# Massachusetts
# Tests for Educator Licensure® (MTEL®)


# Technology/ Engineering (33) PRACTICE TEST APPENDIX: Multiple-Choice Question Analyses

www.mtel.nesinc.com



06/16

# MULTIPLE-CHOICE QUESTION ANALYSES

1. Which of the following is a technology used primarily to reduce CO emissions?

   A. catalytic converter

   B. smokestack scrubbers

   C. carbon offsets

   D. coal gasification

**Correct Response: A.** Catalytic converters catalyze the reactions of toxic emissions, such as CO, into more benign compounds such as $CO_2$. Smokestack scrubbers (**B**) are used to "wash out" particulate and other contaminants from smokestack emissions through the introduction of a washing compound. They are not used primarily to reduce CO emissions. Carbon offsets (**C**) are a market-based mechanism for companies to offset the amount of greenhouse gasses they emit by investing in projects that reduce greenhouse gas emissions. CO is not considered to be a major greenhouse gas. Coal gasification (**D**) is a method of processing coal to create a variety of fuels and other products. It has nothing to do with reducing CO emissions, and it is in fact a source of CO.

2. Which of the following media sources is most likely to be a valid source of information?

   A. popular magazine

   B. infomercial

   C. Web page

   D. professional journal

**Correct Response: D.** Articles in professional journals are written and reviewed by professionals in the relevant field. They contain citations to back up their statements. The primary purpose of a professional journal is to publish the most up-to-date and valid information available. Popular magazines (**A**) are required to write articles that will attract readers to buy the magazines, and to buy the goods and services advertised in the magazines. Infomercials (**B**) are written and produced with the single goal of selling a particular product or service. Web pages (**C**) vary greatly in terms of the validity of the information they contain. Web pages are primarily created to promote a particular point of view, or to sell a product or service.

3. Approximately 3,000 years ago, smelting furnaces that could achieve high temperatures were developed. This new technology was responsible for iron replacing which of the following metals in the industry of the time?

   A. tin

   B. brass

   C. pewter

   D. bronze

**Correct Response: D.** The Bronze Age followed the Neolithic period, or Stone Age. Bronze is a very hard alloy created from copper and tin. The use of bronze to make tools, weapons, and ornaments was a major technological advance. It required the ability to mine for minerals, smelt ores, and develop casting processes. It was the prominent metal for most uses before high-temperature smelting techniques made iron a feasible replacement. None of the other metals—tin, brass, or pewter (**A**, **B**, and **C**)—were used to the same degree as bronze, as they are not hard enough for most applications.

4. In the mid-twentieth century, televisions and radios became smaller and more portable as vacuum tubes were replaced by:

   A. microprocessors.

   B. transistors.

   C. electron guns.

   D. capacitors.

**Correct Response: B.** Vacuum tubes were originally used in televisions and radios to amplify the very weak signal picked up by an antenna and to make it powerful enough to emit sound from a speaker, or to control an image on a screen. In the mid-twentieth century, the much smaller and more durable transistor (**B**) replaced the vacuum tube. This resulted in much smaller and more portable televisions and radios. Microprocessors (**A**) came later and were used for logical computing. Electron guns (**C**) have been used to produce the images on television screens since the very beginning and continued to be used until they were replaced by the newer flat screens. They were not used in radios. Capacitors (**D**) predate televisions and radios by more than 100 years. They were and continue to be a common component in practically all electronic devices.

5. The Manhattan Project was a government-sponsored research project that would eventually provide the foundation for which of the following technologies?

   A. supercomputers

   B. space flight

   C. the Internet

   D. nuclear power

**Correct Response: D.** The Manhattan Project was a United States government research project that produced the first nuclear bomb. This scientific breakthrough, which resulted in the release of energy from the atom, laid the groundwork for nuclear power. None of the other answer technologies—supercomputers, space flight, or the Internet (**A**, **B**, or **C**)—are directly related to the release of energy from the atom.

6. Which of the following is an example of reverse engineering?

   A. disassembling a device to determine its internal mechanisms

   B. redesigning a product to reduce the number of parts or assemblies

   C. finding a new use for an existing tool or machine

   D. replacing energy-intensive processes with more fuel-efficient processes

**Correct Response: A.** Reverse engineering is a method of determining the design features of an existing product by taking it apart to see how it was made. None of the other answer choices (**B**, **C**, or **D**) are specifically about the reverse engineering process. However, reverse engineering might be a reasonable first step toward improving upon (**B** and **D**), or finding a new use for (**C**), an existing product.

7. A rheostat has a maximum resistance of $3.5 \times 10^3$ Ω. A second rheostat also has a maximum resistance of $3.5 \times 10^3$ Ω. What is the sum of the two maximum resistances?

   A. 3,500 Ω

   B. 7,000 Ω

   C. 3,500,000 Ω

   D. 7,000,000 Ω

**Correct Response: B.** The sum of two numbers expressed in scientific notation, where both expressions are in terms of the same power of 10 (exponent), can be found by adding the first parts (coefficients), and keeping the exponent the same. This can be shown arithmetically as follows: $(3.5 \times 10^3) + (3.5 \times 10^3) = (3.5 + 3.5) \times (10^3) = (7) \times (1000) = 7{,}000$. Answer choice **A** is the average of two numbers. Answer choice **C** is found by leaving the coefficients of the numbers unchanged, and adding the exponents. Answer choice **D** comes from adding the coefficients of the numbers, and adding the exponents.

8. What is the product of $2.1 \times 10^3$ and $5.2 \times 10^3$ correctly reported using significant figures?

   A. $1.092 \times 10^6$

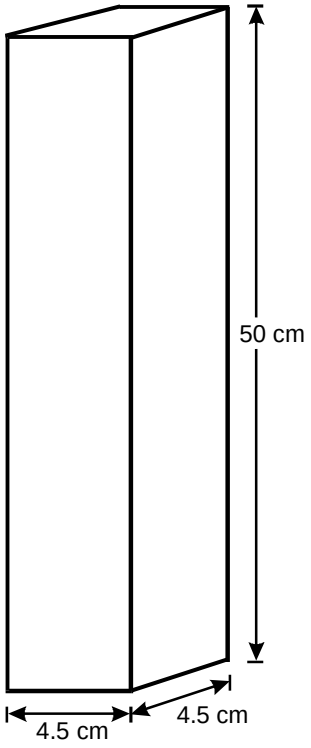
   B. $1.092 \times 10^7$

   C. $1.1 \times 10^6$

   D. $1.1 \times 10^7$

**Correct Response: D.** The product of two numbers expressed in scientific notation can be found by multiplying the first parts (coefficients), and adding the powers of 10 (exponents). This results in $(2.1 \times 5.2) \times 10^{(3+3)}$, which simplifies to $10.92 \times 10^6$. Standard (or normalized) scientific notation form requires that the decimal be moved so that it is positioned directly after the first nonzero digit of the coefficient. This would result in $1.092 \times 10^7$. However, the rules of significant figures dictate that the product can have no more significant figures than either of the factors. In this case, both factors are expressed to two significant digits. Therefore, the product must be rounded to two significant digits, yielding $1.1 \times 10^7$. Choices (**A** and **B**) are not rounded to the correct number of significant figures. Choices (**A** and **C**) contain an exponent error.

9. **Use the diagram below to answer the question that follows.**




Copper has a density of 8.96 g/cm$^3$. What is the approximate mass in kilograms of the solid bar of copper in the diagram?

A. 1.12 kg

B. 9.1 kg

C. 91 kg

D. 112 kg

**Correct Response: B.** The mass is found by multiplying the density of copper by the volume of the solid. In this case, the solid is a right rectangular prism and its volume is $V = l \times w \times h$, where $V$, $l$, $w$, and $h$ represent volume, length, width, and height respectively. Therefore the volume of the solid is (4.5 cm)(4.5 cm)(50 cm) = 1012.5 cm$^3$, and the mass is (1012.5 cm$^3$)(8.96 g/cm$^3$) = 9072 g. The problem asks for the mass expressed in kg so this answer must be converted as (9072 g)(0.001 kg/g) = 9.072 kg. Finally, since the measurements are given to two significant figures, the answer must be rounded to 9.1 kg. Answer choices (**C** and **D**) are incorrectly reached due to an error when converting from grams to kilograms. Answer choices (**A** and **D**) are incorrectly reached due to not multiplying the volume by the mass.

10. In manufacturing and engineering, *tolerance* refers to:

    A. the average error in a series of measurements.

    B. the clearance between two workpieces.

    C. the actual measured dimension of a workpiece.

    D. a permissible deviation from a specification.

**Correct Response: D.** In engineering and manufacturing, dimensions are often specified as follows: .500 +.002 -.001 in. In this case, a part is acceptable if the measurement is no smaller than .500 - .001 in., and no larger than .500 + .002 in. In this case, +.002 in. and -.001 in. are referred to as the tolerances of the specification. Choice (**A**) is concerned with the actual errors in the measurements, which is not the same as tolerance. Tolerance is concerned with the maximum allowable errors specified in the design. Choice (**B**) is concerned with the clearance between two workpieces. While this is not the same as tolerance, it is certainly affected by tolerances. Choice (**C**) is concerned with the actual dimensions of the finished workpiece, while tolerance is only concerned with the design specifications used to make the workpiece.

11. A circular garden has a radius of 12 feet. If the garden is enlarged so that its new radius is 24 feet, by what factor will the garden's area increase?

    A. 2

    B. 4

    C. 8

    D. 12

**Correct Response: B.** The area of a circle can be calculated using the equation, $a = \pi r^2$, where $a$ represents the area, $r$ represents the radius, and $\pi$ is a specific irrational number. In this problem, the original area equals 144 $\pi$ square feet, and the final area equals 576 $\pi$ square feet. The factor requested can be found by dividing the final area by the original area, yielding $(576 \pi)/(144 \pi) = 4$. In general, if a quantity is directly proportional to the square of particular variable, and the value of the variable is multiplied by a factor of $x$, the resulting quantity will increase by a factor of $x^2$. Answer choice (**A**) is reached by assuming that a doubling of the radius would result in a doubling of the area. Answer choice (**C**) is reached by assuming that the scale factor (4) should be cubed. This would have been correct for the volume of a spherical object. Answer choice (**D**) is reached by assuming that an increase of 12 in the radius will increase the area by the same amount.

12. A manufacturing company is producing dowels that have a diameter of 8.5 mm $\pm$ 0.1 mm. The hole the diameter must fit into has a diameter of 9.0 mm $\pm$ 0.1 mm. According to these specifications, what is the greatest clearance that can occur between the two parts?

    A. 0.1 mm

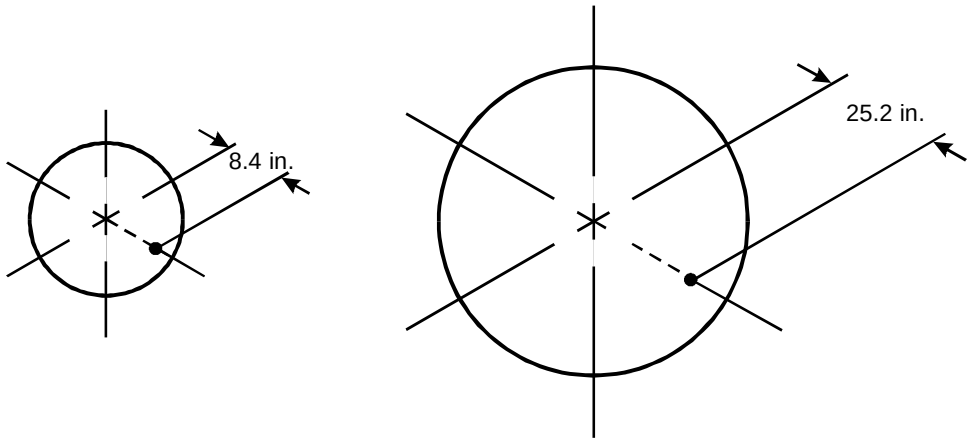
    B. 0.2 mm

    C. 0.5 mm

    D. 0.7 mm

**Correct Response: D.** The greatest clearance will occur for the smallest allowable dowel diameter (8.5 mm – 0.1 mm = 8.4 mm) and the largest allowable hole diameter (9.0 mm + 0.1 mm. = 9.1 mm). This maximum clearance will be the difference between the diameters (9.1 mm – 8.4 mm = 0.7 mm). Answer choice (**A**) assumes that the greatest clearance would be equal to the greatest tolerance. Answer choice (**B**) assumes that the greatest clearance would be equal to the sum of the tolerances. Answer choice (**C**) assumes that the tolerances have no effect on the greatest clearance. It is incorrectly calculated that the greatest clearance is equal to the difference (9.0 mm – 8.5 mm) = 0.5mm.

13. **Use the diagram below to answer the question that follows.**




A spherical workpiece has a radius of 8.4 inches and a volume of *V* cubic inches. A larger spherical version of the sphere has a radius of 25.2 inches. What is the volume of this larger sphere?

A. 8.0*V*

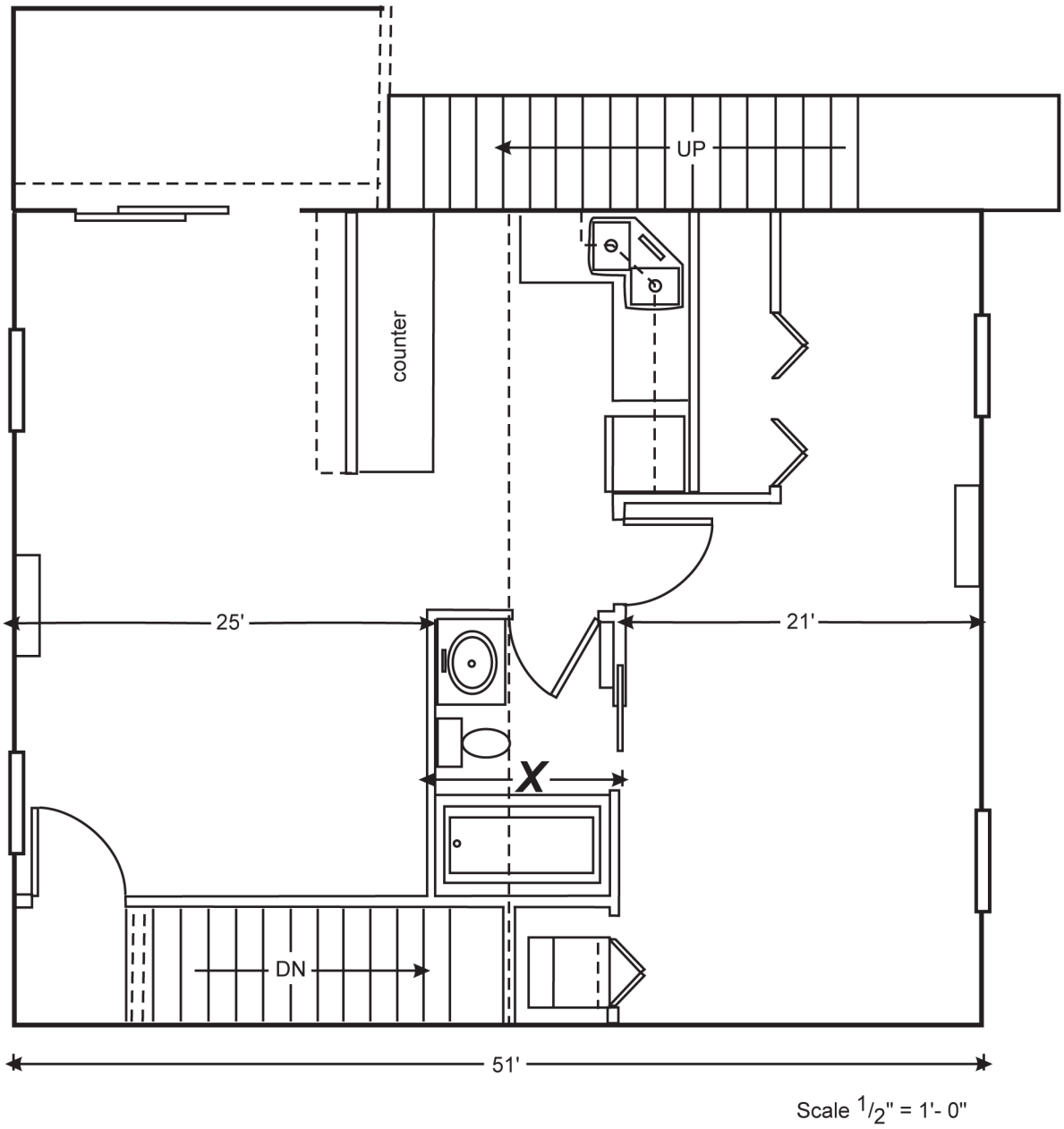
B. 13.5*V*

C. 27.0*V*

D. 54.0*V*

**Correct Response: C.** The volume of a sphere can be calculated using the formula $V = (4/3)\pi r^3$, where *V* represents the volume, $\pi$ is an irrational number, and *r* represents the radius. This formula shows that the volume is directly proportional to the cube of the radius. In general, if quantity is directly proportional to the cube of particular variable and if the value represented by the variable is multiplied by *x*, the resulting quantity will increase by a factor of $x^3$. Since 25.2 ÷ 8.4 = 3, the value represented by the variable *r* is increased by a factor of 3. Hence, if the smaller sphere has a volume of *V*, then the larger sphere must have a volume of $3^3V$ or 27.0*V*. Answer choice **A** assumes that doubling of the radius leads to an increase in volume by a factor of 8, not understanding that this was just a special case of the $x^3$ rule. Answer choice **B** results from assuming that the volume scale factor should be $x^3/2$. Answer choice **D** comes from assuming that the volume scale factor should be $2x^3$.

**Use the floor plan below to answer the two questions that follow.**



14. If the scale used to draw the floor plan is 1/2 inch to 1 foot, what should be the length of the dimension labeled *X* in the floor plan?

    A. 2.0 inches

    B. 2.5 inches

    C. 3.5 inches

    D. 5.0 inches

**Correct Response: B.** The dimension labeled *X* can be determined indirectly as 51' – (21' + 25') = 5'. Since each actual foot in the house is represented by 0.5 inches in the floor plan, the dimension labeled *X*, which is equal to 5 feet in the house, is represented by (5)(0.5) = 2.5 inches in the floor plan. Answer choice (**A**) comes from misreading the floor plan, assuming that *X* only represented the distance from the dotted line to the bathroom wall on the right, and estimating it to be 2.0 inches. Answer choice (**C**) is a rough visual estimate. Answer choice (**D**) comes from calculating 51 – (21 + 25) = 5 and neglecting to use the scale factor to convert the 5 feet of real floor to 2.5 inches of floor plan.

15. Which of the following is not shown in the plan?

    A. kitchen sink

    B. bathroom sink

    C. kitchen range

    D. water closet

**Correct Response: C.** The kitchen sink (**A**) is shown in the kitchen (the center room pictured below the "UP" arrow) as two basins within a corner-mounted counter. The bathroom sink (**B**) is shown in the bathroom (the center room pictured in the lower section of the floor plan) as an oval basin within a corner-mounted rectangular counter. The water closet (**D**), also known as a toilet, is shown in the bathroom as an oval seat mounted in front of a rectangular tank. The kitchen range (**C**) is the only choice that is not shown in the plan. There is one rectangular fixture shown in the kitchen. However, it lacks top burners, which would need to be indicated for a kitchen range. It could be a refrigerator or a dishwasher. Even though many modern ranges feature smooth tops, the floor plan symbol should include circular burners, or it should be specifically labeled to avoid confusion.

16. Which of the following steps should be taken first in administering first aid to a person who has received a puncture wound while using a drill press?

    A. Call 9-1-1.

    B. Apply a bandage.

    C. Apply direct pressure to the wound.

    D. Rinse the wound with running water.

**Correct Response: C.** The first, and most important, step when administering first aid to a person with a puncture wound is to stop the bleeding by applying direct pressure to the wound. If the bleeding is extremely severe, or if it does not stop after 10 minutes of firm direct pressure, then call 9-1-1 (**A**). Once the bleeding has stopped, the wound should be washed with warm water (**D**) and gentle soap. After the wound is cleaned, apply an antibiotic ointment and a sterile bandage (**B**).

17. Which of the following is an important component of a solution used to clean up a blood spill on a workplace floor?

    A. baking soda

    B. acetic acid

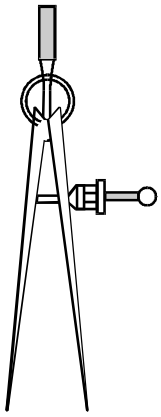
    C. chlorine bleach

    D. hydrogen peroxide

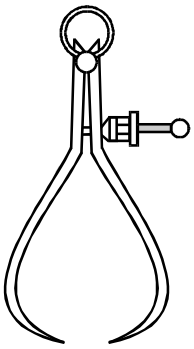
**Correct Response: C.** While many home remedy solutions such as baking soda (**A**), vinegar (which contains acetic acid) (**B**), and hydrogen peroxide (**D**) may be good cleaners and disinfectants, none of them are recommended for cleaning up blood spills on workplace floors. The only recommended chemicals for this application are a 1:10 solution of chlorine bleach (**C**) and water, or a commercial cleaner specifically designed for workplace bodily fluid cleanup.

18. Which of the following tools would be the most appropriate choice for determining the distance between two points on a flat surface of a workpiece?

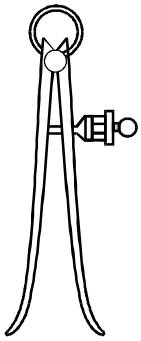
A.



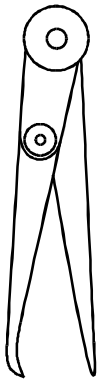
B.



C.



D.



**Correct Response: A.** All four choices are examples of calipers. Choice (**A**) is an example of a type of spring joint caliper known as a divider or a compass. Its two straight legs make it most useful for measuring distances on a flat surface. This caliper is not a direct measurement tool since it has no graduations. It is an example of a transfer measurement tool because it is used to transfer a measurement from one object to another. An actual measurement can be made if the second object is a ruler. This tool is also used for scribing arcs and circles. Choices **B** and **C** are outside and inside spring joint calipers respectively. They too are transfer measurement tools for measuring the outside and inside dimensions of physical objects. Today, they have been mostly replaced by digital calipers. Choice **D** is an example of a hermaphrodite caliper. This type of caliper has one leg with a curved end and one with a straight end. The curved end is used to hook around the edge of an object while the straight end is used for scribing or measuring a distance from the edge.

19. A design engineer would like to determine the diameter of a circle. He begins by using a straightedge to draw a line tangent to the circle. Which of the following steps would be most appropriate next?

    A. Use a compass to construct the perpendicular bisector of the tangent and extend it until it intersects the circle at two points.

    B. Draw a second tangent parallel to the first tangent using a T-square, and then connect the two points of tangency.

    C. Beginning at one end of the tangent, use a straightedge to construct a second tangent, then connect the two free ends of the tangents.

    D. Use a compass to draw an arc centered on one end of the tangent. Draw an equal arc centered on the other end of the tangent.

**Correct Response: B.** For a second tangent line to be parallel to a first tangent line, it must be tangent to that circle at a point that is 180 degrees around the circle from the first tangent line. Any line that joins two points 180 degrees apart around a circle must be a diameter of that circle since it divides it perfectly in half. Therefore, choice **B** is correct. Choices **A**, **C**, and **D** all employ constructions that make use of the endpoints of the originally drawn tangent line. Since these endpoints are not defined in the problem, none of the resulting constructions are completely defined. Hence each construction could result in an infinite number of different drawings, most of which would not lead to the determination of the diameter of the circle.

20. A jointer would most likely be used to create:

    A. flat edges so that two boards may be edge joined.

    B. precisely shaped cuts to produce a dovetail joint.

    C. matching pins and holes for a mortise and tenon joint.

    D. accurately mitered cuts to produce a miter joint.

**Correct Response: A.** A jointer is a power tool that flattens and straightens the edges of boards so that they can be joined together perfectly, edge-edge, with no gaps. It is not used in the making of dovetail joints (**B**), mortise and tenon joints (**C**), or miter joints (**D**).

21. Which of the following is an example of an open geothermal heat pump system?

    A. Water from naturally hot springs is circulated past an evaporator coil containing a refrigerant before being released into a nearby body of water.

    B. Water heated in a boiler is piped to buildings through underground conduits to minimize heat loss and then released into a river.

    C. Thermocouples in the ground take advantage of natural temperature differences in the soil to generate energy.

    D. Subsurface steam from a volcanically active region is circulated throughout a city to heat buildings and melt ice.

**Correct Response: A.** The system described in choice **A** satisfies the requirements of the question. The system is open since the water is not recirculated, the system is geothermal since the hot springs are naturally heated by the earth's internal temperature, and the system involves a heat pump in the form of a refrigerant that is compressed to a liquid and allowed to expand to gas in an evaporator coil. Choice **B** is not primarily powered by geothermal energy and it does not involve a heat pump. Choice **C** is not an open system and it does not involve a heat pump. Choice **D** does not involve a heat pump.

22. Which of the following is commonly used to reduce line pressure in an industrial gas delivery system?

    A. expander

    B. reducer

    C. regulator

    D. decompression valve

**Correct Response: C.** A regulator consists of a valve that is controlled by a spring-loaded diaphragm to meter out the amount of gas necessary to maintain a preset outlet pressure that is lower than the inlet pressure. Expanders (**A**) and reducers (**B**) adapt between different diameters of lines. While they may have some effect on line pressure at very high flow rates, they are not commonly used for this purpose. A decompression valve (**D**) is an emergency pressure relief valve designed to avoid overpressure situations. It is not used to reduce line pressure under normal conditions.

23. Which of the following types of pumps uses an impeller to push fluid entering at the center of the pump housing into a peripheral canal and exit?

    A. turbine pump

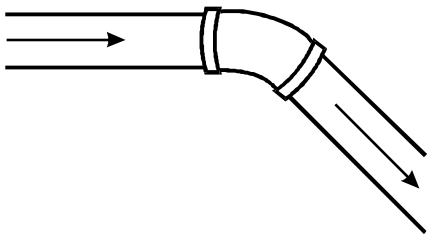
    B. centrifugal pump

    C. rotating vane pump

    D. external gear pump

**Correct Response: B.** A centrifugal pump works according to the principle of an apparent centrifugal force acting on spinning objects when measured from a spinning reference frame. The spinning fluid experiences a force directed from the central inlet to the peripheral outlet. This apparent force comes from the spinning motion imparted by the impeller. In a turbine pump (**A**), the fluid flows in the direction of the axis of rotation of the vanes and not from the center to a peripheral exit. In a rotating vane pump (**C**), the fluid both enters and exits at the periphery of the circular chamber. The fluid is propelled in a semi-circular motion by a configuration of rotating vanes. In an external gear pump (**D**), the fluid is transported by the teeth of two interlocking gears in opposite directions around their outer circumference of the curved housing. This is yet another example where the fluid travels around a semicircular path from the outside of one end of the pump to the outside of the other end.

24. **Use the diagram below to answer the question that follows.**



A straight section of a fluid system carrying water is changed to include a 45° bend and a downward slope as indicated in the diagram. This change is most likely to have which of the following effects on the fluid in the system?

A. Resistance to flow will decrease.

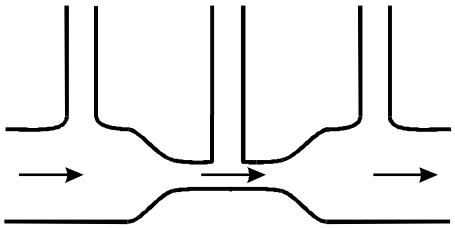
B. Flow will change from laminar to turbulent.

C. Resistance to flow will increase.

D. Flow will change from turbulent to laminar.

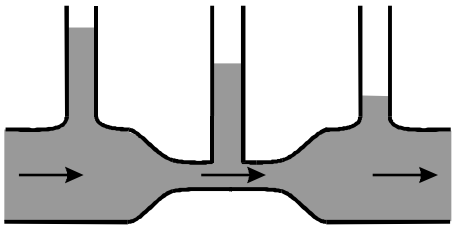
**Correct Response: C.** Any bend in a fluid-carrying line will cause an increase in flow resistance. The fact that the bend is in the downward direction will have no effect unless it implies a lowering of the altitude of the outlet when the outlet is open to atmospheric pressure. Therefore choice **A** is incorrect. Choices **B** and **D** describe the relationship between laminar and turbulent flow. In real-world water plumbing situations, laminar flow is nearly impossible, and turbulent flow is the norm regardless of bends in the pipe. Laminar flow is more common with more viscous fluids flowing at low speeds through narrow pipes.

25. **Use the diagram below to answer the question that follows.**

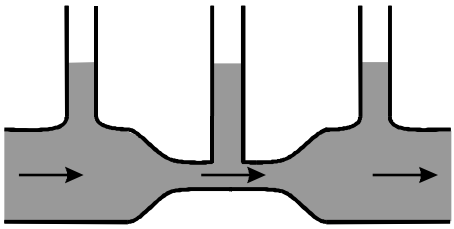


A fluid flows from left to right through a tube in a cooling unit that has a constriction as shown in the diagram. Which of the following diagrams correctly represents the relative pressures within the tube?

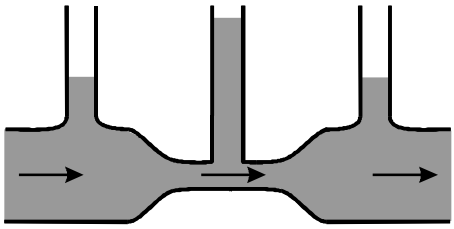
A.



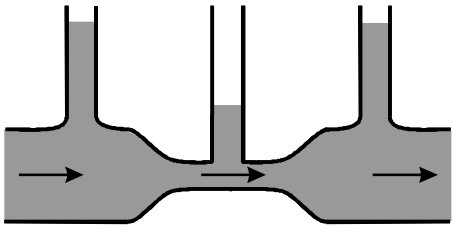
B.



C.



D.



**Correct Response: D.** Conservation of matter and the relative incompressibility of fluids imply that the volume flow rate is equal at all points along the path of the fluid. This means that the velocity of the fluid must be greater in the narrower section of the tube. According to Bernoulli's principle, the pressure must be lower at points where the velocity is greater. This would result in a condition where the center column is lower than the two outer columns (**D**) since the fluid in the center has less pressure to force the column up against atmospheric pressure. The two outer columns would be equal to each other since those regions of the tube have equal cross-sectional area, which would lead to equal velocity and hence equal pressure. Answer choice **A** assumes that there would be continuous reduction in pressure from the input to the output. While it is true that there would be no flow without some pressure differential from left to right in the diagram, that differential would be expected to be extremely small when compared to the pressure drop caused by the narrowing of the passage in the diagram. Answer choice **B** comes from assuming that the pressure is essentially equal throughout the horizontal path. This would only be correct if there were no flow to create the Bernoulli effect in the narrow portion of the tube. Answer choice **C** is reached by the intuitive misconception that the narrowing of a passage causes an increase in pressure.

26. The operation of a typical bimetallic-strip thermostat is based on the difference in two metals':

    A. specific heat.

    B. coefficient of friction.

    C. specific gravity.

    D. coefficient of expansion.

**Correct Response: D.** A bimetallic-strip thermostat contains a flat strip of metal formed in the shape of a coil. As the ambient temperature changes, the coil winds tighter or looser according to the direction of the temperature change. The metal strip consists of two different metals bonded together: one metal is on the inside of the bend of the strip, and the other is on the outside. Since the two metals have different coefficients of thermal expansion, they expand and contract at different rates as the temperature changes. This causes the strip to bend one way or the other, actuating heating and/or cooling switches. Answer choice **A** might make sense for very fast and extreme changes in temperature since the metal with the greater specific heat would react more slowly to the temperature change. However, even under those unlikely circumstances, the coil would eventually return to its original position as temperature equilibrium is reached. This return would make the thermostat ineffective. Answer choice **B** deals with the friction of two objects sliding across each other's surfaces. This phenomenon is not involved in the operation of a bimetallic-strip thermostat. Answer choice **C** deals with the density of materials. This characteristic is not pertinent to the operation of a bimetallic-strip thermostat.

27. A rock that has a mass of 64 kg is at the edge of a cliff that has a height of 20 m. If the rock falls from the cliff, what will be its kinetic energy when it strikes the ground below?

    A. 1,568 J

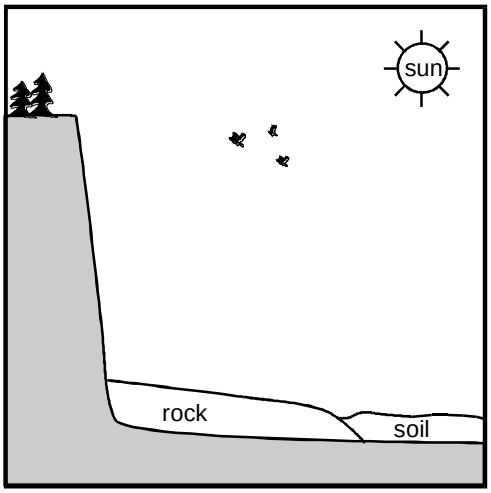
    B. 12,544 J

    C. 15,366 J

    D. 122,931 J

**Correct Response: B.** Due to conservation of mechanical energy, any kinetic energy gained by the rock will have to be equal to any loss of gravitational potential energy. Since the rock started at rest, it can be assumed that the final kinetic energy is equal to the initial gravitational potential energy due to the rock's height relative to the ground. The gravitational potential energy can be calculated as GPE = *mgh*, where GPE represents gravitational potential energy, *m* represents mass, *g* represents acceleration due to gravity (9.8 m/s$^2$), and *h* represents the height of the rock above the ground. Therefore the final kinetic energy equals the initial gravitational potential energy or (64 kg)(9.8 m/s$^2$)(20 m) = 12,544 J. Answer choice **A** comes from using the incorrect formula as GPE = $gh\sqrt{m}$ = 1,568 J. Answer choice **C** is reached from the formula GPE = $g^2h\sqrt{m}$ = 15,366 J. Answer choice **D** comes from the formula as GPE = $mg^2h$ = 122,931 J.

28. **Use the diagram below to answer the question that follows.**




On a warm day, the sun warms the surface of a rock face. Birds soar on the warm air rising from the heated rock. Some of the rock's heat is transferred to the soil that is in contact with the rock. As the birds fly over the rockface, they generate metabolic heat. Which of the following provides the best example of energy transfer by radiation?

A. The sun warms the surface of the rockface.

B. Birds soar on the warm air rising from the heated rock.

C. Some heat is transferred from the rock to the adjoining soil.

D. The birds generate metabolic heat as they fly.

**Correct Response: A.** Energy is transferred by radiation when electromagnetic fields in the radiation (mostly in the infrared part of the spectrum) exert forces on the electric charges in molecules or atoms, causing them to move more rapidly. This movement, or thermal motion, is perceived as heat and is a transfer of energy from the hotter body to the colder body. A prime example of this phenomenon is the radiant heat that is emitted by the sun warming up the surface of a rock face on the earth. Choice **B** describes the mechanical transfer of energy from the moving air to the bird, and the convection transfer of energy from the heated rock to the air. Choice **C** describes the conduction transfer of energy from the rock to the adjoining soil. Choice **D** describes the chemical transfer of energy as the bird utilizes the stored energy from its food.

29. A heat pump is most likely to become inefficient in which of the following environmental situations?

    A. The outdoor temperature falls below freezing.

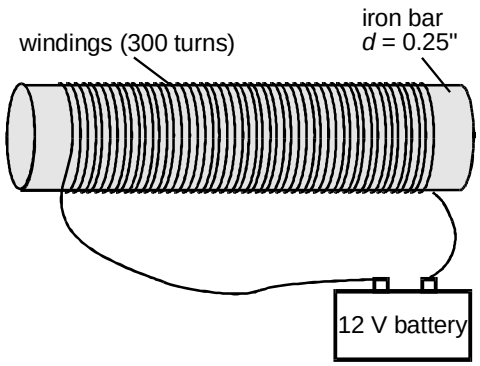
    B. The outdoor temperature rises above 90°.

    C. The indoor temperature is about 10° higher than the outdoor temperature.

    D. The outdoor temperature is about 10° higher than the indoor temperature.

**Correct Response: A.** A heat pump forces heat to flow from a cold space to a hot space. In this example, the heat pump is forcing heat to flow between the outdoors and an indoor space. There is a theoretical limit to efficiency of any heat pump, which is defined as $T_H/(T_H - T_C)$ where $T_H$ and $T_C$ are the temperatures of the hot and the cold spaces respectively as measured in the Kelvin scale. As $T_C$ gets smaller (for example, falling below freezing), the difference $(T_H - T_C)$ gets larger (approximately 22 K between a heated house interior and freezing) and the theoretical efficiency limit $T_H/(T_H - T_C)$ gets smaller, most likely causing the heat pump to become inefficient. This is why it would be better for the heat pump to pull its heat from the more thermally stable earth than from the ambient air. For choice **B**, the heat pump will need to work in reverse to move energy from the interior living space to the warmer exterior. In this case, the difference $(T_H - T_C)$ would be much smaller (approximately 10 K between an air-conditioned interior space and 90º), implying more than double the theoretical efficiency limit. For choices **C** and **D**, the difference $(T_H - T_C)$ would be even smaller (approximately 5.6 K), implying an even higher theoretical efficiency limit.

30. **Use the diagram below to answer the question that follows.**




Which of the following changes in the design of the electromagnet would be most effective in increasing the mass that the electromagnet can lift?

A. replacing the 12-volt DC source with a 12-volt AC source

B. replacing the iron bar with one having a greater diameter

C. replacing the iron bar with a copper bar

D. increasing the number of windings on the bar

**Correct Response: D.** The amount of mass that the electromagnet can lift depends upon the magnetic field induced by the coil (which is proportional to the current and the number of windings), and upon the magnetic properties of the core. Choice **D** would increase the mass that the electromagnet can lift since it involves increasing the number of windings. Choice **A** would not change the average lifting power (assuming that the 12-volt AC rating is measured as RMS voltage), though there would be a minor loss of power resulting from the constantly changing dipole alignment in the core. Choice **B** would result in little or no noticeable change in the performance of the magnet. The increase in the length of wire causing a decrease in current would probably outweigh the decrease in reluctance (magnetic resistance) of the thicker bar. Choice **C** would result in a major reduction in lifting ability since copper is a far less magnetic substance than iron.

31. A transformer has $1.5 \times 10^2$ input windings and $4.5 \times 10^2$ output windings. What is the transformer's output voltage when 220 V is applied to the input windings?

    A. 73.3 V

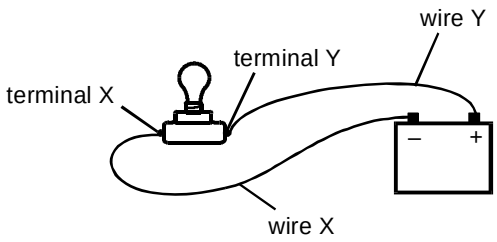
    B. 110 V

    C. 440 V

    D. 660 V

**Correct Response: D.** The input and output voltages of a transformer can be calculated using the equation $V_i/N_i = V_o/N_o$ where $V$ and $N$ represent the voltage and the number of windings respectively, and the subscripts $_i$ and $_o$ represent input and output respectively. In this case, $(220 \text{ V})/(1.5 \times 10^2) = (V_o)/(4.5 \times 10^2)$. Solving this equation yields $V_o = 660$ V. Answer choice **A** is reached by using the formula $V_i/N_o = V_o/N_i$, or $(220 \text{ V})/(4.5 \times 10^2) = (V_o)/(1.5 \times 10^2)$ resulting in $V_o = 73.3$ V. Answer choice **B** is reached by assuming the output voltage is always half the input voltage. Answer choice **C** comes from assuming that the output voltage is always double the input voltage.

32. **Use the diagram below to answer the question that follows.**




A simple circuit consists of a lamp, a battery, and two wires as shown in the diagram. A person who wants to use a multimeter to measure the current through the lamp should connect the meter:

A. between wire X and the negative terminal.

B. between terminal X and terminal Y.

C. between the positive and negative terminals of the battery.

D. from terminal X to terminal Y with the bulb removed.

**Correct Response: A.** In order to measure current with a standard multimeter, the multimeter must first be set to ammeter mode. Next, the circuit must be broken at a point through which the unknown current is flowing. Then the circuit is reconnected so that the unknown current flows into one lead of the multimeter and out the other lead, effectively wiring the multimeter in series with the circuit. Because the multimeter has very low impedance when set to ammeter mode, the circuit should not be affected by its inclusion. Choice (**A**) is an example of such a connection where the circuit is broken between wire X and the negative terminal. Since all of the current flowing through the lamp also flows though wire X, and now through the multimeter, the correct current will be measured. Choices **B**, **C**, and **D** all involve short-circuiting the lamp. This will result in blowing the fuse in the multimeter, or burning out the ammeter mode if there is no fuse.

33. The resistance of a wire is inversely proportional to the square of its diameter. A copper wire of diameter $Y$ has a resistance of 8 Ω. What would be the resistance of a copper wire of diameter $2Y$?

    A. 2 Ω

    B. 8 Ω

    C. 16 Ω

    D. 64 Ω

**Correct Response: A.** The inverse square proportionality relationship described in the problem can be written symbolically as $R = C/D^2$ where $R$ represents the resistance, C is a constant, and $D$ represents the diameter. Therefore, $8\ \Omega = C/Y^2$ and $R_f = C/(2Y)^2$. Solving both equations for C and setting them equal yields $(8\ \Omega)(Y^2) = (R_f)(4Y^2)$. Solving this equation yields $R_f = 2\ \Omega$. In general, in an inverse square proportionality relationship, when a factor (in this case 2) is multiplied by the independent value, the dependent value is divided by the square of that factor (in this case 4). Answer choice **B** assumes that the resistance of a copper wire is a constant. While the resistivity of copper is a constant property of the material, resistance is dependent on resistivity, the cross-sectional area, and the length of the wire. Answer choice **C** assumes that the resistance is doubled when the diameter of the wire is doubled. Answer choice **D** assumes that resistance is squared when the diameter of the wire is doubled.

34. Which of the following is the end product of the chemical process commonly used in fuel cells?

    A. hydrogen

    B. water

    C. carbon dioxide

    D. methane

**Correct Response: B.** The most commonly used fuel cells chemically combine hydrogen with oxygen. Instead of producing only thermal energy, which is generated when hydrogen undergoes combustion with oxygen, the reaction is modified to produce mostly electrical energy. The electrical energy can then be used to perform useful work. The combination of hydrogen and oxygen also produces water ($H_2O$), which is an output of this process. Hydrogen (**A**) is an input for a fuel cell. Carbon dioxide (**C**) is an output for the combustion of carbon in oxygen, not hydrogen, and is produced whenever fossil fuels are used. Methane (**D**) is a hydrocarbon gas that is the primary component of natural gas, and it is often used as an input for internal combustion engines.

35. Which of the following best describes the characteristic of power in mechanical systems?

    A. the rate at which work is done

    B. the total force applied

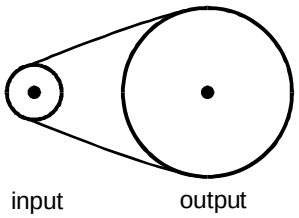
    C. the ability to perform work

    D. the efficiency of energy conversion

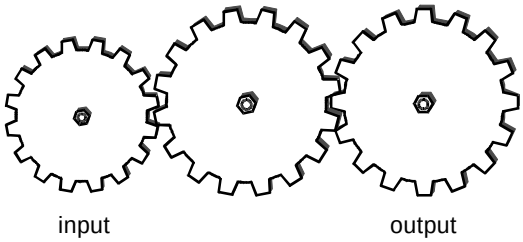
**Correct Response: A.** Power is defined as the rate of change in energy, $\Delta E/\Delta T$. In the SI system, power is measured in Watts, or Joules per second. The Joule is the SI unit for energy. Work is defined as change in energy, $\Delta E$, and is measured in Joules. Therefore, power is defined as the rate at which work is done, (*work*)/($\Delta T$). Force (**B**) is incorrectly defined as (power)/(speed). The ability to perform work (**C**) is a description of energy. The efficiency of energy conversion (**D**) is the ratio of the output energy to the input energy.

36. Which of the following systems allows for the output shaft to rotate faster than the input shaft while rotating in the same direction as the input shaft?

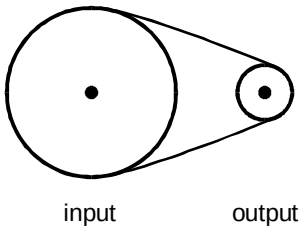
A.



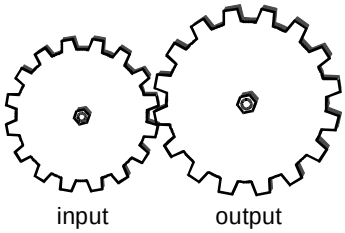

B.




C.

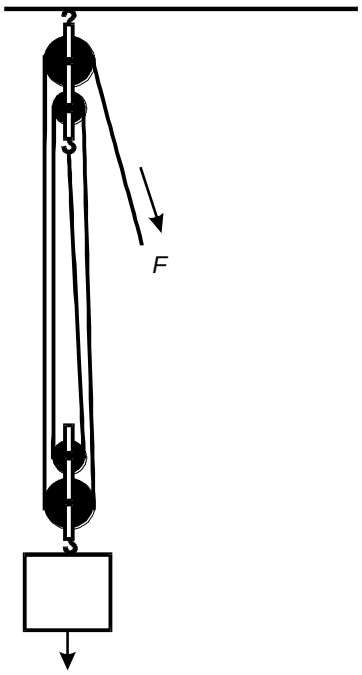



D.




**Correct Response: C.** In pulley and belt systems as well as in gear systems, pulleys and gears with smaller diameters rotate faster than those with larger diameters. In pulley and belt systems, where the belt is not twisted or made to cross itself (as in a figure-8 pattern), all pulleys rotate in the same direction. In a gear system, adjacent gears rotate in opposite directions. In choice **C**, the output pulley has the smaller diameter which means that it will rotate faster than the input pulley. Since it is a simple pulley and belt system, both shafts rotate in the same direction. In choices **A** and **B**, the output shaft rotates slower than the input shaft. In choice **D**, the output shaft rotates slower and in the opposite direction of the input shaft.

37. **Use the diagram below to answer the question that follows.**




In this system, the lifting force is increased at the expense of:

A. work.

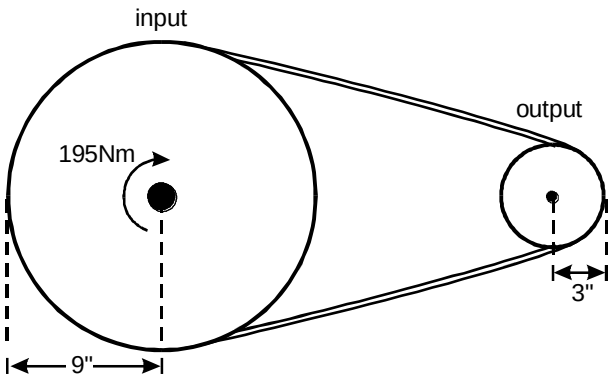
B. distance.

C. power.

D. weight.

**Correct Response: B.** In the arrangement pictured, for every four inches that the rope on the right is pulled, each of the other four ropes is only shortened by one inch. Hence, while four times as much lifting force is applied to the weight, the weight is only lifted one fourth of the distance it would have been lifted for same amount of rope being pulled with the pulleys. Choice **A** states that less work would be done. Due to conservation of energy, the work applied to the rope on the right will always be equal to the work applied to the weight being lifted if frictional loss is neglected. Choice **C** states that there would be a loss of power. As in choice **A**, conservation of energy mandates that power-in equals power-out in all cases if frictional loss is neglected. Choice **D** states that the weight will decrease. Since weight is dependent only on the mass and the gravitational force of the earth, it will remain unchanged.

38. **Use the diagram below to answer the question that follows.**




What is the torque, τ, produced by the output pulley when a torque of 195 Nm is applied to the input pulley?

A. 65.0 Nm

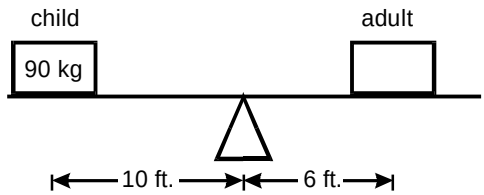
B. 97.5 Nm

C. 390 Nm

D. 585 Nm

**Correct Response: A.** Torque is calculated as $T = F \bullet r$ where $T$ represents torque, $F$ represents force, and $r$ represents radius. In the case of a belt and pulley system, both pulleys experience the same force as applied by or to the belt. Hence, if we solve for $F$ and set $F$ equal for both pulleys, we get $T_i/r_i = T_o/r_o$. Therefore, 195 NM/9 in. = $T_o$/3 in. Solving for $T_o$ yields $T_o$ = 65.0 Nm. Answer choice **B** assumes that the torque would be cut in half, and choice **C** assumes that the torque would be doubled. Answer choice **D** comes from using the formula $T_i/r_o = T_o/r_i$, or (195 Nm)/3 in = $T_o$/9 in to get $T_o$ = 585.

39. **Use the diagram below to answer the question that follows.**




An adult and a child are balanced on a seesaw as shown in the diagram. What is the weight of the adult?

A. 135 kg

B. 150 kg

C. 175 kg

D. 240 kg

**Correct Response: B.** In order for the seesaw to be balanced, the torques must sum to zero. Torque is force times lever arm. The force is the weight, which is the product of mass and the acceleration of gravity. Therefore, $[(90\text{ kg})(9.8\text{ m/s}^2)(10\text{ ft})] - [(W_a)(9.8\text{ m/s}^2)(6\text{ ft})] = 0$ where $W_a$ represents the weight of the adult. Solving this equation yields $W_a = 150$ kg. The other answer choices (**A**, **C**, or **D**) are incorrect and do not directly relate to the information provided.

40. State and local building codes are primarily intended to perform which of the following functions?

    A. protecting environmentally sensitive areas from development that could degrade natural habitats

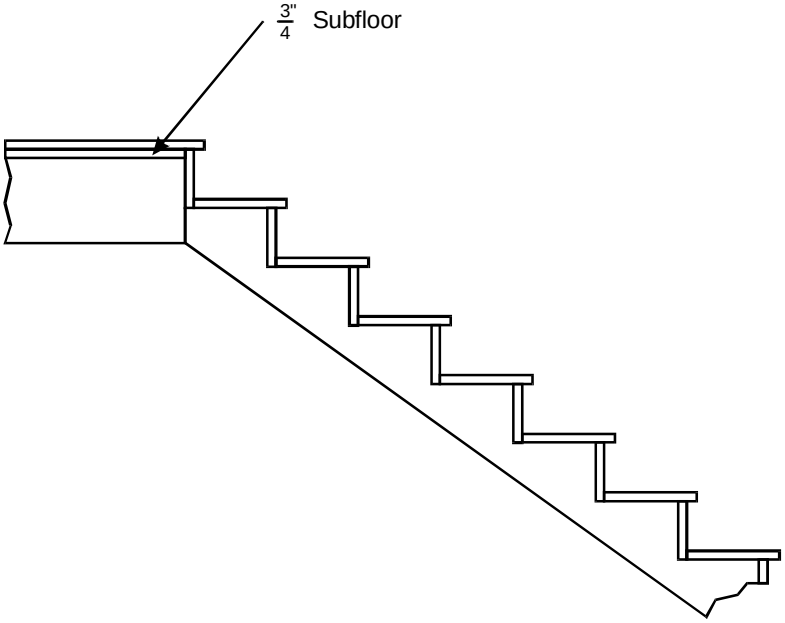
    B. guiding the growth and development of towns and cities by designating areas for various uses

    C. specifying materials and procedures that should be followed in building projects in order to ensure safety and sound construction

    D. ensuring that the most recent innovations in the construction industry are incorporated into building projects

**Correct Response: C.** State and local building codes are intended to ensure minimum standards for safety and sound construction of building projects. They are not intended to ensure that every building project makes use of the most recent innovations in the construction industry (**D**). The codes are not intended to protect environmentally sensitive areas from development (**A**). That responsibility would fall under the National Environmental Policy Act. The codes are not intended to guide the growth and development of towns and cities (**B**). That responsibility would fall under the regional zoning codes.

41. **Use the diagram below to answer the question that follows.**




In the stairs in the diagram, the subfloor transfers loads directly to:

A. risers.

B. stringers.

C. studs.

D. joists.

**Correct Response: D.** According to standard construction terminology, the long horizontal boards that support the subfloor are called joists. Risers (**A**) are the vertical components, sometimes called kickboards, that support the treads that people stand on while climbing the stairs. Some designs do not include risers. These are called open-riser stairs. Stringers (**B**) are the diagonal support boards that run from the top to the bottom of a stair. Stair treads and risers are attached to the stringers. Studs (**C**) are the vertical boards that are contained within walls to provide structural support.

42. A furniture manufacturing company is designing a new wooden dresser. Use of which of the following types of wood would result in the highest shipping costs of finished products?

    A. maple

    B. cedar

    C. balsa

    D. ebony

**Correct Response: D.** Shipping costs are based on physical dimensions and weight. The physical dimensions will be the same regardless of the type of wood used to build the dresser. However, the weight will vary depending upon the density of the wood that is used. Of the four choices given, ebony (**D**) is the most dense, with a density of 69–83 $lb/ft^3$. This would make it the heaviest, and hence the most expensive to ship. Maple (**A**) has a density of 39–47 $lb/ft^3$. Cedar (**B**) has a density of 23 $lb/ft^3$. Balsa (**C**) has a density of 7–9 $lb/ft^3$. While balsa would be the least expensive from a shipping standpoint, it does not have the required structural strength for this application.

43. Which of the following metals has a high compressive strength but very low tensile strength?

    A. cast iron

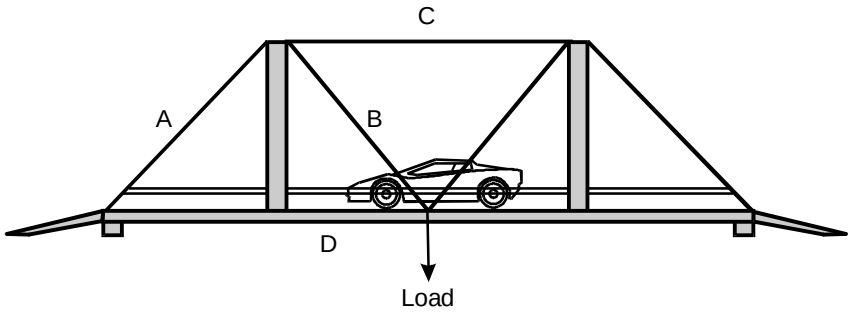
    B. copper

    C. structural steel

    D. zinc

**Correct Response: A.** Cast iron has a crystalline structure and it contains many impurities. Both of these features result in making cast iron very brittle and weak in tension. It is, however, very strong in compression. Copper and zinc (**B** and **D**) are more malleable, and hence more likely to spread under a compressive load. Structural steel (**C**) is extremely strong under a tensile load.

44. **Use the diagram below to answer the question that follows.**




In the bridge design above, which member is in compression?

A. A

B. B

C. C

D. D

**Correct Response: C.** The load pictured in the diagram will be transferred as tension forces in members **B** and **A**. The load will also be transferred as a bending force on member **D**. Hence, the top surface of member **D** will be in compression and the bottom surface will be in tension. The only labeled member that will experience pure compression will be member **C**, which will be pushed together as the two support columns are angled inward.

45. Which of the following types of bridges is most appropriate for short spans?

    A. suspension

    B. beam

    C. cantilever

    D. truss

**Correct Response: B.** A beam bridge is the simplest bridge design. It consists of simple horizontal beams, which must support the entire load. For this reason, they are only appropriate for short spans. Suspension bridges (**A**), cantilever bridges (**C**), and truss bridges (**D**) make use of more complex structures to share the load, thereby allowing them to span longer distances.

46. Which of the following features is an important advantage of slab-on-grade foundations over slab-and-crawl-space foundations?

    A. Construction is less costly and takes less time.

    B. Plumbing and wiring are easily accessible.

    C. Heat is easily conducted out of the house.

    D. Footings are protected from weather and humidity.

**Correct Response: A.** A major advantage of slab-on-grade foundations over slab-and-crawl-space foundations is that they do not require deep excavations and cement basement walls. This can result in major cost and time savings due to the need for less material and less labor. This can be especially true if blasting is required. One disadvantage is that plumbing and wiring are typically embedded in the cement slab, making them inaccessible (**B**). Heat loss through the slab (**C**) is another disadvantage since incorporating insulation is made more difficult. When it comes to protecting footings from weather and humidity (**D**), the footings of a slab-on-grade foundation are closer to grade, and hence more vulnerable.

47. In choosing materials for structural members of an aircraft, there is most often a trade-off between which of the following characteristics?

    A. strength and weight

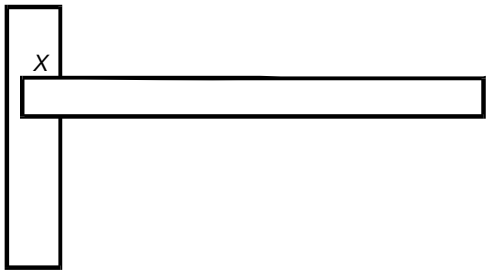
    B. plasticity and weight

    C. strength and elasticity

    D. plasticity and elasticity

**Correct Response: A.** When choosing materials for structural members of an aircraft, the two most important considerations are strength and weight. The thrust of the motors and the long spans of the wings make strength critical in airplane design. At the same time, every extra pound translates into extra fuel usage since, unlike with land and sea vehicles, there is nothing but the power of the engines to support all of the weight. Plasticity (**B** and **D**) and elasticity (**C** and **D**) are also important factors to be taken into account. However, they do not rank as high in importance as strength and weight.

48. **Use the diagram below to answer the question that follows.**




In the cantilever above, what type of force is being applied to the wall at point *X*?

A. compression

B. tension

C. shear

D. torsion

**Correct Response: A.** Any downward load (weight) on the horizontal member (the beam) will create a tendency for it to pivot clockwise around the point where the underside of the beam meets the outer surface of the wall. Hence, a downward force on the exposed part of the beam will cause an upward force on the portion of the beam that is embedded in the wall. This will result in a compression force applied to the wall at point *X*. One could argue that the top surface of the beam will have a tendency to slide out of the notch in the wall as the beam rotates clockwise. If the joint was glued or even if there was appreciable friction, this could lead to forces of tension (**B**) and shear (**C**) at point *X*. But these would be due to the resulting displacement of the beam. The primary static force would still be compression (**A**), even if there were no actual movement. There is no torsion (i.e., twisting) (**D**) force at point *X*.

49. The weight of which of the following is part of the live load on a building?

    A. air conditioning unit

    B. accumulated snow

    C. roof trusses

    D. structural members

**Correct Response: B.** The live load is any load applied to a building that is not due to the weight of the building and its designed components. This typically includes loads attributable to outside forces such as weather, or to loads during use such as the weight of people and furniture. The weight of accumulated snow is a typical example of a live load. The weight of air-conditioning units (**A**), roof trusses (**C**), and structural members (**D**) are all examples of dead loads since they are due to the weight of the building and its designed components.

50. The stability of a truss bridge is based primarily on the integrity of:

    A. circles.

    B. triangles.

    C. squares.

    D. cylinders.

**Correct Response: B.** Because a triangle is the simplest geometric figure that will not change shape when the lengths of its sides are fixed (due to the side-side-side theorem of congruent triangles), the triangle is the basic structural unit of a truss bridge. Circles (**A**) and cylinders (**D**) can also be very stable shapes. But they do not lend themselves as well to truss constructions, which typically consist of a lattice of straight beams. Squares (**C**) that are not reinforced by triangles result in bending forces at the nodes of the lattices due to the fact that their angles are not geometrically constrained. Hence, they are not as stable as triangles.

51. A person using a wrench to tighten a bolt applies excessive pressure and snaps the bolt. Which of the following types of forces is the primary cause of the failure of the part?

    A. torsion

    B. shear

    C. compression

    D. tension

**Correct Response: A.** In this case, the failure is due to an excessive twisting of the bolt. A twisting force (two opposite torques around the same axis) is called torsion. Shear (**B**) is caused by two non-collinear forces acting in opposite parallel directions. Compression (**C**) is caused by two collinear forces acting in opposite directions towards the interior of an object. Tension (**D**) is caused by two collinear forces acting in opposite directions towards the exterior of an object. Torsion (**A**) is the only type of force that caused the failure in this situation.

52. A winch is being used to raise a beam to an upper floor of a building under construction. The primary force on the winch's cable is:

    A. shear.

    B. compression.

    C. tension.

    D. torsion.

**Correct Response: C.** The primary forces on a winch cable are the two opposite collinear forces that tend to stretch the cable. This type of force is called tension. Since the cable is being pulled uniformly, there are no shear (**A**) forces acting in parallel but opposite non-collinear directions. Since the ends of the cable are pulled outward and not pushed inward, there is no compression (**B**). Since there is no twisting action on the cable, it is not undergoing torsion (**D**).

53. Rebar in concrete is primarily intended to increase the material's strength in:

    A. compression.

    B. curing.

    C. torsion.

    D. tension.

**Correct Response: D.** Rebar (short for reinforcing bar) is a steel bar that is added to concrete because of its tensile strength. This combination of concrete and rebar is known as reinforced concrete. Reinforced concrete combines the compressive strength of concrete with the tensile strength of the steel rebar. Since concrete is already extremely strong under compression (**A**), improving this property is not a primary reason for adding rebar. In fact, adding too much rebar can lead to compression failure because of a mismatch between tensile and compress strength. The adding of rebar has no appreciable effect on curing (**B**). To reinforce concrete to withstand torsion (**C**) forces, steel fibers are used instead of rebar.

54. A 600 N piece of metal rests on a concrete column. The line from a winch is pulling upward on the column with a force of 25 N. What is the resultant force on the column?

    A. 575 N compression

    B. 575 N tension

    C. 625 N compression

    D. 625 N tension

**Correct Response: A.** The top of the column is being pushed downward with a force of 600 N by the piece of metal. The top of the column is also being pulled upward with a force of 25 N by the line from the winch. The resultant combined force on the top of the column is (-600 N) + (25 N) = -575 N where the (-) sign indicates a downward force. Since the 575 N force is directed downward on the top of the column, the resultant force is a compression force of 575 N. Answer choices **B** and **D** are incorrectly reached by failing to realize that the net downward force on the top of the column will result in compression, and not tension. Answer choices **C** and **D** are incorrectly reached by adding the magnitudes of the two forces. Since the forces act in opposite directions, the net force is found through subtraction with the resulting direction being determined by the force with the larger magnitude.

55. Metal fatigue is most likely to result from which of the following types of forces?

    A. tension

    B. compression

    C. shear

    D. bending

**Correct Response: D.** Metal fatigue is the failure of a metal part after repeated stress cycles. Metal fatigue is most likely to result when the direction of stress is reversed with each cycle. The most common example of this is when a metal part is bent back and forth. At a localized level, the two sides of the part are undergoing repeated cycles of tension followed by compression, and compression followed by tension, respectively. This is far more damaging to the part than repeatedly subjecting it to only tension (**A**), compression (**B**), or shear (**C**).

56. Placer mining and panning separate ore from surrounding sediments by taking advantage of the ore's:

    A. buoyancy.

    B. particle size.

    C. density.

    D. melting point.

**Correct Response: C.** These techniques are used where small particles of precious metal ores are mixed with sediments in a stream. A slurry from the stream sediment is agitated in a pan with water running over it. The ores sink to the bottom of the pan due to higher density while the rest of the sediment is washed over the top edge. Buoyancy (**A**) is not a factor since most if not all of the particulates are denser than water. Particle size (**B**) is not a factor since the particles are not passed through a sieve. Melting point (**D**) is not a factor since the entire process is carried out at ambient temperature, which is far below the melting points of any of the materials involved.

57. Polymerization is a process used to produce which of the following materials?

    A. ball bearings

    B. textiles

    C. metallic wire

    D. plastics

**Correct Response: D.** Polymerization is a process that takes small molecules called monomers and combines them together into very long molecular chains called polymers. The original substance tends to be in the form of a viscous fluid. After polymerization, the longer polymer chain molecules form a microscopic mesh giving the newly formed plastics a semi-rigid structure. Ball bearings (**A**) are produced by a process called cold heading where short pieces of metal wire are smashed between hemispherical forms. While some textiles (**B**) are made from plastic fibers (which are made through polymerization), the actual textiles are woven on looms from a variety of different types of fiber. Metallic wire (**C**) is made by drawing a thick metal rod through dies that stretch and narrow the rod until it is at the specified gauge.

58. The increased efficiency that results from assembly-line manufacturing processes is primarily a result of:

    A. a reduction in energy use.

    B. a reduction in nonproductive efforts.

    C. a decreased need for raw materials.

    D. a greater reliance on human inputs.

**Correct Response: B.** In an assembly-line manufacturing process, the unfinished products are transported along a moving belt. At different stations along the path of the belt, workers perform different steps in the manufacturing process. This eliminates the need for the nonproductive efforts of workers delivering parts from station to station as the various manufacturing steps are completed. Or, if the other choice is for one worker to perform the entire process from start to finish, this eliminates the nonproductive effort to continually switch tools for each step of the process. The assembly-line manufacturing process does not necessarily save energy (**A**) and in fact, the belt itself consumes energy. The amount of raw materials (**C**) needed for an assembly-line manufacturing process is similar to the amount needed for other processes. An assembly-line manufacturing process relies less on human inputs (**D**) since some of those inputs are replaced by the action of the belt.

59. Which of the following welding processes is used primarily to weld metals such as aluminum and magnesium?

    A. shielded metal arc welding

    B. oxyacetylene welding

    C. gas tungsten arc welding

    D. carbon arc welding

**Correct Response: C.** When welding some metals such as aluminum and magnesium, it is very important to protect the high-temperature metal from the oxygen and water vapor that are in the air. For this reason, an inert shielding gas is used (typically a combination of helium and argon). The most common welding process for these metals is gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding. Shielded metal arc welding (**A**) is mostly used for welding steel and iron. It is not commonly used with nonferrous metals such as aluminum and magnesium because the shielding gas, which is given off by the flux, does not tend to be extensive enough to protect these metals from oxidizing. As the name implies, oxyacetylene welding (**B**) uses a combination of pure oxygen and acetylene gases. The presence of pure oxygen precludes the use of this welding technique with aluminum and magnesium because these metals will react with the oxygen, creating oxides that interfere with the welding process. Since carbon arc welding (**D**) is carried out without any mechanism to shield the metal from the oxygen and water vapor in the air, it is not appropriate for welding aluminum and magnesium.

60. In preparing petroleum products, cracking is a process used to:

    A. break complex molecules into simpler molecules.

    B. remove impurities from crude oil.

    C. convert liquid petroleum products into tars and plastics.

    D. assay the quality of petroleum.

**Correct Response: A.** Cracking is a process used to break up the complex long-chain hydrocarbon molecules found in crude oil and produce simpler short-chain hydrocarbon molecules, thereby yielding lighter oils such as diesel fuel and gasoline. Impurities (**B**), such as sulfur and nitrogen, are removed using a process called hydrotreating. Crude oil must first undergo a distillation process where it is separated into different products such as tar (**C**) and naphtha. Naphtha is used to make plastics (**C**). A quality assay (**D**) is an evaluation of the chemical makeup of a particular crude oil in order to determine its compatibility with a particular refinery and to check for possible environmental or other problems.

61. Which of the following manufacturing processes is most commonly used to create detailed metal parts that require minimal finishing?

    A. sand casting

    B. mold casting

    C. centrifugal casting

    D. die casting

**Correct Response: D.** Due to highly detailed die molds and high-pressure molten metal injection, die casting produces the most finely detailed metal parts requiring the least amount of finishing. As the name implies, sand casting (**A**) is a casting process where the mold is made out of sand held together with a binder. While this process is less expensive than others, the mold is limited in terms of detail, finish, and ability to withstand high-pressure injection. In conventional mold casting (**B**), the molten metal is poured into the mold under the influence of gravity. Because the molten metal is not injected under high pressure, the results are not as finely detailed as those from die casting. Centrifugal casting (**C**) is primarily used to manufacture stock materials in axially-symmetric shapes, such as pipes and flanges. These materials typically require machining before they are ready to be used. Centrifugal casting is not generally used to create specific finished parts.

62. Which of the following manufacturing processes is most appropriate for producing steel I-beams?

    A. forging

    B. casting

    C. extrusion

    D. injection

**Correct Response: C.** Extrusion is a manufacturing process where material is pushed through a die that has an opening with the same shape as the cross-section of the desired part. Hence, it is the technology of choice for producing a long part with a single continuous cross-section. An I-beam is a perfect example of such a part since it has a continuous I-shaped cross-section. Forging (**A**) would be prohibitively difficult and expensive for creating a piece as large as an I-beam. Casting (**B**) and metal injection (**D**) both require the use of a mold. To create a part the size of an I-beam, there are two molding issues that present difficulties. The first is that the molding apparatus must be extremely large. The second is that a massive amount of molten metal must be delivered to the mold, and then cooled. Both of these difficulties are avoided through the use of extrusion (**C**).

63. The steel connecting rods for an engine need to be strong and lightweight and have a consistent grain. Which initial manufacturing process would be most appropriate for creating these rods?

    A. machining

    B. investment casting

    C. molding

    D. hot forging

**Correct Response: D.** Hot forging is a metal part manufacturing process involving the pounding of a heated piece of metal into a desired shape. A major advantage of this process is that, as the part is pounded into shape, the internal metal grains are deformed to become aligned along the contours of the part. This results in greater material strength. Therefore less material is required, and the resulting part is both stronger and lighter. Machining (**A**) involves the cutting away of metal from a blank, typically a rectangular block of metal. Since the metal is not deformed, there is no altering of the internal grain. Hence there are none of the associated improvements in strength and weight. Investment casting (**B**) and molding (**C**) involve the pouring of molten metal into a mold. The internal grain alignment resulting from these processes tends to be random, resulting in a weak, brittle part. This would not be appropriate for a high-stress application such as a connecting rod in an engine.

64. A company that decides to adopt lean manufacturing techniques will most likely focus primarily on the company's:

    A. quality control.

    B. resource expenditures.

    C. accounts receivable.

    D. management structure.

**Correct Response: B.** Lean manufacturing is a strategy for assessing and reducing all aspects of waste in the manufacturing process. While quality control (**A**), accounts receivable (**C**), and management structure (**D**) are all aspects of the manufacturing process that need to be looked at from the perspective of waste reduction, resource expenditures (**B**) will most likely be the primary focus when adopting lean manufacturing techniques.

65. The quality control team for a company that produces camshafts for gasoline engines currently takes one camshaft in every 100 off the production line and subjects it to rigorous testing. The company is considering changing the production process to include sampling one camshaft out of every 75 camshafts. Arguments against this change will most likely focus on which of the following factors?

    A. long-term profits

    B. production costs

    C. sales volume

    D. marketing needs

**Correct Response: B.** This change will result in a 33% increase [(1/75)/(1/100)] in time and money spent on testing. This increase will have to be added directly to the overall production costs. On the other hand, this change could have a positive influence on long-term profits (**A**), sales (**C**), and marketing (**D**) since it should result in a higher quality product.

66. A production line produces electric golf carts and ride-on mowers. For which of the following steps in the company's production lines is robotics most likely to be appropriate?

    A. troubleshooting part failures

    B. adding custom details

    C. spot-welding metal body parts

    D. final product inspection

**Correct Response: C.** Robots are best suited for precise repetitive tasks that do not require subtle thinking or dealing with unpredictable situations. Spot-welding body parts is a perfect and very common robotics manufacturing application. A robot does not suffer from eye damage or fatigue and it can execute precise uniform welds. Troubleshooting part failures (**A**) requires complex and adaptable reasoning, often dealing with unforeseen circumstances. Adding custom details (**B**) is a case-by-case procedure that is custom in nature and therefore not well suited for robotics. Final product inspection (**D**) needs to be performed by a human who can spot unforeseen problems.

67. Which of the following correctly defines the relationship between the fields of biomechanics and bioengineering?

    A. Bioengineering is a field within the larger field of biomechanics.

    B. Biomechanics is a field within the larger field of bioengineering.

    C. Bioengineering is related to large-scale structures such as limbs and organs while biomechanics is related to individual cells.

    D. Biomechanics is related to large-scale structures such as limbs and organs while bioengineering is related to individual cells.

**Correct Response: B.** Biomechanics works specifically with forces and structural mechanisms within the body. This includes the creation of joint implants, better corrective surgeries, and prosthetic, orthopedic, and therapeutic devices. Bioengineering is a much broader category that includes all engineering related to the science of living things. Some examples include genetic engineering, diagnostic devices, and even food production technology. Biomechanics is one of many fields included within the field of bioengineering. Hence, bioengineering is not a field within the field of biomechanics (**A**). The relationship is the exact opposite. Bioengineering is not limited to large-scale structures (**C**), and biomechanics is not related to individual cells. While biomechanics is related to large-scale structures (**D**), bioengineering is related to far more than just individual cells.

68. Which of the following is an example of cloning?

    A. artificially cross-pollinating corn plants

    B. selectively breeding cattle

    C. fertilizing a mammalian egg in vitro

    D. propagating a plant using cuttings

**Correct Response: D.** Cloning is the process of using tissue from a single individual to produce genetically identical offspring. It is carried out without the use of sexual reproduction. An example is the propagation of a plant by using cuttings (**D**). Artificially cross-pollinating corn plants (**A**), selectively breeding cattle (**B**), and fertilizing a mammalian egg in vitro (**C**) all involve sexual reproduction, and are therefore not examples of cloning.

69. The Human Genome Project is expected to benefit primarily which of the following areas?

    A. biomechanics and bionics

    B. trauma response and remediation

    C. medical diagnosis and treatment

    D. prosthetic manufacturing

**Correct Response: C.** The Human Genome Project is a research project with the goal of fully understanding human DNA and the function of all of its parts. This knowledge could be used to diagnose a patient based upon the patient's genetic makeup. It could also be used to develop new treatments that operate at the genetic level to cure diseases. Biomechanics and bionics (**A**) and prosthetic manufacturing (**D**) are mostly involved with manufactured devices and are not closely related to genetics. Hence, they are not among the areas expected to benefit primarily from the Human Genome Project. The field of trauma response and remediation (**B**) deals with trauma victims from a psychological perspective. Since genetic factors are not known to play a major role in this field, it is not expected to benefit significantly from the Human Genome Project.

70. Which of the following is most commonly used as a vector for gene transfer in genetic engineering?

    A. insect

    B. fungus

    C. bacterium

    D. virus

**Correct Response: D.** A virus is a partial string of DNA that is sometimes encapsulated within a protein shell. Viruses enter a cell and go to the cell's nucleus where they use the cell's reproductive mechanisms to make copies of themselves. Genetic engineers create special viruses that do not replicate themselves. Instead, these special viruses add their own DNA to that of the host cell and act as a vector for gene transfer. Insects (**A**) are often vectors of disease, but are not generally used in genetic engineering. Fungi (**B**) are not used for this purpose, and bacteria (**C**) are not commonly used as vectors in genetic engineering.

71. In which of the following situations is a living organism used in food production?

    A. emulsification

    B. homogenization

    C. pasteurization

    D. fermentation

**Correct Response: D.** Fermentation is a process that living organisms use to convert sugar to acids, gases, or alcohol. Many foods such as bread, yogurt, and alcoholic beverages are produced through the use of fermentation carried out by yeasts and bacteria. Emulsification (**A**) is the introduction of an ingredient (an emulsifier) for the purpose of preventing separation. This is typically used when a product includes oil and water. Emulsifiers can be natural ingredients, such egg yolks, but the process does not involve the use of living organisms. Homogenization (**B**) is also a way of preventing products from separating over time. The most common application is homogenized milk. Instead of adding an emulsifier, milk processors break up the large fat globules found in natural milk into much smaller globules that will not separate out over time. No living organisms are involved. Pasteurization (**C**) is a method of destroying pathogens in beverages and foods through the use of heat. It does not involve the use of living organisms.

72. A small business has several computers and printers that are not networked throughout its office. The business owner is considering installing a local area network (LAN). Which of the following is the most significant benefit of installing a local area network?

    A. Software applications with a single-use license can legally be installed on multiple networked computers.

    B. Printers on the network can be accessed from any of the networked computers.

    C. The performance of the computers and peripherals on the network will improve.

    D. Peripheral devices installed on the network are less likely to experience technical difficulties.

**Correct Response: B.** A local area network (LAN) will allow networked peripherals such as printers and scanners to be shared by all workers on the network. A single-user software license (**A**) does not allow multiple installations even if all computers are on the same network. A LAN should not have any effect on the performance of computers or peripherals (**C**). A LAN would not reduce the likeliness of technical difficulties (**D**). There is a possibility of increased technical difficulties due to the increased complexity of the connections.

73. Which of the following is typically a digital signal?

    A. the output from a microphone

    B. the input to a sound amplifier

    C. the output from a computer's speaker

    D. communication between computers

**Correct Response: D.** Computers typically send and receive data in the form of a digital signal. In some cases, a modem may convert a computer's outgoing signal to analog, but the signal will have to be converted back to a digital signal before it can be received by another computer. The output from a microphone (**A**) is analog, not digital. The input to an amplifier (**B**) from many devices is an analog signal. The output from any speaker (**C**) is a sound wave. Sound waves are analog by definition.

74. Which of the following statements regarding digital and analog sound files is accurate?

    A. Digital signals more closely represent natural sound than do analog signals.

    B. Digital files can be copied more times without loss of quality than can analog files.

    C. Analog files can be transferred electronically whereas digital files cannot.

    D. Analog files can be directly stored on a CD.

**Correct Response: B.** Since a digital file is merely a series of binary digits, it can be copied many times with very little deviation from the original file. When copying an analog file, there is always some loss of information as well as the addition of some extraneous noise. A natural sound wave is a smooth analog curve. A digital signal can approximate this curve with a very fine step function. But it will never be indistinguishable from a true natural sound wave (**A**). An analog signal is qualitatively more similar to a natural sound wave but its fidelity to the original is limited by the sensitivity of the recording device and by the level of shielding from outside noise sources. Both analog and digital signals can be transferred electronically (**C**). A CD is a digital storage device. Therefore, an analog signal cannot be directly stored on a CD (**D**).

75. Which of the following best explains why electromagnetic waves, but not sound waves, can travel through interstellar space?

    A. Sound waves attenuate over distance more easily than electromagnetic waves.

    B. Sound waves require a gravitational force in order to propagate.

    C. Sound waves have a greater amplitude than electromagnetic waves.

    D. Sound waves are dependent on a carrying medium.

**Correct Response: D.** Electromagnetic waves can propagate through the vacuum of space, but sound waves rely upon a carrying medium, such as air, for propagation. This is because sound is transmitted via collisions between the molecules in the carrying medium, whereas electromagnetic waves are oscillating electric and magnetic fields. The relative rates of attenuation over distance (**A**) of sound waves and electromagnetic waves depend upon many factors but this does not explain why sounds waves cannot travel through empty space. Gravity (**B**) does not play a role in the propagation of sound waves. The amplitude of electromagnetic waves is measured in electromagnetic field strength. The amplitude of sound waves is measured in ambient pressure. Therefore, they cannot be compared (**C**).

76. An optical cable has a critical angle of 40°. Which of the following best describes rays of light that strike the internal wall of the cable at angles closer than this to perpendicular?

    A. They are scattered.

    B. They are partially reflected.

    C. They are dispersed.

    D. They are totally reflected.

**Correct Response: B.** At angles less than the critical angle, all of the light is refracted back into the interior of the cable. This phenomenon is known as total internal reflection. If the angle is larger than the critical angle (closer to perpendicular), some of the light escapes and there is only partial internal reflection. Hence, there is not total reflection (**D**). The light rays do however continue in straight lines. They are neither scattered (**A**) nor dispersed (**C**).

77. Which of the following is the best example of the Doppler effect?

A. An ambulance's siren changes from high pitch to low pitch after passing an observer.

B. An ambulance's siren changes from low pitch to high pitch after passing an observer.

C. An ambulance's siren changes from high amplitude to low amplitude after passing an observer.

D. An ambulance's siren changes from low amplitude to high amplitude after passing an observer.

**Correct Response: A.** The Doppler effect is an apparent shift in the frequency of a wave as experienced by an observer when the source is in motion relative to the observer. The frequency is experienced as shifting higher when the source is approaching the observer, and it is experienced as shifting lower when the source is moving away from the observer. Hence, the ambulance's siren would change from a high pitch as it is approaching to a low pitch as it is receding (**A**). The opposite (**B**) would not be the case. The amplitude (**C** and **D**) of the experienced sound wave would only depend on the distance of the ambulance, and not on whether it was approaching or receding.

78. The period of a wave is 30 seconds. What is its approximate frequency?

A. 0.033 Hz

B. 0.50 Hz

C. 33 Hz

D. 50 Hz

**Correct Response: A.** The frequency of a wave is measured on Hz, or cycles per second, and is the reciprocal of the period, which is measured in seconds. Therefore the frequency of the wave is 1/30 s = 0.033 Hz. Choice **B** comes from converting 30 seconds to 0.50 minutes. Choice **C** comes from converting 30 seconds to 0.5 minutes and matching the order of magnitude of the frequency. Choice **D** comes from converting 30 seconds to 0.50 minutes, and matching to the order of magnitude of the period.

79. A sound wave having a frequency of 80 Hz interacts with a sound wave having a frequency of 90 Hz. The interaction will produce a beat frequency of:

    A. 0.9 Hz.

    B. 10 Hz.

    C. 85 Hz.

    D. 170 Hz.

**Correct Response: B.** When two sound waves are close in frequency, they interfere in such a way that repeating beats can be heard superimposed on the two original tones. The frequency of the beats can be calculated as the difference in the frequencies of the two original sound waves. This is called the beat frequency. In this case, the beat frequency is 90 Hz – 80 Hz = 10Hz. Choice **A** comes from dividing 80 Hz by 90 Hz, and rounding the result. Choice **C** is the average of the two original frequencies. Choice **D** is the sum of the two original frequencies.

80. A sound is traveling through a gas. Which of the following changes would most likely cause an increase in the speed of the sound?

    A. reducing the frequency of the sound

    B. replacing the gas with a more dense gas

    C. raising the temperature of the gas

    D. increasing the amplitude of the sound

**Correct Response: C.** The speed of sound in a gas is approximately equal to the average speed of the gas molecules. Since the average speed of the gas molecules increases with temperature, the speed of sound through a gas increases with increasing temperature. The speed of sound in an ideal gas is not affected by the frequency (**A**) of the sound. In air, reducing the frequency results in a very slight reduction in the speed of sound. Replacing the gas with a more dense gas (**B**) would result in a reduction in speed since the molecules are heavier. The speed of sound is independent of the amplitude (**D**).

81. Which of the following is most likely to cause a refraction of sound waves as they travel across an open outdoor area?

    A. rainfall

    B. moving air

    C. regions of sun and shade

    D. temperature differences

**Correct Response: D.** Refraction occurs when one part of a wave front travels at a greater speed than another part of a wave front. For example, if the temperature is higher near the ground, the part of the sound wave front near the ground will travel faster, causing the sound wave to refract upward. Rainfall (**A**) and moving air (**B**) would not cause refraction of a sound wave unless there were differences across the wave front in the amount of rainfall or moving air. Regions of sun and shade (**C**) would only cause refraction indirectly, and only if they resulted in temperature differences.

82. Which of the following best describes the function of a laser in a laser printer?

A. fusing carbon particles to each other

B. detecting the ink on the original document

C. changing an electrostatic charge

D. heating the paper to a specified temperature

**Correct Response: C.** A laser printer contains a positively charged drum. The laser shines on specific spots on the drum, causing them to become negatively charged. Fine, positively charged toner particles stick to the spots on the drum that were negatively charged by the laser. This creates the image that is transferred to the paper through the action of the hot fuser. The laser is not involved in the fusing of the toner particles (**A**). There is no original printed document (**B**) since this is a printer, and not a scanner or a copier. The laser is not used to heat the paper (**D**).

83. Which of the following is a primary color for pigment?

A. orange

B. yellow

C. green

D. black

**Correct Response: B.** The primary pigment colors or subtractive model primary colors are cyan, yellow, and magenta. Printers also include black ink, which is sometimes referred to as the key. This color model is often referred to as the CMYK model. Monitors and projectors use an additive color model often referred to as the RGB model since its primary colors are red, green, and blue. Orange (**A**) is not a primary color in either model. Green (**C**) is not a primary color for pigment. While printers contain black ink, black (**D**) is not considered a primary color for pigment.

84. A person places a pencil in a glass of water and notices that the pencil appears to bend at the point of entry into the water. This illusion occurs primarily because:

    A. light behaves as either a wave or a particle depending on the medium.

    B. some media absorb more light than others.

    C. eyes process light differently depending on the medium observed.

    D. light travels at different speeds in different media.

**Correct Response: D.** The parts of objects below the surface of the water appear to be at a different angle than the parts that are above the surface. This is because light bends as it passes between mediums with different indices of refraction. The index of refraction of a medium describes the speed of light in that medium. This phenomenon of bending light is known as refraction. This phenomenon is not related to the particle/wave duality of light (**A**), nor to differential absorption of light (**B**). It is also not related to the ways that the eyes process light (**C**).

85. The lenses of a pair of binoculars perform their basic function primarily as a result of:

    A. dispersion.

    B. refraction.

    C. reflection.

    D. diffraction.

**Correct Response: B.** The curvature of the surface of a lens causes parallel light rays to bend towards a focal point. This bending is the result of the difference between the index of refraction of the lens material and that of air. This bending phenomenon is called refraction. Dispersion (**A**) is the separating of a ray of light into different colors, often by a prism. This is not a basic function of binocular lenses. While some light reflects (**C**) off of the surface of the lens, this is not its basic function. Diffraction (**D**) is a phenomenon that occurs when light passes through one or more narrow slits. This not related to the basic function of binocular lenses.

86. Typically, lasers in DVD players operate at a wavelength of about 640 nm. Lasers in CD players typically operate at a wavelength of 780 nm. The reason for the smaller wavelength in DVDs is that the smaller wavelength:

    A. results in higher resolution.

    B. allows for compact equipment.

    C. saves on energy usage.

    D. has greater burning power.

**Correct Response: A.** The maximum possible resolution of a laser, as well as other optical instruments, is inversely proportional to the wavelength of the light. This limitation is caused by the diffraction of the light rays, which is proportional to the wavelength. Hence, a smaller wavelength is required to attain the required high resolution of a DVD player. This design constraint for DVD players is not related to compactness of equipment (**B**), energy efficiency (**C**), or burning power (**D**).

87. In fiber-optic telephone systems, messages are transmitted along optical cables as:

    A. light pulses.

    B. electrical current.

    C. changes in wavelength.

    D. changes in color.

**Correct Response: A.** In fiber-optic telephone systems, a digital signal is transmitted by a laser through an optical cable. Because it is a digital signal, it is composed of binary digits represented by the light source turning on and off extremely rapidly. These cables contain glass fibers that are not used for conducting electrical current (**B**). Being digital in nature, the information is contained in the on and off switching of the light source and not in changes in wavelength (**C**) or color (**D**).

88. A compression gauge is most likely to be used to diagnose a problem in the:

    A. ignition coil.

    B. crankcase.

    C. engine cylinders.

    D. fuel system.

**Correct Response: C.** Internal combustion engines operate by the ignition of a fuel-air mixture that is heated and pressurized. This process takes place within the engine cylinders, which need to be well sealed in order maintain pressure. A compression gauge is used to check that the proper pressure levels are reached and maintained. Otherwise, there may be a problem in the cylinders. The ignition coil (**A**) is an inductive coil that is used to generate the high voltage needed to fire a spark plug. It is not diagnosed with a pressure gauge. The crankcase (**B**) is an oil bath from which oil is pumped to lubricate various parts of the engine. It is a vented system that is not pressurized. Therefore, it cannot be diagnosed with a compression gauge. The fuel system (**D**) on many engines is pressurized. It can be diagnosed with a similar, but different, device. This specialized device is called a fuel pressure gauge.

89. Which of the following best describes the primary reason for using multistaging in launching rockets?

    A. Lower stages that have become depleted of fuel provide an increase in the efficiency of upper stages.

    B. Stages can be recovered and reused after they are jettisoned and fall back to Earth.

    C. Total weight is reduced by jettisoning unnecessary empty stages.

    D. Stages provide additional thrust as they fall away from the rest of the rocket.

**Correct Response: C.** Weight reduction is a paramount goal in rocket design. It takes a massive amount of energy to escape the earth's gravitational pull, and any reduction in weight significantly reduces the amount of fuel required for the rocket to reach orbit. Therefore, once the lower stages have accomplished their tasks, they are jettisoned for weight savings. Without such a multistage system, empty fuel storage containers would weigh down the rocket for no reason. Once empty, the lower stages only serve to reduce efficiency (**A**) until they are jettisoned. Reuse of jettisoned stages (**B**) reduces cost associated with multistaging, but is not the primary reasoning for multistaging. Once a stage separates from the rocket, it can no longer provide additional thrust (**D**).

90. For which of the following types of marine vehicles is lift an important force?

A. barge

B. hydrofoil

C. tanker

D. tug

**Correct Response: B.** A hydrofoil is a type of boat that includes wing-shaped vanes mounted below the hull. These vanes provide lift in the same way that an airplane wing provides lift. The lift force raises the hull of the boat above the surface of the water, greatly reducing the amount of drag, and allowing for much greater speeds. Barges (**A**), tankers (**C**), and tug boats (**D**) do not make use of this feature.

91. Which of the following types of motors is most commonly used in automotive starters?

    A. AC induction motor

    B. AC synchronous motor

    C. DC brushed motor

    D. DC stepper motor

**Correct Response: C.** Automotive starters most commonly consist of a simple DC brushed motor with a retractable drive gear that pops out when the starter is engaged. Because most automotive electrical systems use 12 volts DC, it does not make sense to use an AC motor such as an AC induction motor (**A**) or an AC synchronous motor (**B**). Even if the system were AC, it would be highly unlikely that something as sophisticated as a synchronous motor would be used. A DC stepper motor (**D**) would not make sense for this application since these are designed for situations where the exact rotational angle of the motor can be controlled precisely. For a starter, a motor that simply spins when energized is all that is needed.

92. The primary motivation for companies using containers in intermodal freight transport is that this system:

    A. reduces delivery time.

    B. minimizes weight.

    C. reduces fuel consumption.

    D. minimizes freight handling.

**Correct Response: D.** Intermodal freight transport is a term for transporting the same shipment of freight using several different modes such as on boats, trucks, and trains. Rather than load and unload the individual crates of freight from one vehicle to the next, they can all be packed into one large universal container that can then be stacked on a large ship, attached to a special railroad car, or converted into a truck trailer. This system drastically minimizes freight handling. While this added efficiency could reduce delivery time (**A**), this is not the primary motivation. The use of containers does not usually reduce overall weight (**B**), and hence fuel consumption (**C**). It could even increase weight since the container itself needs to be extremely rugged.

93. A test vehicle uses a parachute to decrease speed at the end of a trial run. This parachute functions by increasing which of the following forces?

    A. lift

    B. thrust

    C. drag

    D. gravity

**Correct Response: C.** Vehicle design typically takes into account four forces. Drag is the force that slows the vehicle down. An example would be a parachute used to decrease speed at the end of a run. Lift (**A**) is the force that allows an airplane or a helicopter leave the ground. Lift is not desirable for land vehicles. Thrust (**B**) is the force that drives the vehicle forward. Finally, weight is the gravitational force (**D**) that pulls all vehicles downwards.

94. Compared to non-stretching seatbelts, stretching seatbelts more effectively contribute to automobile passenger safety by:

    A. reducing the average impact force on the passenger during a collision.

    B. better protecting passengers with a wider variety of body types.

    C. providing greater comfort and increasing the likelihood that a seatbelt will be worn.

    D. keeping the passenger's hips positioned more securely in the seat.

**Correct Response: A.** When a vehicle is involved in a crash, the vehicle and its passengers go from a high speed to a stop in a short amount of time. In order to bring a passenger to a stop, the seat belt must exert a force on the passenger over a duration of time. The average force required is inversely proportional to the length of time over which it is exerted. This means that, if the seat belt can bring the passenger to more gradual stop by stretching over a longer duration of time, a smaller average force will be required and the passenger is less likely to be harmed. The amount of stretch required would not be noticeable during everyday use. Hence, it would not result in accommodating a wider variety of body types (**B**) or providing greater comfort (**C**). It would not result in keeping the passenger's hips positioned more securely in the seat (**D**).

95. Safety guidelines recommend that infants be placed in rear-facing car seats rather than front-facing car seats because:

    A. the seat of the car provides a soft point of impact during a collision.

    B. rear-facing car seats better protect the infant's head, neck, and shoulders.

    C. the car's seatbelt holds rear-facing car seats in place more securely.

    D. infants in rear-facing car seats are less likely to be thrown from a moving car.

**Correct Response: B.** Since the majority of severe car crashes involve front-end collisions, these are the most important events to protect an infant against. Add to this the facts that infants' heads are disproportionately heavy compared to their bodies, their spines are not fully formed, and their neck and shoulder muscles are not fully developed. In a front-end collision, the infant's heavy head will tend to continue moving forward as the car is stopped. Therefore, the best way to protect the infant is to face the car seat towards the back of the car so that the infant's head is restrained from motion by the car seat headrest. The softness of the seat of the car (**A**) is of no relevance since the infant will not come into contact with it. A car's seatbelt is equally capable of holding a front-facing or rear-facing car seat securely (**C**). In addition, most modern cars come equipped with brackets designed specifically for securing car seats. If properly secured, an infant is not likely to be thrown from a car seat (**D**) regardless of the direction that it is facing.

96. Which of the following is a safety guideline that should be followed regarding the replacement of a motorcycle helmet?

    A. The helmet should be replaced after it has sustained an impact during an accident.

    B. The helmet does not need to be replaced unless visible damage is apparent.

    C. The helmet should be replaced every ten years even if it has not been dropped or sustained an impact.

    D. The helmet should be replaced whenever the visor is scratched.

**Correct Response: A.** A motorcycle helmet contains energy-absorbing rigid foam beneath the outer plastic shell. After a helmet has sustained an impact during an accident, this foam is likely to have been compressed, and hence it will have lost some of its protective capability. Since the compression would occur between the foam and the outer shell, there is no way to detect it without disassembling the helmet. Therefore the helmet should be replaced. The absence of visible damage (**B**) does not ensure that the helmet is still effective. A high-quality, well-maintained helmet made with modern materials, and that has never been in an accident, should still be replaced every five years (**C**). The materials degrade with time and lose their energy-absorbing qualities. If the visor becomes scratched (**D**) and reduces visibility, it should be replaced. However, that is not a reason to replace the entire helmet.

97. Which of the following statements about air bags is correct?

A. Infants should only ride in a front seat with a passenger-side air bag if the infant is in a rear-facing car seat.

B. An adjustable steering wheel should be tilted up to ensure that the airbag points toward the head and neck.

C. An air bag is only effective when a vehicle's occupant is no more than ten inches from the air bag.

D. Air bags are only effective when they are used with a lap/shoulder belt.

**Correct Response: D.** Automobile air bags are designed to be used in conjunction with lap/shoulder belts. Without such belts in place, air bags may not be effective, and they could actually be dangerous. Infants should never ride in the front seat of a vehicle (**A**). Air bags are designed to operate with normal settings of the steering wheel (**B**) and seat position (**C**).

98. In turning a ship, the main advantage of using a bow thruster rather than a rudder is that a bow thruster:

    A. does not require forward motion.

    B. can make small directional adjustments.

    C. does not increase fuel consumption.

    D. allows for computerized course adjustments.

**Correct Response: A.** The rudder on the stern (rear) of a ship steers the ship by deflecting the stern to the left or the right. However, this deflection depends upon water flowing past the rudder. As the ship slows to a stop, the rudder becomes less and less effective for steering. When maneuvering a large ship up to a dock, side-mounted bow thrusters allow the bow (front) of the ship to be moved to the left or the right even when there is little or no forward motion. However, in most situations, minor directional adjustments (**B**) are best made using the rudder. Bow thrusters use fuel when they are operating (**C**); this is in addition to the fuel used when steering with a rudder. When on a relatively steady course such as a computer-controlled course (**D**), the rudder is the steering tool of choice.

99. A torsion bar is part of what system in a car?

    A. propulsion

    B. suspension

    C. guidance

    D. control

**Correct Response: B.** Car suspensions come in a wide variety of forms but every suspension includes some sort of a spring system to hold the car up off of the road. The spring usually consists of a piece of steel that is deflected in some way as the car is weighed down. Common types of automotive springs are coil springs in the form of coils that are compressed, leaf springs in the form long flat bars that are bent, and torsion bars in the form of long rods that are twisted. Torsion bars are typically only found in the suspension system. They are usually not included in propulsion (**A**), guidance (**C**), or control systems (**D**).

100. In automobiles, rack-and-pinion gears are commonly used in which of the following systems?

A. support

B. suspension

C. steering

D. braking

**Correct Response: C.** One common form of automobile steering system is the rack and pinion system. In this type of steering system, a small round gear on the end of the steering column engages a long flat toothed rack gear. This system converts the rotational motion of the steering column to the linear motion of the rack. As the car is steered, the rack moves to the left and to the right. Linkages from the rack pivot the front wheels to steer the car. Rack and pinion gears are not commonly used in the support (**A**), suspension (**B**), or braking (**D**) systems.