The Mathematical Grammar School Cup

Physics Competition Solutions

28.06.2022.

# of question	answer	# of question	answer
1.	**B**	17.	**E**
2.	**E**	18.	**D**
3.	**D**	19.	**C**
4.	**C**	20.	**A**
5.	**A**	21.	**E**
6.	**D**	22.	**D**
7.	**E**	23.	**A**
8.	**C**	24.	**B**
9.	**B**	25.	**C**
10.	**D**	26.	**D**
11.	**A**	27.	**A**
12.	**B**	28.	**E**
13.	**D**	29.	**C**
14.	**B**	30.	**B**
15.	**B**	31.	**E**
16.	**C**	32.	**D**

1. (**B**) Alessandro Volta

2. (**E**) 299 792 458

3. (**D**) one SI base unit of time. Namely, $\sqrt{\frac{\mathrm{C}}{\mathrm{V}}\frac{\mathrm{Wb}}{\mathrm{A}}} = \sqrt{\frac{\mathrm{A \cdot s}}{\mathrm{V}}\frac{\mathrm{V \cdot s}}{\mathrm{A}}} = \mathrm{s}$.

4. (**C**) all the five stoppers get ejected instantaneously. Apply Pascal's principle.

5. (**A**) Distant objects appear smaller than nearer objects.

6. (**D**) ⊤⊤⊤

7. (**E**) light intensities of both bulbs will remain unchanged. No extra electric current is to flow through the left branch of the second part of the circuit upon switching.

8. (**C**) $v_y^{(\mathrm{A})} = v_y^{(\mathrm{C})} > v_y^{(\mathrm{B})} \neq 0$. No vertical component of the stone velocity exists at the highest point reached (B); such components are however equal at the same horizontal level.

9. (**B**). Consider cable tension T at any point P of the cable. We can say that T comes from two forces exerted on the part of the cable below P: (*i*) the weight of that part of the cable, which gives T its vertical component (*ii*) and air resistance on that part of the cable, which gives T its horizontal component. As we look at different points P along the cable, we see that these two forces are always proportional to the length of the cable below P, and so T has the same direction at any point on the cable. For this reason, the cable will be shaped as a straight line, thence the answer.

10. (**D**) The water will start fountaining from the middle tube. The pressure difference between the air inside and outside is what drives the fountain to run. This is due to the difference between the level of the water in the uppermost and lowermost containers.

11. (**A**) $\varphi_1 = \varphi_2$ and $E_1 > E_2$.

12. (**B**). Apply Newton's third law.

13. (**D**) If the inclined plane angle is θ, the normal force is $N = mg\cos\theta$ and acts perpendicular and into the plane. The friction force on the inclined plane is oriented down the plane and is equal to $F = \mu N = \mu mg\cos\theta$. Only answer (D) has both “into” and “down” components.

14. (**B**) Concave spherically-shaped mirror.

15. (**B**) Ice melts under pressure as the freezing point of water decreases in that case, yet ice does refreeze when the pressure is reduced back to the initial value. For the same reason, ice-skaters glide on solid ice as a result of the pressure-induced liquid layer formation that is to refreeze right after his/her passage.

16. (**C**) C. Induced electromotive forces are respectively: $\mathcal{E}_\mathrm{A} = Bav,\ \mathcal{E}_\mathrm{B} = Bav,\ \mathcal{E}_\mathrm{C} = 2Bav$, whereas electric resistances are respectively: $R_\mathrm{A} \propto 4a,\ R_\mathrm{B} \propto 6a,\ R_\mathrm{C} \propto 6a$, where B is induction of magnetic field, v velocity, and a is side-length of the square.

17. (**E**) $R/2$. Two parallel regular pentagons single out. Both are perpendicular to AB direction. All five nodes in each of the two pentagons share the same electric potential, so the two pentagons can either be shrunk into two nodes or their side-lengths can be removed.

18. (**D**). Use the fact that mass density of the liquid decreases with increasing temperature as the liquid expands. That is why there may be differences in the column heights to ensure transmission of the hydrostatic pressure via the connector.

19. (**C**) Movement of the shower curtain is due to the spraying-water-generated pressure difference between the inner and outer surface of the curtain.

20. (**A**) $2k$ and $(l_1 + l_2)/2$. If the two springs are extended by Δx then restoring force reads as $F = (k + k)\Delta x$. The relaxed length is obtained once the net force is reduced to zero. Therefore, one spring must be contracted/extended by $(l_1 - l_2)/2$, while the other contracted/extended by $(l_1 - l_2)/2$.

21. (**E**).

22. (**D**). Rely on both refraction law and Huygens principle whereby the wave frequency remains the same along its passage from one medium to another. The shorter wavelength in the second medium suggests that the wave speed in it is slower so that the refracted angle becomes smaller with respect to the 1-2 direction.

23. (**A**) The object comes to rest at position $x = 44\ \mu$m.

24. (**B**) The ball will start inclining to the left, i.e. opposite to the arrow direction, keeping the thread taut.

25. (**C**). Apply the refraction law and use the fact that speed of light varies as $c(\lambda) = c/n(\lambda)$. Numeric value of λ increases over spectra from violet up to red light.

26. (**D**). Such a point that the sum of the distances from each of the three vertices of the triangle to the point T is the smallest possible. Let l_1, l_2, and l_3 be these three distances and let L_1, L_2, and L_3 be the thread lengths. In the mechanical equilibrium, the minimum of the potential energy is reached, so that

$$-mg(L_1 + L_2 + L_3) + mg(l_1 + l_2 + l_3) \to \text{min.}$$

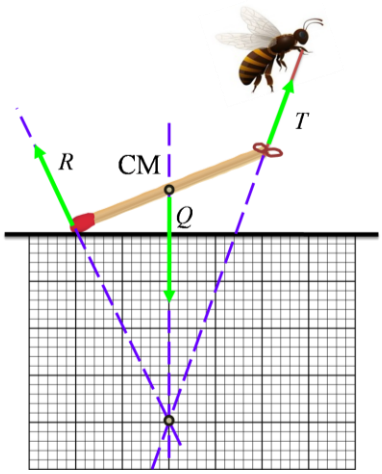
27. (**A**). For converging lens: $\frac{1}{|\mathbf{u}|} \pm \frac{1}{|\mathbf{v}|} = \frac{1}{|\mathbf{f}|}$. For diverging lens: $\frac{1}{|\mathbf{u}|} - \frac{1}{|\mathbf{v}|} = -\frac{1}{|\mathbf{f}|}$.

28. (**E**) $3\sqrt{3}m/32R^3$. The volume of the unit cell is $\left(\frac{4R}{\sqrt{3}}\right)^3$. There are two atoms in total occupying the cubic cell: one at the centre and the other $1 = 8$ (corners) $\times \frac{1}{8}$(fraction).

29. (**C**).

30. (**B**) 29 cm/s upwards. Let's consider a very small time interval Δt, and see how the individual parts of the system move. Point A will move up by $v\Delta t$, the leftmost block will move down by $2v\Delta t$, and so on. This means that point A tends to lengthen the leftmost section of the thread by $v\Delta t$, and the block by $2v\Delta t$, i.e. in total by $3v\Delta t$. Similarly, for the next section of the thread, we get the lengthening $3v\Delta t + 2v\Delta t$, etc. In total, the thread should lengthen by $(v + 4v + 6v + 8v + 10v)\Delta t - u\Delta t$. But the total elongation is zero, which means that $u = 29v$, or 29 cm/s.

31. (**E**) 0.50. There are three relevant forces acting on the matchstick: tension force (T), gravity force (Q), and reaction force (R). The reaction force has friction force as its horizontal component (F) and normal reaction force as its vertical component (N). The three mentioned forces must intersect at one point to maintain the balance of the moment of the forces. Accordingly, $F{:}N = 20{:}40$.



32. (**D**) $\ell = 19.7$ mm. Readings on the left and right figures are 0.6 mm (offset) and 20.3 mm, respectively.