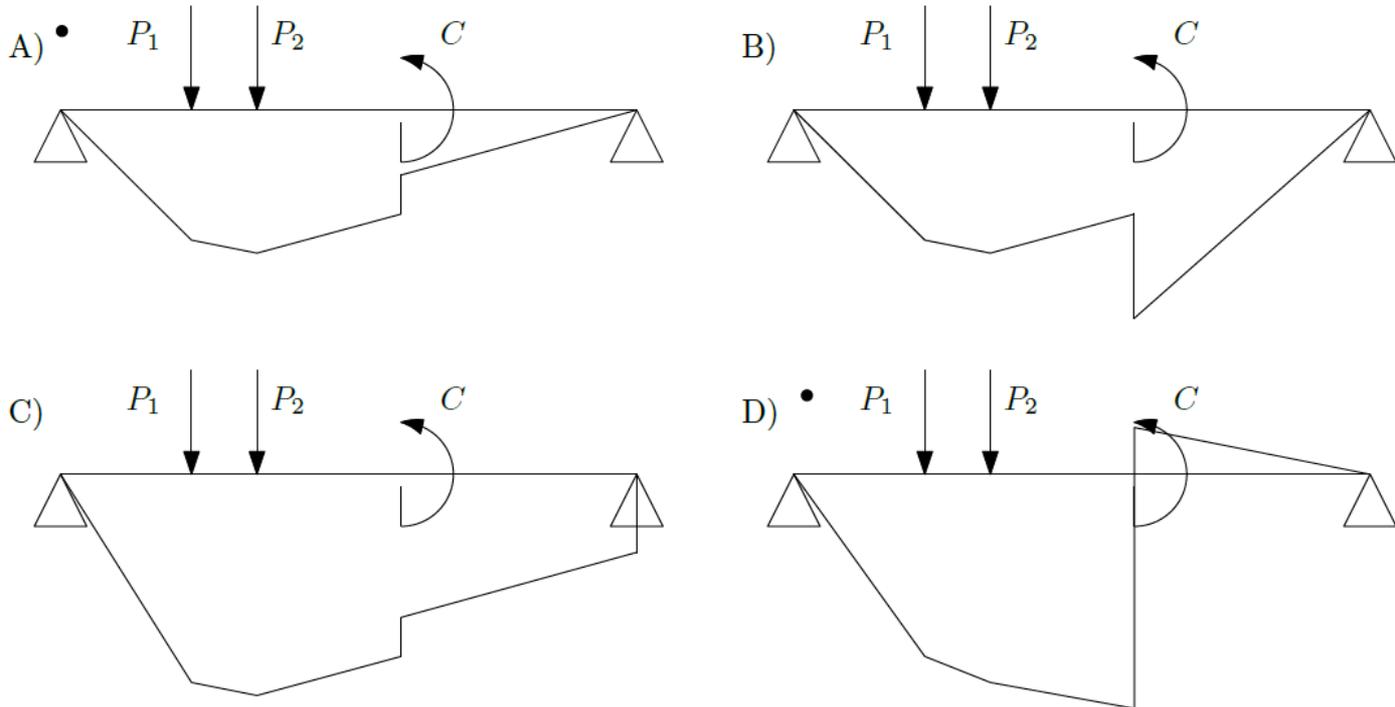
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- A) the points A, B and C represent critical points for the shaft, whereas the points D and E are not critical
- B) the points B, C and D represent critical points for the shaft, whereas the points A and E are not critical
- C) the points C, D and E represent critical points for the shaft, whereas the points A and B are not critical
- D) the points A, C and D represent critical points for the shaft, whereas the points B and E are not critical
- E) None of them

33. The figures represent a simply supported beam loaded by two transverse concentrated forces ( $P_1$ ,  $P_2$ ) and a couple  $C$ , of unknown intensity. Figures (a), (b), (c) and (d) represent four possible profiles of the bending moment acting on the beam. Which of the displayed profiles is correct?

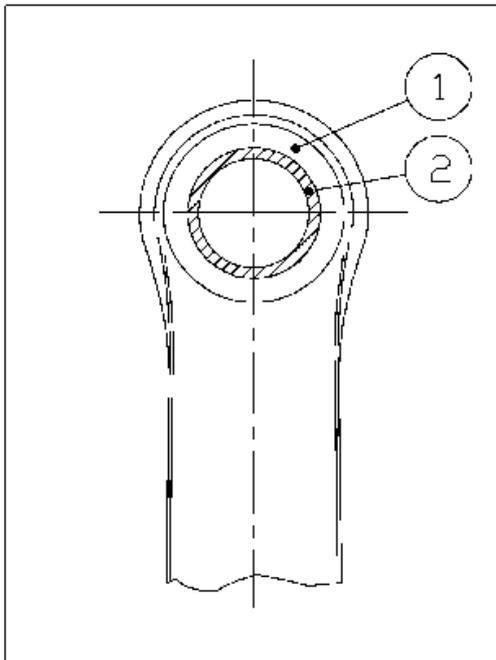
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- A) Profiles (a) and (b)
- B) Profiles (b) and (c)
- C) Profiles (c) and (d)
- D) Profiles (a) and (d)
- E) Profiles (b) and (d)

**34. Consider the press-fitting of a metallic bush (2) into a conrod small-end (1), see Figure. The maximum equivalent stress registered in the bush related to the press-fitting alone:**

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- A) falls at the bush inner border
- B) falls at the bush outer border
- C) falls at the bush mean radius
- D) falls at the bush neutral radius
- E) is constant along the bush radial thickness

35. Which type of bearing is shown in the figure?

- a. deep grooved ball bearing
- b. self-aligning ball bearing
- c. thrust bearing
- d. linear bushing
- e. None of the others



36. What is the exact definition of Ra roughness?

a.  $Ra = 1/l \int_0^l |y| dx$

b.  $Ra = 1/l \int_0^l y^2 dx$

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c.  $Ra = (1/l \int_0^l y^2 dx)^{1/2}$

d.  $Ra = \sum |y| / n$

e. None of the others

**37. The projection method of the first dihedral is an orthographic representation in which:**

a. the object to be represented is located between the observer and the coordinated planes on which the object is projected perpendicularly

b. the object to be represented is located behind the coordinated planes on which the object is projected perpendicularly

c. the observer is located between the object to be represented and the coordinate planes on which the object is projected perpendicularly

d. All of the others

e. None of the others

**38. If, from the survey of a mechanical detail, a dimension equal to 220 mm is found and this dimension, shown in scale on the drawing, appears 1.1 cm long, the standard used was:**

a. 2:1

b. 1:2

c. 1:20

d. 20:1

e. None of the others

**39. The symbol on the figure represents:**

a. roughness 5  $\mu\text{m}$ , 1,6 of machining allowance

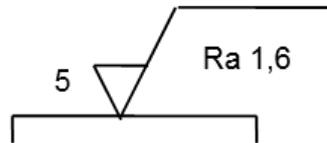
b. roughness 1,6  $\mu\text{m}$ , 5  $\mu\text{m}$  of machining allowance

c. roughness 1,6  $\mu\text{m}$ , 5 mm of machining allowance

d. roughness 1,6  $\mu\text{m}$ , 5  $\mu\text{m}$  of planarity error

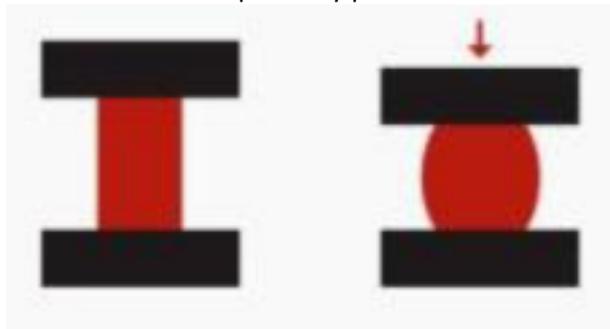
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- e. None of the others



**40. During a compressive test such as that in the figure, if the platen speed is constant, the force measured by the load cell of the press will be:**

- a. Always constant if the test is executed in hot conditions
- b. Constant in specific hot test condition
- c. Always constant if the test is executed in cold conditions
- d. Never constant
- e. Constant for perfectly plastic materials



**41. In arc welding, a reverse polarity allows to:**

- a. Have a proper fusion of the base metal
- b. Weld metals with high melting point
- c. Increase the life of the electrode in the case of non consumable electrode
- d. Weld thick parts
- e. Weld reactive metals

**42. In a face turning operation:**

- a. the cutting speed is constant if the spindle speed is constant
- b. the cutting speed decreases during the operation if the spindle speed is constant
- c. the machining time depends on the depth of cut
- d. the cutting speed is parallel to the part axis
- e. the material removal rate is independent on the depth of cut

**43. On a worn drill bit:**

- a. flank wear can be measured on an optical image that is parallel to the tool axis
- b. flank wear is constant at different radial distances

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- c. flank wear increases at increasing radial distances
- d. crater wear can be measured on an optical image that is orthogonal to the tool axis
- e. the cutting speed is parallel to the tool axis

**44. During a tensile test of a metallic material that shows necking in the plastic region:**

- a. the force steadily increases until rupture
- b. the true stress shows a point of maximum, then decreases
- c. the engineering stress shows a point of maximum, then decreases
- d. the ultimate tensile strength is calculated at the rupture point
- e. the elongation at break is calculated at the necking point

**45. What is an industrial Supply Chain?**

- a. An iron chain to move goods in a ship
- b. A management tool for the product design
- c. A product forecasting method
- d. a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer.
- e. The process of evaluating and approving potential suppliers by quantitative assessment.

**46. A fork lift used in a production system:**

- a. moves materials from different pick-up and drop-off points
- b. is an automatic equipment to lift materials for 2 different floors in a production system
- c. is an automatic equipment to lift people for 2 different floors in a production system
- d. is an automatic equipment to assembly product
- e. Move people from different pick-up and drop-off points

**47. What is the main use of an Automatic Storage and Retrieval system (AS/RS)?**

- a. To assembly product, in particular "high volume" product
- b. To stock product when there are a lot picking action to do
- c. To move product from storage systems to assembly lines
- d. The stock product when there aren't picking action to do
- e. To move product from assembly lines to storage systems

**48. What is a method to evaluate the return of an industrial investment?**

- The opportunity cost of capital, OCC
- The net present value, NPV
- The supply chain management, SCM
- The cost diagram
- The just in time, JIT

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**49. The production organization defined "job shops" is:**

- A way to find jobs
- The location in which you can find job
- The productive organization that you can easily find in big companies
- The productive organization that you can easily find in small companies
- An innovative production organization

**50. Considering a uniform magnetic circuit, where  $l$  is the length of the circuit in meters,  $\mu$  is the permeability of the material ( $\mu = \mu_0 \times \mu_r$ ) and  $A$  is the cross-sectional area of the circuit in square meters, the circuit reluctance is defined as:**

- a.  $\mathfrak{R} = \mu/A$
- b.  $\mathfrak{R} = \mu A/l$
- c.  $\mathfrak{R} = l/(\mu A)$
- d.  $\mathfrak{R} = A/(\mu l)$
- e.  $\mathfrak{R} = \mu/(lA)$

**51. In a single-phase alternate current circuit, being  $I$  the RMS values of the current flowing in a wire of resistance  $R$ , the power dissipated in the wire according to the Joule's first law is:**

- a.  $P = RI^2$
- b.  $P = \sqrt{2}RI^2$
- c.  $P = \sqrt{2}IR^2$
- d.  $P = IR^2$
- e.  $P = RI$

**52. Two capacitors connected in parallel, can be considered as 1 single capacitor whom equivalent value is given by:**

- a. The sum of the values of the two
- b. The difference of the values of the two
- c. The multiplication of the values of the two
- d. The division between the values of the two
- e. The multiplication of the values of the two divided by the sum of the values of the two

**53. In a three-phase AC balanced circuit, being the line voltage between phases a and b**

$V_{ab} = V \sin(\omega t)$ . **The phase voltage  $E_a$  is:**

- a.  $E_a = \frac{V}{\sqrt{3}} \sin(\omega t - \frac{\pi}{6})$
- b.  $E_a = \frac{V}{\sqrt{3}} \sin(\omega t - \frac{\pi}{3})$
- c.  $E_a = \frac{V}{\sqrt{3}} \sin(\omega t + \frac{\pi}{3})$
- d.  $E_a = \sqrt{3}V \sin(\omega t - \frac{\pi}{6})$

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e.  $E_a = \sqrt{3} V \sin \left( \omega t - \frac{\pi}{3} \right)$

**54. Let  $x \in [-1, 1]$  be an analog value that goes through a uniform quantization and is represented by a digital word with 10 bits. We know that**

- a. we are able to distinguish not more than 256 signal levels
- b. the minimum possible quantization interval is  $2^{-9}$
- c. the minimum quantized value is -512
- d. the quantization error is uniformly distributed in the interval  $[-2^{-9}, 2^{-9}]$
- e. the value  $x=+1$  cannot be represented

**55. Let  $x_1, x_2, x_3,$  and  $x_4$  be four measurements of the same quantity that are known to be affected by independent random disturbances corresponding to the same root-mean-square (RMS) error. If  $x = (x_1 + x_2 + x_3 + x_4) / 4$  then**

- a. the disturbances affect  $x$  causing an RMS larger than the one affecting  $x_1, x_2, x_3,$  and  $x_4$
- b. the disturbances on  $x_1, x_2, x_3,$  and  $x_4$  cancel each other and  $x$  is not affected by any error
- c. the disturbances affect  $x$  causing an RMS equal to the one affecting  $x_1, x_2, x_3,$  and  $x_4$
- d. the disturbances affect  $x$  causing an RMS that is non-null but smaller than the one affecting  $x_1, x_2, x_3,$  and  $x_4$
- e. the error on  $x$  is independent of the disturbances affecting  $x_1, x_2, x_3,$  and  $x_4$

**56. Let  $a$  and  $b$  be two digital  $n$ -bits words representing non-negative integer numbers. A digital multiplier computes  $p = ab$ . We know that**

- a. the number of bits needed to represent  $p$  is at most  $n+1$
- b. computing  $p$  is equivalent to  $n$  sums of digital words of at most  $n$  bits
- c. if  $a$  and  $b$  are equal the least significant bit of  $p$  is 0
- d. if  $a$  and  $b$  are equal the least significant bit of  $p$  is 1
- e. the number of bits needed to represent  $p$  is at most  $2n$

**57. An acquisition system outputs 128 samples/s, each of them represented by a 10bit word. Samples are processed by a microcontroller and compressed without any loss of information to be transmitted through a serial channel capable of 256bit/s. Transmission cannot accumulate delays. The compression algorithm running in the microcontroller**

- a. must compress the data of a factor at least 5
- b. can compress the data of a factor lower than 5
- c. must compress each 10bit word into a 2bit word
- d. can expand each 10bit word into a 128bit word
- e. must re-encode every group of  $8 \times 10$ bit words in a pair of 8bit words

**58. A microcontroller has 128Kbit (1Kbit=1024bit) of working memory. The program it runs must compute a vector-by-matrix product  $A \cdot x$  in which  $A$  is an  $m \times n$  matrix containing nonnegative integer**

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values  $A_{j,k} \in \{0, \dots, 127\}$  for  $j=1, \dots, m$  and  $k=1, \dots, n$ , while  $x$  is an  $n \times 1$  vector of integers each encoded with 16 bits. Assuming that no other memory can be used to store  $A$  and  $b$ , we know that

- a. we can cope with the case  $m=16$  and  $n=1024$
- b. we spare some memory if  $m=14$  and  $n=1024$
- c. if  $n=512$  then it must be  $m < 32$
- d. we cannot cope with a square  $128 \times 128$  matrix
- e. we can avoid storing the vector  $x$

**59. Placing multiple capacitors in a series:**

- a. The behavior of the resulting two terminal device is characterized by proportionality between voltage and current;
- b. The behavior of the resulting two terminal device is equivalent to that of a single capacitor whose capacitance is larger than the capacitance of the largest capacitor in the series;
- c. The behavior of the resulting two terminal device is equivalent to that of a single capacitor whose capacitance is smaller than the capacitance of the largest capacitor in the series and larger than the capacitance of the smallest capacitor in the series;
- d. The behavior of the resulting two terminal device is equivalent to that of a single capacitor whose capacitance is smaller than the capacitance of the smallest capacitor in the series;
- e. The power dissipation of the resulting circuit increases as the number of capacitors in the series is increased.

**60. A circuit is composed of a battery in series with an open switch, a discharged capacitor, and a resistor. When the switch is closed, the voltage across the capacitor will:**

- a. approach the voltage given by the battery with a negative exponential characteristic
- b. approach zero at  $t = \infty$
- c. remain constant
- d. oscillate at angular frequency  $\omega = 1/RC$
- e. none of the others

**OPEN QUESTIONS**

**Describe the geometrical differences between spur and helical gears, as well as the operational advantages and disadvantages of helical gears with respect to spur gears.**

**Please list the main advantages of adopting a parallel electric hybrid configuration for a passenger car vehicle, and provide the corresponding motivations.**