Solutions to the Physics Competition

Circle the correct answer

1. **a) (B)**
b) (D)

$$1\text{F} = \frac{1\text{C}}{1\text{V}} = \frac{1\text{A}\cdot\text{s}}{1\text{J/C}} = \frac{1\text{A}^2\cdot 1\text{s}^2}{1\text{kg}\cdot\text{m}^2/\text{s}^2} = \frac{1\text{A}^2\cdot 1\text{s}^4}{1\text{kg}\cdot\text{m}^2}$$

2. **(E)**

$$\frac{400\cdot O}{1\text{ min}} = 72\frac{\text{km}}{\text{h}} \rightarrow O = \frac{72000\text{ m}\cdot 1\text{ min}}{400\cdot 60\text{ min}} \rightarrow O = 3\text{ m}$$

3. **(B)**
Bolt first accelerates but his acceleration decreases until his speed reaches a 'plateau' when the acceleration is approximately zero and then he decelerates meaning that his acceleration becomes negative.

4. **(E)**

5. **(B)**

$$P = \frac{0{,}6\text{ kg}\cdot 200\text{ kJ}}{40\text{ s}} = 3000\text{ W}$$

6. **(D)**
While the train is approaching the station, the conductor hears a higher frequency of sound emitted by the horn because of the Doppler effect. Since the train's speed is constant the perceived frequency doesn't change up until the moment when the train passes through the station where the frequency abruptly decreases below f_0 and then stays constant.

7. **(C)**
Using the inequality between arithmetic and harmonic means as well as the lens equation we get

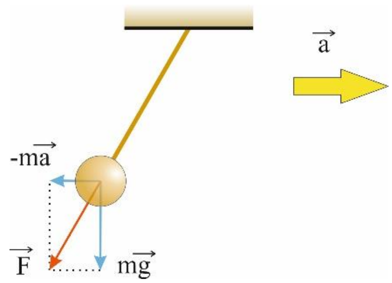
$$\frac{p+l}{2} \geq \frac{2}{\frac{1}{p}+\frac{1}{l}} = \frac{2}{\frac{1}{f}} \rightarrow p+l \geq 4f$$

8. **(C)**
If we denote with u – uphill distance, d – downhill distance and f – length of the flat part of the road then we can write $\frac{u}{3\frac{\text{km}}{\text{h}}} + \frac{f}{3{,}6\frac{\text{km}}{\text{h}}} + \frac{d}{4{,}5\frac{\text{km}}{\text{h}}} = 1\text{ h}$ and $\frac{d}{3\frac{\text{km}}{\text{h}}} + \frac{f}{3{,}6\frac{\text{km}}{\text{h}}} + \frac{u}{4{,}5\frac{\text{km}}{\text{h}}} = 75\text{ min}$. If we add the two equations we get $(u+d)\cdot\left(\frac{1}{3\frac{\text{km}}{\text{h}}} + \frac{1}{4{,}5\frac{\text{km}}{\text{h}}}\right) + 2\cdot\frac{f}{3{,}6\frac{\text{km}}{\text{h}}} = 2{,}25\text{ h} \rightarrow (\text{u}+\text{d}+\text{f})\cdot\frac{5}{9} = 2{,}25\text{ km}$
$\rightarrow u+f+d = 4{,}05$ km.

Answer with: it increases, it decreases, or it doesn't change

9. **a) doesn't change**
b) decreases

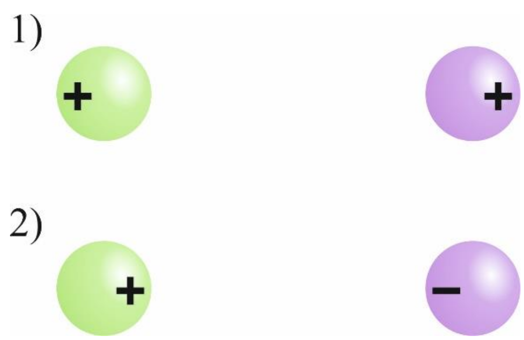
When the elevator is accelerating in its frame there's an additional inertial force acting on the pendulum so that the total force 'playing the role of gravity' is $F = m\sqrt{g^2 + a^2}$. This constant force acts on the pendulum irrespective of its position, the same as gravity with a different gravitational acceleration $g' = \sqrt{g^2 + a^2}$. Thus, the pendulum's period is



$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2+a^2}}} < 2\pi\sqrt{\frac{l}{g}} = T_0$ where T_0 is the pendulum's period when the elevator is at rest.

10. **increases**

The balls are metallic which means that the charge can move freely on them. That's why when their charges are of the same sign they will collect on the farther ends of the balls, whereas the situation is opposite in the second case. Knowing that the Coulomb's force decreases with increasing distance between charges it follows that the intensity of the force between balls will increase.



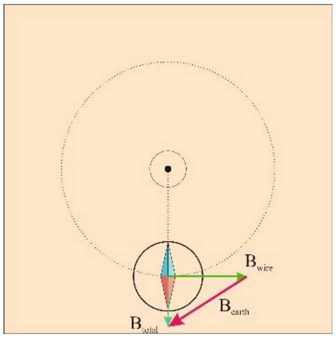
Answer with: A>B, A<B or A=B

11. **A=B**

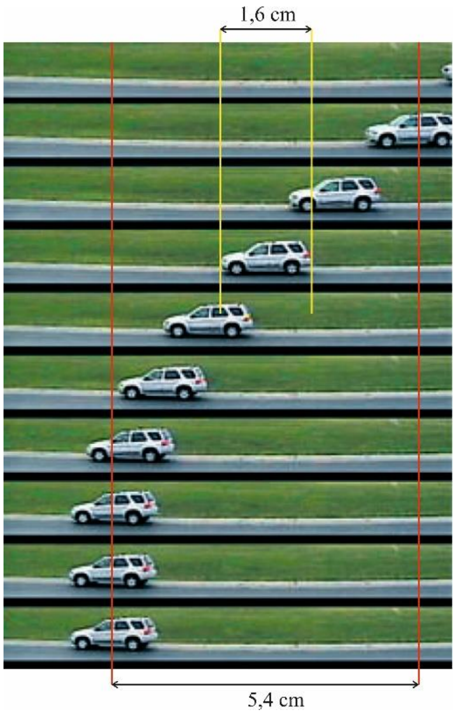
The short answer is that if the flies are flying around the jar chaotically the centre of mass of the whole system (flies, jar and the air inside it) is still which means that the scales will show the same mass of the jar. The longer answer should address the fact that even though the flies are not pressing the bottom of the jar with their weight anymore, while flying they are pushing the air downwards that's pressing the bottom with same force.

12. **A>B**

One could argue the Earth's magnetic field lines are not exactly horizontal, but in that case the Earth's magnetic field would have a vertical component and would then have an even bigger intensity so the answer is still the same.

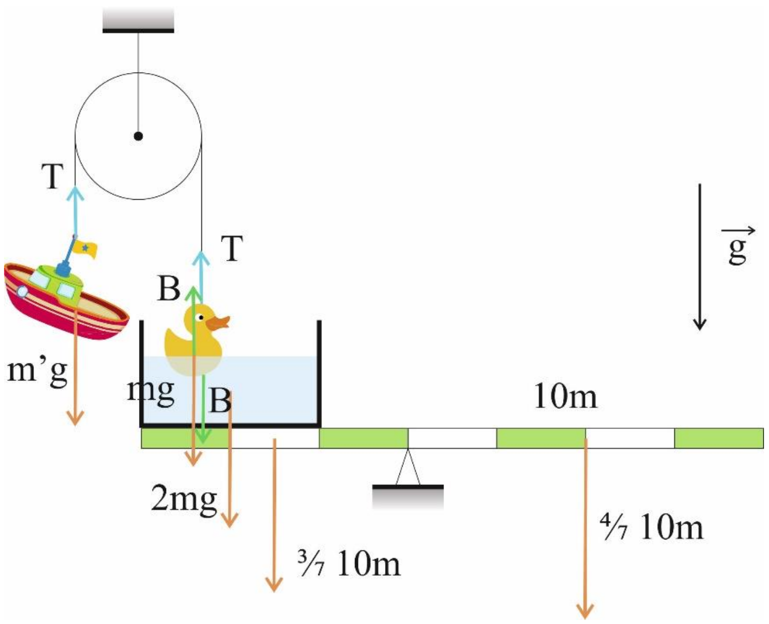


Solve the following problems

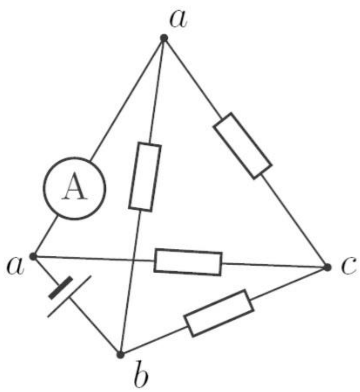


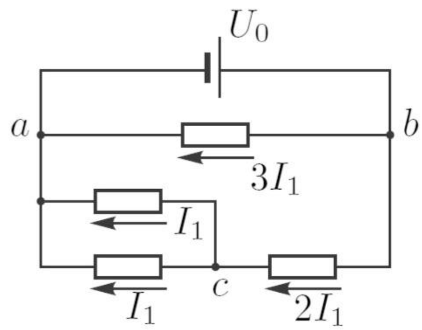
13. First, let us notice that on the last three photographs the position of the car doesn't change. So, what we need to do first is to measure the car's length on the photograph to establish a scale. Using a ruler, we get $l = 1{,}6\ \mathrm{cm}$ which corresponds to the real length of the car of $4{,}44\ \mathrm{m}$. Then we measure the distance the car travels before stopping and it is $s_0 = 5{,}4\ \mathrm{cm} \rightarrow \frac{5{,}4\ \mathrm{cm}}{1{,}6\ \mathrm{cm}} \cdot 4{,}44\ \mathrm{m} = 14{,}98\ \mathrm{m} \approx 15\ \mathrm{m}$. The car took $t_0 = 6 \cdot 0{,}333\ \mathrm{s} = 1{,}998\ \mathrm{s}$ to stop so that the acceleration is then equal to $a = \frac{2 \cdot s_0}{{t_0}^2} = 7{,}51\ \frac{\mathrm{m}}{\mathrm{s}^2} \approx 8\ \frac{\mathrm{m}}{\mathrm{s}^2}$.

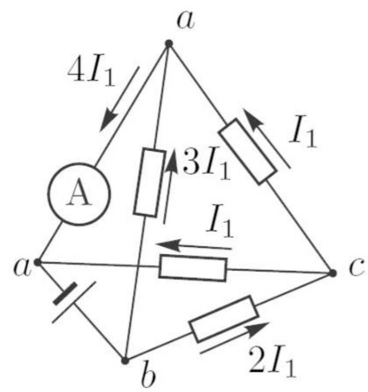
14. Let us first consider all the forces acting on our system. Since the system is in equilibrium it follows for the boat toy $T = m'g$, where T is the tension force and for the duck toy $mg = T + B$, where B is the buoyant force. The equilibrium of torques acting on the beam gives $(2mg + B) \cdot 2x + \frac{3}{7} \cdot 10mg \cdot 1{,}5x = \frac{4}{7} \cdot 10mg \cdot 2x$, where x is the length of one seventh of the beam. In total we have three linear equations with three unknowns. Solving for m' we get $m' = {}^{m}/_{2}$.



15. When the ideal ammeter is in the circuit the circuit can be drawn as follows, since ideal ammeters don't have any resistance. Notice the nodes a and a in the picture indicating that the voltage on ammeter is 0. Here we have used the Ohm's law noticing that the currents I_{ba} and $I_{bca}$are inversely proportional to resistances $R_{ba} = R$ and $R_{bca} = R + {R^2}/{2R} = {3R}/{2}$ so $I_{ba} \div I_{bca} = R_{bca} \div R_{ba} = 3 \div 2$. For branch ba we can write $U_0 = R \cdot 3I_1$ while the current through ammeter is $I_A = 4I_1 = 2$ A. Thus, we get ${U_0}/{R} = 1{,}5$ A.

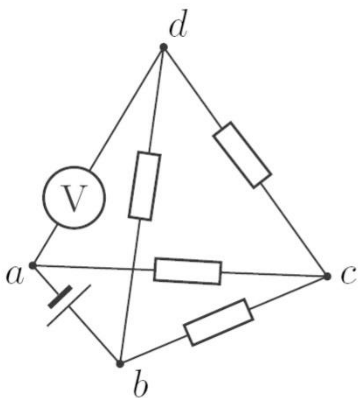


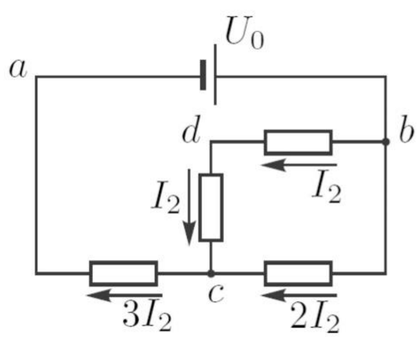


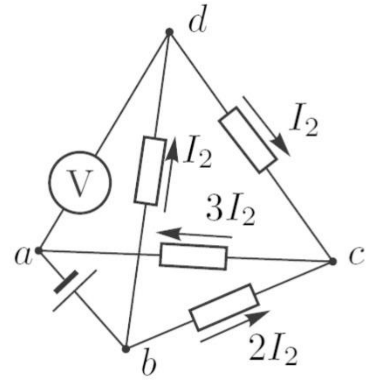


When the ideal voltmeter is in the circuit since its resistance is infinite there is no current going through it. The circuit can then be shown as follows.

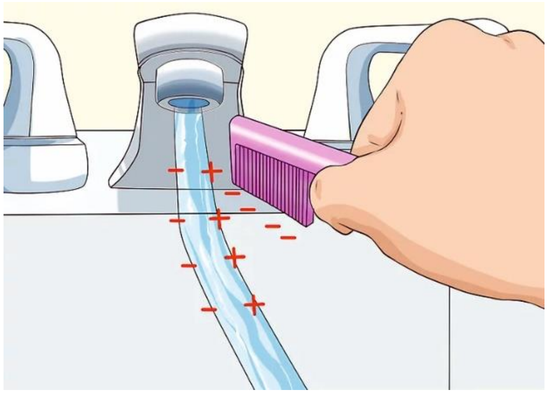
The voltage between nodes ba is $U_0 = 2I_2R + 3I_2R = 5I_2R$ and also the voltage measured by the voltmeter is $U_V = U_{da} = U_0 - I_2R = 4I_2R = {4U_0}/{5} = 12$ V. Finally, the solutions are $U_0 = 15$ V and $R = 10\ \Omega$.





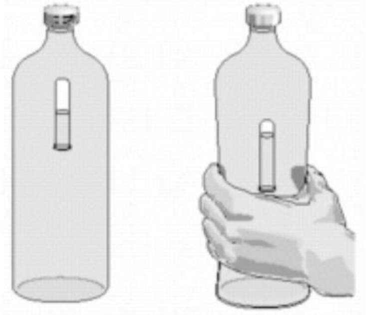


Answer the following questions and provide an explanation



16. By passing the comb through dry hair we bring excess charge to it. This surplus of charge on the comb creates an electric field that polarizes the water. Namely, water molecules are polar molecules which means that they act as electric dipoles (neutral systems with separated centres of positive and negative charges) that orient themselves along the electric field lines. What's more, the inhomogeneous electric field draws the molecules towards the area where the filed is stronger i.e. towards the comb.

When the temperature of water is increased, the chaotic character of water molecules motion is more pronounced thus lessening the degree of orientation of molecules along the field lines and consequently how much the water bends.



before after

17. When we squeeze the plastic bottle we reduce its volume and since the water is incompressible that means that the air inside the tube will be compressed. Thus, the buoyant force acting on the tube and air in it will decrease and make the tube sink.

Another way to look at the problem is to realize that the air pressure in the tube increases when it is compressed so in order to reach equilibrium the tube needs to descend for the hydrostatic pressure to equal the air pressure.

18. The slinky will freefall in a very interesting way. The upper end of the slinky will start falling with an acceleration greater than g. As soon as the deformation below decreases the lower parts gradually start falling as well. All the while the bottom part of the slinky is still, waiting for the upper parts to descend to it.

Pay attention to an object on top of the slinky in the photo which was released at the same time. It falls with regular gravitational acceleration g, while the upper parts of the slinky have greater acceleration because, aside from gravity, the parts below them also pull them downwards.