STUDENT NAME: ________________________

STUDENT NUMBER: ______________________

The University of Western Ontario

Faculty of Engineering Science

ES 1021a – Properties of Materials

Final Examination
December 16, 2010
2:00 pm – 5:00 pm

Time: 3 hours
Aids: Programmable calculators, one 8½" × 11" handwritten cribsheet

Format: 60 Multiple choice questions to be answered on the form provided

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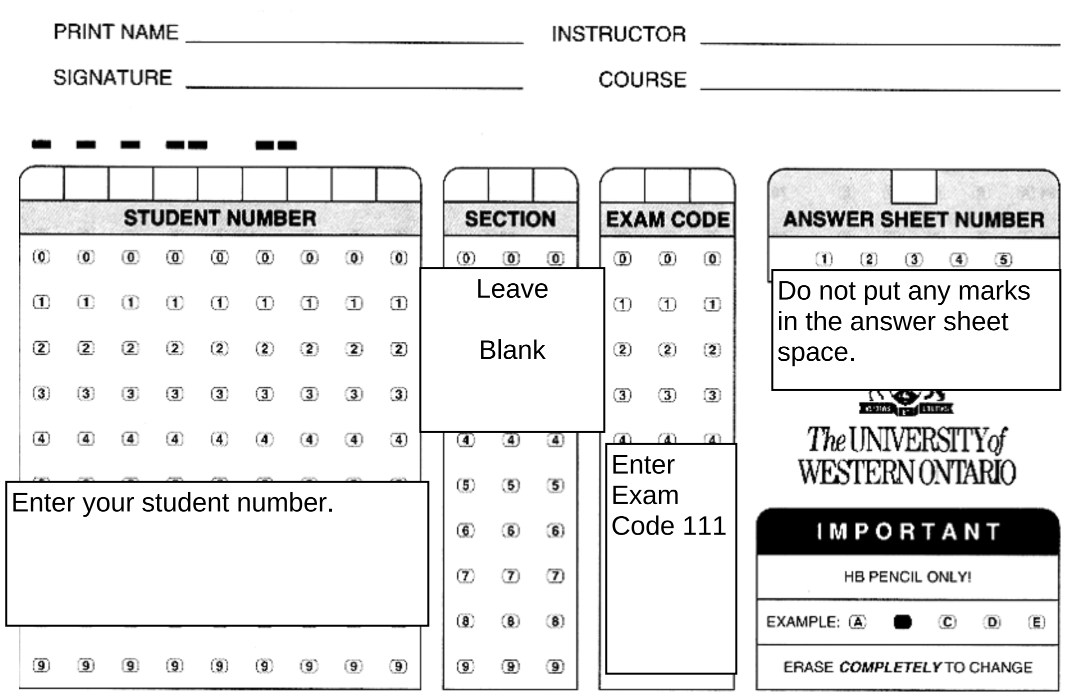
Fill out the top of your answer form as indicated below:


PRINT NAME ____________________ INSTRUCTOR ____________________

SIGNATURE ____________________ COURSE ____________________

STUDENT NUMBER — Enter your student number.

SECTION — Leave Blank

EXAM CODE — Enter Exam Code 111

ANSWER SHEET NUMBER — Do not put any marks in the answer sheet space.

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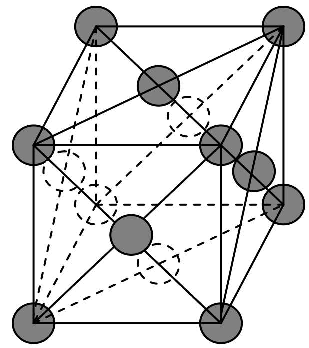
IMPORTANT

HB PENCIL ONLY!

EXAMPLE: (A) ● (C) (D) (E)

ERASE *COMPLETELY* TO CHANGE

1) The number of atoms in the unit cell represented by the diagram shown at right is:

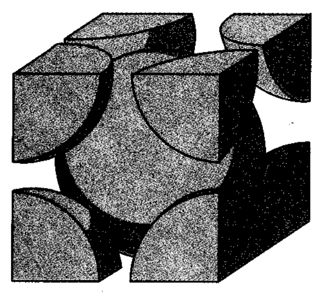


a) 1
b) 2
c) 4
d) 7
e) 14

2) The number of independent close-packed directions in a close-packed plane of atoms is:

a) 0
b) 1
c) 2
d) 3
e) 6

3) Tungsten has a body-centred cubic unit cell (shown at right), an atomic radius of 0.137 nm, and an atomic mass of 183 g/mol. (1nm = 1×10^{-9}m, 1 mole = 6.023×10^{23}atoms). The theoretical density of tungsten is:



a) 10.5 g/cm³
b) 15.8 g/cm³
c) 19.2 g/cm³
d) 23.9 g/cm³
e) 79.0 g/cm³

4) If a material is amorphous, it can be characterized as having:

a) Transparency
b) Very high mechanical stiffness.
c) An arrangement of atoms or molecules with short and long-range order.
d) An atomic structure without long-range order
e) None of the above.

5) A thermoplastic polymer is best described as being comprised of:

a) Ionically bonded metallic and non-metallic atoms with no long-rage order

b) Ionically bonded metallic and non-metallic atoms arranged in a repeating unit cell.

c) Covalently bonded, long-chain molecules held together by van der Waal's forces with or without long-range order.

d) An amorphous, three-dimensional network of covalently bonded molecules.

e) None of the above

6) Which of the following is the most important physical characteristic that influences the elastic properties of a material?

a) Density

b) Atomic weight

c) Bond strength

d) The presence/absence of carbon

e) Atomic radius

7) As it refers to polymers, the term cross-linking means:

a) The process of welding to polymers together

b) Creating covalent bonds along the "backbone" of the polymer chains

c) The process of converting covalent bonds to van der Waal's bonds.

d) The formation of covalent bonds between polymer chains

e) Melting and re-solidifying thermoplastic polymers.

8) Although the density can vary widely within any class of materials, the density of a metal is generally greater than the density of a ceramic because:

a) Atoms are more closely packed in metals than in ceramics

b) Atoms are more closely packed in ceramics than in metals

c) Ceramics are usually a mixture of metal atoms and lighter, non-metallic elements.

d) a) and c) are both correct

e) b) and c) are both correct

9) The mass of an object, measured in air, is 51.2 grams. The mass of the same object, submerged in methyl alcohol (ρ=0.79 g/cm^3), is 44.2 grams. The density of the object is:

a) 0.93 g/cm^3

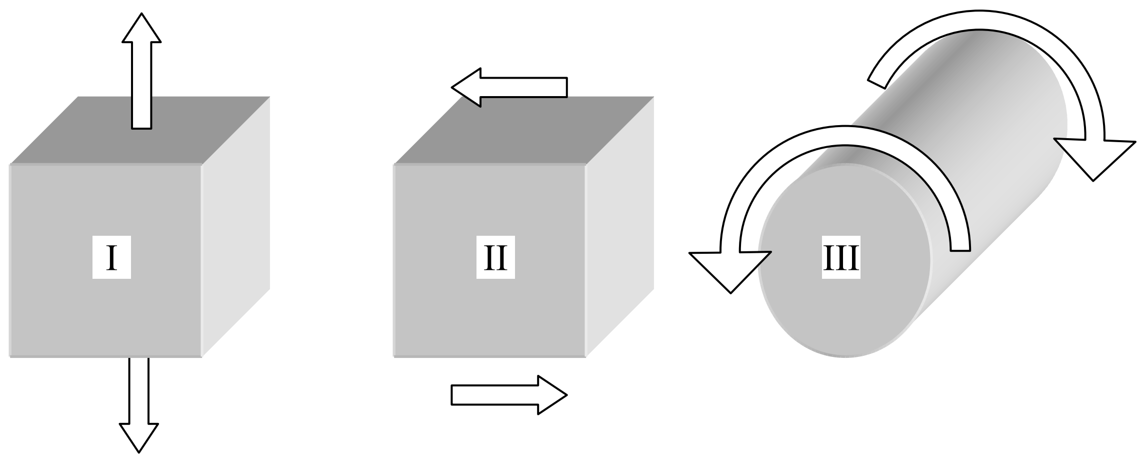
b) 1.47 g/cm^3

c) 3.50 g/cm^3

d) 5.78 g/cm^3

e) 9.26 g/cm^3

10) Choose the answer that correctly matches the diagram with the mode of loading:



a) I = Shear; II = Normal; III = Torsion

b) I = Shear; II = Bending; III = Torsion

c) I = Normal; II = Bending; III = Torsion

d) I = Normal; II = Torsion; III = Bending

e) I = Normal; II = Shear; III = Torsion

11) A steel bar has a cross-sectional area of 12.5 mm^2. What is the maximum load that it can support if the normal stress is not to exceed 400 MPa?

a) 32 N
b) 113 N
c) 5000 N
d) 32000 N
e) 5×10^9 N

12) Two specimens of a material are prepared so that the second specimen has exactly twice the cross-sectional are of the first. If both specimens are stretched perpendicular to their cross-sections by the same amount, what is the ratio of the loads (F_1:F_2)?

a) 1:1
b) 1:2
c) 2:1
d) 1:4
e) 4:1

13) The bulk modulus of a material is used to characterize:

a) The weight of a given volume of the material
b) The stiffness of the material subjected to a transverse load
c) A materials resistance to bending
d) A materials resistance to torsion
e) The resistance of a material to volume change during hydrostatic loading

14) A cube of high-strength steel (E = 200 GPa, G = 80 GPa, K = 165 GPa) is subjected to a shear stress such that the angle between two adjacent sides changes from 90° to 89.8°. The magnitude of the shear stress is:

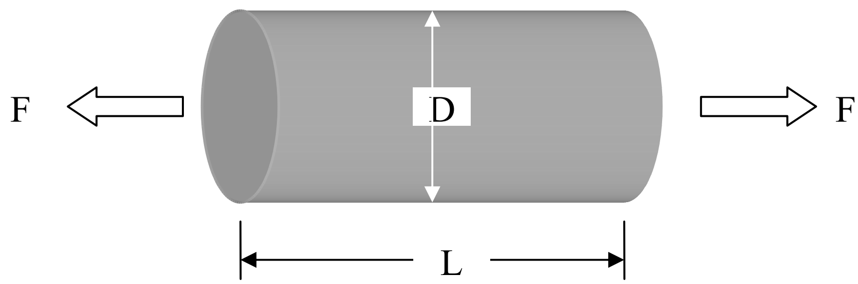
a) 40 MPa
b) 100 MPa
c) 280 MPa
d) 400 MPa
e) 700 MPa

15) The percent change in volume of a piece of steel (E = 200 GPa, G = 80 GPa, K = 165 GPa) subjected to a hydrostatic tensile stress of 100 MPa is:

a) 0.048%
b) 0.061%
c) 0.12%
d) 0.60%
e) 1.65%

Questions 16) through 19) require the following information:

Geometry:	Cylindrical bar of dimensions L = 1.00 m, D = 10.0 mm
Material:	Copper alloy (E = 120 GPa, ν = 0.35)
Loading:	Axial force F=12500 N



16) The tensile stress in the bar is:

a) 125 MPa
b) 160 MPa
c) 980 MPa
d) 1250 MPa
e) 1530 MPa

17) The tensile strain in the bar is:

a) 1.33×10^{-3}
b) 1.33
c) 19.2
d) 56
e) 770

18) The length of the bar while under load is:

a) 0.999 m
b) 1.000 m
c) 1.001 m
d) 1.013 m
e) 1.133 m

19) The elastic energy per unit volume stored in the bar while under load is:

a) 107 kJ/m³
b) 133 kJ/m³
c) 160 kJ/m³
d) 213 kJ/m³
e) Can not be determined

20) A unidirectional, aligned fibre composite is to be fabricated from epoxy resin and HM carbon fibres. (Material properties can be found in Table 1) If the volume fraction of fibres is 45%, the density of the composite is closest to:

a) 1540 kg/m³
b) 1610 kg/m³
c) 1640 kg/m³
d) 1670 kg/m³
e) 1690 kg/m³

21) A unidirectional, aligned fibre composite is to be fabricated from a polyester resin and E-glass fibres. (Material properties can be found in Table 1) If the volume fraction of fibres is 50%, the Young's modulus of the composite measured perpendicular to the fibre direction is closest to:

a) 0.6 GPa
b) 1.5 GPa
c) 30 GPa
d) 38 GPa
e) 45 GPa

22) The minimum volume fraction of HM carbon fibres in a polyester matrix required to achieve a Young's modulus parallel to the fibres of 240 GPa is closest to:

a) 10%
b) 15%
c) 25%
d) 35%
e) 45%

23) A unidirectional composite of 65% by volume E-glass fibres in epoxy is subjected to a stress of 100 MPa parallel to the fibre direction. The strain in the epoxy is closest to:

a) 0.002
b) 0.020
c) 0.040
d) 0.200
e) There is not enough information to calculate the strain in the matrix.

24) As it refers to the atomic structure of a crystalline material, which of the following is a “line” defect?
   a) An edge dislocation
   b) A vacancy
   c) A grain boundary
   d) a, b, and c are all line defects
   e) None of the above

25) The defects marked by the letter ‘B’ in Figure 1b are called:
   a) interstitial atoms
   b) substitutional atoms
   c) edge dislocations
   d) grain boundaries
   e) vacancies

26) The defect shown in Figure 1c is:
   a) A grain boundary
   b) A screw dislocation
   c) An edge dislocation
   d) A solid solution
   e) A volumetric defect

27) The Burgers vector of a dislocation

   a) has a magnitude equal to the shear stress at yield
   b) has a magnitude equal to the tensile strain at yield
   c) has a magnitude equal to the shear displacement caused by the motion of the dislocation
   d) is equal to the work hardening rate for the metal
   e) is always equal to the dimension of the unit cell

28) Plastic deformation increases the yield strength of a metal because:

   a) the Young's modulus increases.
   b) the Young's modulus decreases.
   c) the number of vacancies decreases.
   d) the number of entangled dislocations increases.
   e) the number of substitutional impurities increases.

29) Brass (a Cu-Zn alloy) is stronger than pure copper. This is because:
   a) The zinc atoms distort the copper lattice
   b) The Young’s modulus of zinc is higher than that of copper
   c) The copper-zinc bond is stronger than the copper-copper bond
   d) The zinc atoms prevent dislocations from forming
   e) Dislocations are repelled by zinc atoms

30) The 0.2% offset yield strength of the material in Figure 2 is closest to:
   a) 300 MPa
   b) 350 MPa

c) 400 MPa
d) 450 MPa
e) 500 MPa

31) If the specimen in Figure 2 was loaded to the point A labelled on the figure and then the load was removed, the total plastic strain in the specimen would be:
a) 0
b) 0.002
c) 0.005
d) 0.007
e) 0.14

32) Which of the following statements is/are true in their description of a thermosetting polymer:
a) The structure of a thermoset is a 3-D network of covalently bonded molecules
b) The Young's modulus of a thermoset is generally higher than a thermoplastic polymer.
c) Plastic deformation is accomplished by the rotation and sliding of polymer chains.
d) a) and b) are both correct
e) b) and c) are both correct

33) Crystalline ceramics do not experience significant plastic deformation because:
a) The stress required to move dislocations is greater than the fracture stress.
b) The ionic bonds are too strong.
c) Small flaws in the material act as stress concentrators, causing fracture before plastic deformation can occur
d) All of the above
e) None of the above

34) The vulcanizing process is used to:
a) Increase the crystallinity of thermoplastic polymers
b) Reduce the crystallinity of thermosetting polymers
c) Inhibit branching during polymerization
d) Create cross-links in elastomers
e) Remove unwanted sulphur following the polymerization process

35) A specimen, having a thermal expansion coefficient of 4×10^{-5}/K and a length of 100mm at 20 ºC, is heated to 100 ºC, how much will the length change?
a) 0.0032 mm
b) 0.004 mm
c) 0.32 mm
d) 0.4 mm
e) 0.2 mm

36) Based on your knowledge of atomic bonding and its influence on the mechanical and physical properties of materials, which of the materials listed in Table 1 would you expect to have the highest coefficient of thermal expansion?
a) Low carbon steel
b) Aluminum

c) Copper
d) Epoxy
e) Glass (E-glass)

37) The specific heat, C_p, of a material is equal to:
a) The absolute melting temperature divided by the density.
b) The creep temperature divided by the density.
c) The rate of steady-state heat transfer
d) The energy required to raise the temperature of a unit mass of the material by one degree.
e) None of the above.

38) A 15cm thick concrete wall (C_p = 950 J/kg·K; λ=1.6 W/m·K; ρ=2450 kg/m³; $\alpha=1\times10^{-5}$ ºC^{-1}) separates a mechanical room (T=35ºC) from an adjacent office (T=22º). The heat flux through the wall is approximately:
a) 185 J/m²
b) 1390 W/m²
c) 2350 W/m²
d) 3730 W/m²
e) 454,000 J/m²

39) A 1000W heating element is embedded in a block of concrete with a volume of 1000 cm³. The thermal properties of concrete are listed in Question 38) above. If the exterior of the block is perfectly insulated, how long must the heater operate in order to deliver enough energy to raise the temperature of the block by 50ºC? (Recall that 1 W = 1 J/s)
a) < 30s
b) ≈ 2 min
c) ≈ 5 min
d) ≈10 min
e) > 12 min

40) Metals typically have a higher value of fracture toughness than ceramics because:
a) Ceramics contain larger flaws
b) Metals have lower Young's Moduli
c) Ceramics have lower Young's Moduli
d) Metals plastically deform
e) The process zone in ceramics is larger than in metals

41) A tensile sample has a diameter of 5 mm and a surface crack of a depth of 0.2mm. If the far-field tensile stress is 300 MPa, what is the local stress at a location 1mm away from the tip of the crack?
a) 228 MPa
b) 250 MPa
c) 350 MPa
d) 395 MPa
e) 435 MPa

42) The toughness of the aluminum alloy in Table 1 is approximately:
a) 11 MJ/m²
b) 400 kJ/m²
c) 11 kJ/m²
d) 400 J/m²
e) 11 J/m²

43) At a given temperature, the steady-state creep rate of a material is characterized by the equation:

$$\dot{\varepsilon}_{ss} = A\sigma^n$$

Presented with data of $\dot{\varepsilon}_{ss}$ at various levels of applied stress, the constants A and n are determined graphically by plotting (*y-axis* vs. *x-axis*):

a) $\log(\dot{\varepsilon}_{ss})$ vs. $\log(\sigma)$: slope = A; y-intercept = log(n)
b) $\log(\dot{\varepsilon}_{ss})$ vs. $\log(\sigma)$: slope = n; y-intercept = log(A)
c) $\log(\sigma)$ vs. $\log(\dot{\varepsilon}_{ss})$: slope = n; y-intercept = log(A)
d) σ vs. $\dot{\varepsilon}_{ss}$: slope = log(n); y-intercept = log(A)
e) $\dot{\varepsilon}_{ss}$ vs. σ : slope = log(A); y-intercept = log(n)

44) A stress of 550 MPa is enough to cause a piece of steel (K_{IC} = 80 MPa.m$^{1/2}$, σ_{uts} = 800 MPa) to fracture. The depth of the surface flaw in this sample is closest to: (assume Y = 1.0)
a) 3.1 mm
b) 6.7 mm
c) 13.5 mm
d) 32.8 mm
e) 46.3 mm

45) In choosing the best metal for a given application, an engineer chooses to compare values of K_{IC} . In Table 1, the property which is K_{IC} is:
a) Yield stress
b) Ductility
c) Fatigue Limit
d) Fracture toughness
e) None of the listed properties

46) A component made from low carbon steel (Table 1) is known to contain surface flaws as deep as 0.5mm. If the component is subjected to a constantly increasing tensile stress, which of the following best describes the response of the component:
a) Elastic deformation → fast fracture
b) Elastic deformation → yield → fast fracture
c) Elastic deformation → yield → necking → fracture
d) Can not be determined without knowledge of the specimen geometry.

47) A sample of a brittle material with K_{IC} = 10 MPa·m^{½} has an effective strength of 170 MPa when the internal flaws are 100 μm in width. The effective strength when the flaws are 400μm wide would be approximately:
a) 42 MPa
b) 85 MPa
c) 120 MPa
d) 240 MPa
e) 680 MPa

48) The basic result obtained from a creep test is a plot with which two parameters:
a) stress and time
b) stress and strain
c) strain and time
d) strain and ductility
e) stress and Poisson's ratio

49) Creep deformation becomes an important consideration at which homologous temperature?
a) 0
b) 0.4
c) 1.0
d) 100
e) 1000

50) The steady state creep rate for a metal follows the functional form:

$$\dot{\varepsilon}_{ss} = C\sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

Experimentally, the steady state creep strain rate is measured for a number of temperatures at a constant stress. The activation energy for creep can be obtained most easily by plotting the variables on an XY graph and calculating from the slope as follows:

	X-axis	Y-axis	Slope
a)	$\ln\dot{\varepsilon}_s$	1/R	Q_c
b)	$\ln\dot{\varepsilon}_s$	1/T	$-Q_c$/R
c)	1/T	$\ln\dot{\varepsilon}_s$	$-Q_c$/R
d)	$\dot{\varepsilon}_s$	$\ln K_2\sigma^n$	$-Q_c$/R
e)	$K_2\sigma^n$	$\ln\dot{\varepsilon}_s$	$-Q_c$

51) *Choose the correct statement from the list below*. When conducting creep experiments, assuming the stress is held constant, as temperature is increased:

a) Instantaneous deformation will increase and rupture life will decrease
b) Steady-state creep rate will increase and rupture life will increase.
c) Steady-state creep rate will decrease and rupture life will increase.
d) Instantaneous deformation will decrease and rupture life will decrease
e) Steady-state creep rate will increase and total creep strain will increase

52) A cylindrical component is fabricated from a low carbon-nickel alloy with a diameter of 20.0mm. The maximum load that may be applied for it to survive 10000 hours at 538°C is closest to (see Figure 3):

a) 22 N
b) 35 N
c) 22,000 N
d) 28,000 N
e) 35,0000N

53) Figure 4 is a plot of stress-rupture data for an Fe-Cr-Ni alloy. A rectangular bar of this material with a cross-sectional area of $5 cm^2$ will be used at a constant temperature of 980°C. What is the maximum load it can carry if it must survive for one year (365 days) without failing?

a) 900 N
b) 2000 N
c) 5000 N
d) 9000 N
e) 50000 N

54) The activation energy for creep of copper is 205 kJ/mol. If the steady-state creep rate measured at 700°K is 0.01 s^{-1}, the creep rate at 750°K and the same applied stress will be approximately:

a) 0.001 s^{-1}
b) 0.015 s^{-1}
c) 0.100 s^{-1}
d) 0.250 s^{-1}
e) Can not be determined without more information

55) The resistivity of pure copper at room temperature is $1.7 \times 10^{-8}\ \Omega \cdot m$. The conductivity of pure copper at room temperature is:

a) $5.9 \times 10^5\ \Omega^{-1} \cdot m^{-1}$
b) $1.7 \times 10^7\ \Omega^{-1} \cdot m^{-1}$
c) $5.9 \times 10^7\ \Omega^{-1} \cdot m^{-1}$
d) $1.7 \times 10^8\ \Omega^{-1} \cdot m^{-1}$
e) Not enough information to determine.

56) The resistance (at room temperature) of a 100m length of copper wire with a diameter of 1mm is:

a) $1.3\times10^{-16}\ \Omega$
b) 0.00017 Ω
c) 0.0017 Ω
d) 2.16 Ω
e) 170 Ω

57) The power lost in a 100m copper wire carrying a current of 10A is:

a) 0.17 W
b) 216 W
c) 1000 W
d) 17000 W
e) Cannot determine without knowing the voltage.

58) A material carries a current density of 2.5 A/m^2 under an electric field of 110 V/m. The conductivity of the material is approximately:

a) $3.6\times10^{-3}\ \Omega^{-1}\cdot m^{-1}$
b) $2.3\times10^{-2}\ \Omega^{-1}\cdot m^{-1}$
c) $32\ \Omega^{-1}\cdot m^{-1}$
d) $44\ \Omega^{-1}\cdot m^{-1}$
e) $275\ \Omega^{-1}\cdot m^{-1}$

59) The resistance of two wires: one a metal and the other an intrinsic semiconductor is measured at different temperatures near room temperature. The expected behaviour for the resistance is: as the temperature increases, the resistance:

	Metal	Semiconductor
a)	increases	increases
b)	increases	decreases
c)	decreases	decreases
d)	decreases	increases
e)	remains unchanged for both materials	

60) The band-gap of a material is used to characterize
a) The Fermi Energy of the material
b) The mobility of conduction electrons in a semiconductor
c) The energy barrier to the promotion of electrons to the conduction band
d) The width between adjacent electrons
e) The resistivity of electrically insulating materials.