

13<sup>th</sup> INTERNATIONAL JUNIOR SCIENCE OLYMPIAD



MULTIPLE CHOICE COMPETITION

--- *SOLUTIONS* ---

DECEMBER, 4<sup>th</sup> 2016

1. Answer: C

Explanation:



$$\text{Mol of Na}_2\text{CO}_3 = 50 \text{ mL} \times 0.15 \text{ M} = 7.5 \times 10^{-3} \text{ mol}$$

$$\text{Mol of CaCl}_2 = \text{Mol of Na}_2\text{CO}_3 = 7.5 \times 10^{-3} \text{ mol}$$

$$\text{Volume of CaCl}_2 = 7.5 \times 10^{-3} \text{ mol} / 0.25 \text{ M} = 0.03 \text{ L} = 30 \text{ mL}$$

2. Answer: B

Explanation:

Catalyst is a substance that changes the rate of a chemical reaction without itself being used up. Although the catalyst is not part of the overall reaction it does participate by changing the mechanism of the reaction. The catalyst provides a path to the products that has a rate-determining step with a lower activation energy than that of the uncatalyzed reaction. Therefore, statements (2) and (4) are correct.

3. Answer: A

Explanation:

Electron has its own orbital energy, when it move up to the higher energy, there should be absorbed energy which is equal to the difference between to orbitals. So the correct answer is A.

4. Answer: A

Explanation:

$$\text{Mol of bioethanol} = (13.8 \text{ g} : 46 \text{ g/mol}) = 0.3 \text{ mol}$$

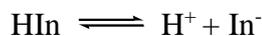
$$\text{Mol of oxygen} = (19.2 \text{ g} : 32 \text{ g/mol}) = 0.6 \text{ mol}$$

Since 0.3 mol bioethanol requires 0.9 mol of oxygen, oxygen becomes the determining reactant, so the calculation is based on the mol of oxygen.

$$\text{The volume of CO}_2 = (0.6 \text{ mol} \times 22.4 \text{ L/mol}) \times 2/3 = 8.96 \text{ L.}$$

5. Answer: A

Explanation:



$$K_a = \frac{[\text{H}^+][\text{In}^-]}{[\text{HIn}]}$$

$$\frac{[\text{In}^-]}{[\text{HIn}]} = \frac{K_a}{[\text{H}^+]} = \frac{1 \times 10^{-5}}{1 \times 10^{-4}} = \frac{1}{10}$$

There is 10 times as much as HIn as In<sup>-</sup>, and the colour that we see is due to HIn (yellow).

6. **Answer: D**  
Explanation:  
 $K^+$ , Ar and  $Cl^-$  have the same electronic configuration, but they have the nuclear charge increases in the order  $K^+ > Ar > Cl^-$ , so the order of the ionization potential is  $Cl^- < Ar < K^+$ .
7. **Answer: B**  
Explanation:  
 $H_2A + 2KOH \rightleftharpoons K_2A + 2H_2O$   
  
mmol KOH =  $40.0 \times 0.100 = 4$  mmol  
  
mmol  $H_2A = 0.5 \times$  mmol NaOH = 2 mmol  
  
Molecular mass of  $H_2A = 0.244 \text{ g} / 2 \text{ mmol} = 0.244/2 \cdot 10^{-3} \text{ g/mol} = 122 \text{ g/mol}$ .
8. **Answer: C**  
Explanation:  
Carbon =  $6/1 \times 30 \text{ gram} = 180 \text{ gram}$
9. **Answer: C**  
Explanation:  
Unpolluted and pure rain is slightly acidic due to the absorption of atmospheric carbon dioxide to partly form carbonic acid.  
 $CO_2(g) + H_2O \rightleftharpoons H_2CO_{3(aq)}$   
  
Carbonic acid is weak acid and the pH of water in equilibrium with atmospheric carbon dioxide is approximately 5.6
10. **Answer: B**  
Explanation:  
The ratio of the mass of Si to the mass of O is the same for both samples:  $3 \text{ g Si} / 4 \text{ g O} = 6 \text{ g Si} / 8 \text{ g O} = 0.75$ . Therefore, zeolite is a compound.

11. Answer: A

Explanation:

The total volume  $V_{total}$  of a sample is

$$V_{total} = V_{grains} + V_{voids}$$

From the void ratio

$$e = \frac{V_{voids}}{V_{grains}} \rightarrow V_{voids} = eV_{grains}$$

By substituting this equation to the total volume,  $V_{total}$ , and solving for  $V_{grains}$ , we find

$$V_{grains} = \frac{V_{total}}{1+e}$$

The total mass  $m_{sand}$  of the sand grains is the product of the density of silicon dioxide  $\rho_{SiO_2}$  and the total volume of the sand grains:

$$m_{sand} = \rho_{SiO_2} V_{grains} \rightarrow m_{sand} = \rho_{SiO_2} \frac{V_{total}}{1+e}$$

Since, the total mass  $m_{sand}$  of the sand grains is also the product of the sand density  $\rho_{Sand}$  and the total volume of the sample, we find

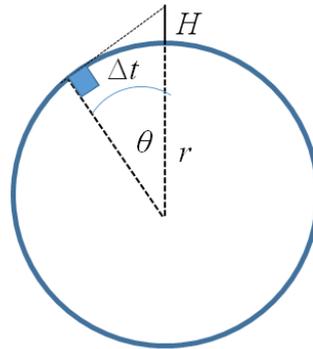
$$\rho_{Sand} V_{total} = \rho_{SiO_2} \frac{V_{total}}{1+e} \rightarrow \rho_{Sand} = \frac{\rho_{SiO_2}}{1+e}$$

Using the numerical values of  $e$  and  $\rho_{SiO_2}$ , we find that  $\rho_{Sand} = 1.58 \times 10^3 \text{ kg/m}^3$ .

12. Answer: B

Explanation:

A schematic diagram of the observation process is given in figure below.



The angle  $\theta$  is achieved during elaps time, which can be calculated using a comparison with a complete rotation on its axis every twenty-four hours. Therefore, we have,

$$\frac{\theta}{360^\circ} = \frac{\Delta t}{24\text{hours}} \rightarrow \theta = \frac{11.1}{86400\text{s}} 360^\circ = 0.046^\circ$$

The radius of Earth can be estimated using trigonometric of the triangle as shown in the figure. Here, we have

$$\cos \theta = \frac{r}{r+H} \rightarrow r = H \frac{\cos \theta}{1 - \cos \theta} = 1.7 \frac{\cos(0.046)}{1 - \cos(0.046)} = 5.3 \times 10^6 \text{ m}$$

13. Answer: D

Explanation:

Let  $d_1$  and  $d_2$  be the distance between the two upper plates and the two lower plates, respectively. Therefore, from the Figure we see that

$$d_1 + d_2 = a - b$$

The capacitance for each capacitor can be written as

$$C_1 = \frac{\epsilon_0 A}{d_1}, \quad C_2 = \frac{\epsilon_0 A}{d_2}$$

Therefore, the total capacitance in series can be expressed as

$$C_{tot} = \frac{C_1 C_2}{C_1 + C_2} = \frac{\epsilon_0 A}{d_1 + d_2} = \frac{\epsilon_0 A}{a - b}$$

Furthermore, the total energy stored in the capacitors is given by

$$W = \frac{CV_0^2}{2} = \frac{\epsilon_0 AV_0^2}{2(a - b)}$$

When the center section is removed, the energy stored in the capacitor becomes

$$W' = \frac{\epsilon_0 AV_0^2}{2a}$$

Finally, the change in the energy stored in the capacitors is

$$\Delta W = W - W' = \frac{\epsilon_0 AV_0^2}{2(a - b)} \frac{b}{a}$$

14 Answer: A

Explanation:

We imagine that the ends of both bolts expand into the gap between them as the temperature rises. We categorize this as a thermal expansion problem, in which the sum of the changes in length of the two bolts must equal the length of the initial gap between the ends. This leads to the fact that

$$\Delta L_{Br} + \Delta L_{St} = 5 \times 10^{-6}$$

Here,

$$\Delta L_{Br} = \alpha_{Br} L_{i=Br} \Delta T$$

And

$$\Delta L_{St} = \alpha_{St} L_{i=St} \Delta T$$

Where  $\alpha_{Br}$  and  $\alpha_{St}$  are thermal expansion coefficient for brass and steel, respectively, while  $L_{i=Br}$  and  $L_{i=St}$  are the initial length of brass and steel, respectively.

Using all above equation, we find that

$$5 \times 10^{-6} = \alpha_{Br} L_{i=Br} \Delta T + \alpha_{St} L_{i=St} \Delta T \rightarrow \Delta T = \frac{5 \times 10^{-6}}{\alpha_{Br} L_{i=Br} + \alpha_{St} L_{i=St}}$$

$$\Delta T = \frac{5 \times 10^{-6}}{19 \times 10^{-6} (0.03) + 11 \times 10^{-6} (0.01)} = 7.4$$

Finally, the temperature at which the bolts touch is  $27^\circ\text{C} + 7.4^\circ\text{C} = 34.4^\circ\text{C}$ .

15. Answer: D

16. Answer: C

Explanation:

On a level (unbanked) road, the force that causes the centripetal acceleration is the force of static friction between car and road. However, if the road is banked at an angle  $\theta$ , as in Figure, the normal force  $\mathbf{n}$  has a horizontal component,  $n_x$ ,

$$n_x = n \sin \theta$$

pointing toward the center of the curve. Because the ramp is to be designed so that the force of static friction is zero, only the component  $n_x$  causes the centripetal acceleration. Hence, Newton's second law for the radial direction gives

$$F_r = n_x \rightarrow m \frac{v^2}{r} = n \sin \theta$$

On the other hand, the car is in equilibrium in the vertical direction. Thus, from  $\sum F_y = 0$  we have

$$n \cos \theta = mg$$

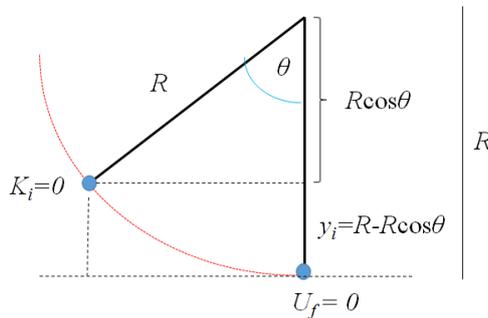
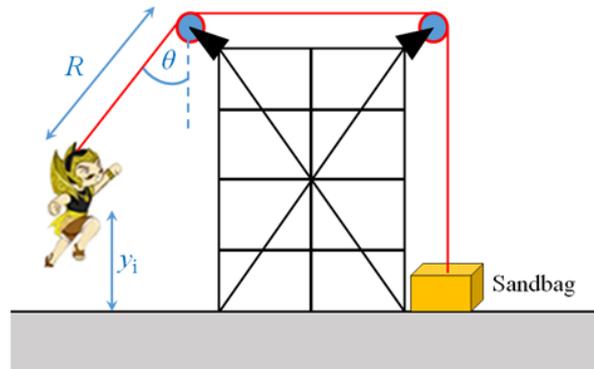
Dividing the previous equation with above equation, we find that

$$\tan \theta = \frac{v^2}{rg} \rightarrow \theta = \tan^{-1} \left( \frac{(13.4)^2}{50 \times 9.8} \right) = 20.1^\circ$$

17. Answer: C

Explanation:

Let us imagine what happens as the actor approaches the bottom of the swing. At the bottom, the cable is vertical and must support his weight as well as provide centripetal acceleration of his body in the upward direction. At this point, the tension in the cable is the highest and the sandbag is most likely to lift off the floor.



At the swinging of the actor from the initial point to the lowest point, we categorize this as an energy problem involving an isolated system that is the actor and the Earth. Here, we find that

$$K_f + U_f = K_i + U_i \rightarrow \frac{1}{2} m_{actor} v_f^2 + 0 = 0 + m_{actor} g y_i$$

where  $y_i$  is the initial height of the actor above the floor and  $v_f$  is the speed of the actor at the instant before he lands. It is noted that  $K_i = 0$  because he starts from rest and that  $U_f = 0$  because we define the configuration of the actor at the floor as

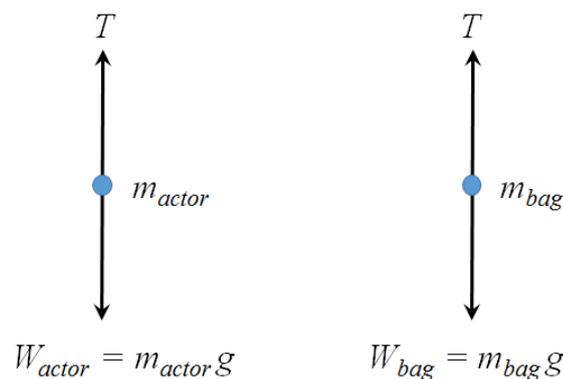
having a gravitational potential energy of zero. Here,  $y_i$  is related to  $R$  and  $\theta$  through the relation (see figure),

$$y_i = R - R \cos \theta$$

Then, we have

$$v_f^2 = 2gR(1 - \cos \theta)$$

At the lowest point, the tension in the cable is transferred as a force applied to the sandbag, we categorize the situation at this instant as a Newton's second law problem. We apply Newton's second law to the actor at the bottom of his path, using the free-body diagram as shown below.



Here, for the mass of actor, we have,

$$\begin{aligned} \sum F_y = m_{actor} \frac{v_f^2}{R} &\rightarrow T - m_{actor}g = m_{actor} \frac{v_f^2}{R} \\ T &= m_{actor}g + m_{actor} \frac{v_f^2}{R} \\ T &= m_{actor}g + m_{actor} 2g(1 - \cos \theta) \end{aligned}$$

And for the mass of sandbag, we have,

$$\begin{aligned} T = m_{bag}g &\rightarrow m_{actor}g + m_{actor} 2g(1 - \cos \theta) = m_{bag}g \\ \theta &= \cos^{-1} \left( \frac{3m_{actor} - m_{bag}}{2m_{actor}} \right) = \cos^{-1} \left( \frac{3(65) - 130}{2(65)} \right) = \cos^{-1}(0.5) = 60^\circ \end{aligned}$$

18. Answer: A

Explanation:

The magnitude of force acting on electrons:

$$F = -eE = ma \rightarrow a = -eE/m$$

where  $e$  is electron charge,  $m$  is electron mass, and  $a$  is the electron acceleration.

Here,  $E$  is the electric field which can be related to the potential difference  $V$  as

$$E = V/d$$

where  $d$  is the distance between the plates. Therefore, we find

$$a = -eV/dm$$

The horizontal distance can be found by using the equation below,

$$v_t^2 = v_0^2 + 2ax$$

When the electrons hit the positive plate,  $v_t$  is zero. Therefore, we find that

$$x = \frac{v_0^2}{2a} = \frac{v_0^2 dm}{2eV}$$

19. Answer: C

Explanation:

The force done by the magnetic field across to the wires is

$$F = ma = BId \rightarrow m \left( \frac{v_t - v_0}{t - t_0} \right) = BId$$

Since the wires is initially at rest,  $v_0 = 0 \rightarrow t = 0$ , we find

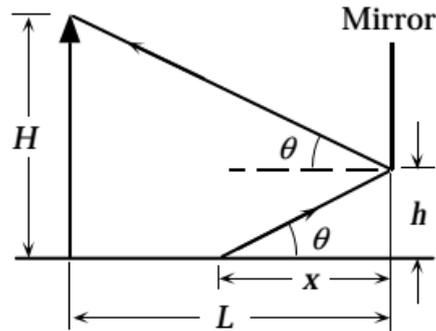
$$v_t = \frac{BId}{m}t$$

Therefore,  $v_t$  linearly depends on the time  $t$ .

20. Answer: B

Explanation:

From the figure, it is clearly seen that the angle of incidence is the angle of reflection.



Thus we have,

$$\tan \theta = \frac{H-h}{L} = \frac{h}{x} \rightarrow x = \frac{Lh}{H-h}$$

Here,  $H = 1.68$  m,  $h = 0.43$  m, and  $L = 2.2$  m, we find that

$$x = \frac{Lh}{H-h} = \frac{2.2 \times 0.43}{1.68 - 0.43} = 0.76 \text{ m}$$

21. Answer: A

Explanation:

Female silkworm moths (*Bombyx mori*) attract males by emitting chemical signals that spread through the air. A male hundreds of meters away can detect these molecules and fly toward their source. The sensory organs responsible for this behavior are the comblike antennae visible in the photograph shown here. Each filament of an antenna is equipped with thousands of receptor cells that detect the specific sex attractant.



22. Answer: B

Explanation:

Slope of Bt ORG2 (0,5245) is greater than slope of Bt ORG1 (0,2069)

LC50 of Bt ORG1 during 24 hours =  $3.15 \times 10^{10}$  cell/mL is greater than LC50 of Bt ORG2 during 24 hours =  $2.15 \times 10^{10}$  cell/mL

23. Answer: D

Explanation:

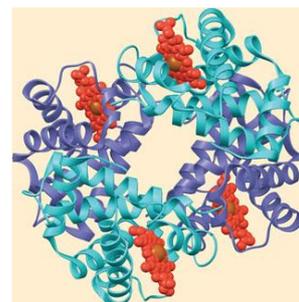
Centriole: One of a pair of small, cylindrical organelles lying at right angles to each other near the nucleus in the cytoplasm of animal cells and certain protist and plant cells.

24. Answer: B

Explanation:

Hemoglobin, the oxygen-binding protein of red blood cells shown below, is another example of a globular protein with quaternary structure. It consists of four polypeptide subunits, two of one kind ( $\alpha$ ) and two of another kind ( $\beta$ ).

Both  $\alpha$  and  $\beta$  subunits consist primarily of  $\alpha$ -helical secondary structure. Each subunit has a non-polypeptide component, called heme, with an iron atom that binds oxygen.



25. Answer: A

26. Answer: B

Explanation:

The plasmodium-carrying mosquito is still survive because there are not bird predator and monkey Species B is not immune to plasmodium

27. Answer: A

Explanation:

Out of 1000 human population, 840 are tongue rollers (TT or Tt) and 160 are not tongue roller(tt). The dominant allele can be calculated by using the formula  $P + p = 1$  (P: dominant allele, and p: recessive allele). The frequency of the dominant allele in the population is ...

$$P + \sqrt{\frac{160}{1000}} = 1; \quad P = 0,6$$

28. Answer: B

Explanation:

Human has dozens of antigens on the surface of his/her blood cells. One group of antigens, designated as the MN blood group, stimulates the production of antibodies when injected into rabbit. Allele for MN blood groups, usually designated as M and N, are codominant. It means that Genotype MM produces only antigen M, while genotype NN produces only antigen N, and the heterozygous genotype MN produces both antigens. Given the following data:

Genotype	Observed
MM	320
MN	480
NN	200
Total	1000

Because 1000 diploid individuals are in the sample, there are a total of 2000 allele. By the Hardy-Weinberg principle, the sum of allele frequencies is  $p + q = 1$ . What is the frequency of allele M?

$$M = \frac{(2 \times 320)}{2000} = 0.56$$

29. Answer: A

Explanation:

Embryo:

In plant the young sporophyte produced following fertilization and subsequent development of the zygote.

30. Answer: D

Explanation:

The Calvin Cycles: Cyclic series of reaction in the chloroplast stroma in photosynthesis; fixes  $\text{CO}_2$  and produced carbohydrate