Final Answer Table

Question	Answer	Question	Answer
01.	E	17.	B
02.	E	18.	D
03.	A	19.	A
04.	C	20.	D
05.	B	21.	C
06.	B	22.	B
07.	C	23.	C
08.	A	24.	D
09.	B	25.	E
10.	D	26.	B
11.	D	27.	B
12.	A	28.	C
13.	A	29.	E
14.	E	30.	D
15.	D	31.	E
16.	D	32.	D

Answers with Hints

Answer 1. (E) Isaac Newton and Christiaan Huygens.

Answer 2. (E) $0\ \mathrm{m/s}$, oftentimes considered undefined.

Answer 3. (A) $\ominus \oplus \ominus$.

Answer 4. (C) water.

Answer 5. (B) sunlight refraction/reflection by tiny ice crystals in the atmosphere.

Answer 6. (B) the speed of light is much higher than the speed of man.

Answer 7. (C) $F = 0$.

Answer 8. (A) Moon is tidally locked to Earth's gravity so that it orbits the Earth and spins at the same period of nearly a month, both anti-clockwise.

Answer 9. (B) Metal conducts heat significantly faster than wood.

Answer 10. (D) $n_1 \neq n_2 \Rightarrow \nu_1 \neq \nu_2$

Answer 11. (D) $\mathrm{O}_1 - \mathrm{I}_1 - \rceil\lceil \quad \& \quad \mathrm{I}_2 - \mathrm{O}_2 -) (\quad \& \quad \mathrm{O}_3 -) (- \mathrm{I}_3$

Answer 12. (A) Kirchhoff's nodal law in the circuit

Answer 13. (A)

Hint. Use the fact that a point charge produces a radial electric field of which intensity falls off with distance from its source (the common point of the intersecting vector lines).

Answer 14. (E) is reflected internally multiple times inside the stream of water which is optically denser than air.

Answer 15. (D) Work done by all the force in region $\mathrm{OA} \cup \mathrm{BD}$ is positive.

Hint. Adhere to the principle of work and kinetic energy stating that the work done by all the force equals the change in the kinetic energy. Instantaneous speed of the particle can be estimated at any point of $x(t)$ graph. Create tangent lines at the relevant points and compare their slopes.

Answer 16. (D) $\Delta\ell \approx 0.25\ \mathrm{cm}$.

Hint. A single pulley (eyelet) is able to move so that the mechanical advantage is gained by factor two. Each eyelet is moved inward by $\Delta\ell/2$ leaving nearly $\Delta\ell$ of the shoelace length available for pulling. There are four eyelets per column. Thus, $4\Delta\ell \approx 1.00\ \mathrm{cm}$.

Answer 17. (B) $B_1 < B_2$ and $\Phi_1 = \Phi_2$.

Hint. The magnetic induction B (surface magnetic flux density) represents the magnetic flux Φ (the number of magnetic lines) per certain surface that pass through it.

Answer 18. (D)

Hint. There are no more nor less than three real forces acting on the block, as viewed from the laboratory inertial frame. Bear in mind that ma represents only a force resultant, not a fundamental force itself resulting from mutual object interactions.

Answer 19. (A) (1) will switch to (2).

Answer 20. (D) $T = 2\pi\sqrt{\ell\sqrt{2}/g}$

Hint. Effectively, the period $T = 2\pi\sqrt{\ell_{\text{eff}}/g_{\text{eff}}}$, where $\ell_{\text{eff}} = \ell\cos\beta$ and $g_{\text{eff}} = g\sin\alpha$.

Answer 21. (C) Even if all the thunderstorms were suddenly switched off, the global capacitor would never discharge.

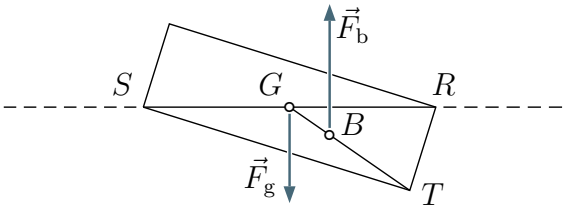
Answer 22. (B) $n_3 < n_1 < n_2$

Hint. As the ray moves toward the normal while entering medium 2 from 1, there must be $n_2 > n_1$. For total internal reflection at interface of 2 and 3, $n_2 > n_3$. Besides, n_3 should also be less than n_1. Otherwise, the ray would have emerged in medium 3, parallel to its path in medium 1.

Answer 23. (C) Given $\vec{B}_0 = \vec{0}$ there is no direction.

Answer 24. (D) $1/3$

Hint. The points of application of gravitational, $|\vec{F}_{\text{g}}| = \rho V g$, and buoyancy force, $|\vec{F}_{\text{b}}| = \rho_0(V/2)g$, are at G and B, respectively. G is the mid-point of diagonal RS, while B stands for the centroid of right triangle ΔRST. Thus, $|TB| = 2|BG|$. Look into the torque equilibrium with respect to the axis passing through the edge at point T, where the string is attached so that one doesn't have to deal with the tension force.



Answer 25. (E) The milk in the cup is boiling.

Hint. Even though the pot water is boiling, it will not exceed $100°\text{C}$ by order of priority. Thus, there is no temperature difference between the two, and thus there is no thermal energy transfer. Accordingly, there is no extra energy for the milk to undergo change of state, so that it fail to boil staying at $100°\text{C}$.

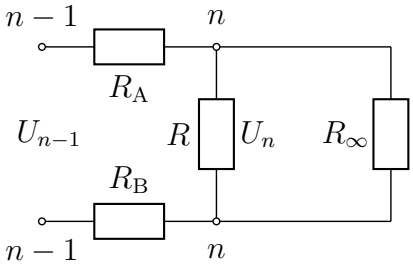
Answer 26. (B)

Hint. The rod is in static equilibrium so that all the three coplanar forces acting on it: tension, gravity, and reaction exerted by the wall, must intersect at one point.

Answer 27. (B) $U_0 = 345.6\ \text{V}$

Hint. Adding yet another link to the infinite link chain does practically not affect its total resistance. Let us denote it by R_∞. The figure shows the link number n, its voltage U_n across the resistor R, while the entire subsequent semi-infinite chain is replaced by an equivalent resistor R_∞. By Ohm's law and the properties of series and parallel-connected resistors, it is possible to write down the following equation:

$$\frac{U_{n-1}}{R_{\text{A}} + \dfrac{RR_\infty}{R+R_\infty} + R_{\text{B}}} = \frac{U_n}{\dfrac{RR_\infty}{R+R_\infty}} \Rightarrow U_n = \kappa \times U_{n-1} = \kappa^n \times U_0,$$



where $\kappa = const$. Thus, $U_0 = \sqrt[(6-4)]{\dfrac{U_4^6}{U_6^4}} = \dfrac{(240\ \text{V})^3}{(200\ \text{V})^2} = 345.6\ \text{V}.$

Answer 28. (C) $\kappa_1 = 3\kappa$ and $\kappa_2 = 3\kappa/2$.

Hint. Let's cut the major spring in three equal parts. Accordingly,

$$\frac{1}{\kappa} = \frac{1}{\kappa_1} + \frac{1}{\kappa_1} + \frac{1}{\kappa_1} \text{ and } \frac{1}{\kappa_2} = \frac{1}{\kappa_1} + \frac{1}{\kappa_1}.$$

Answer 29. (E)

Hint. The points of the front and rear wheels must everywhere be the same distance apart. The rear wheel cannot be steered and the tangent of its track always points towards the position of the front wheel at the same time.

Answer 30. (D) $0.10\ \mathrm{cm}$

Hint. Note that the m^{th} mark on the hypotenuse scale coincides with the n^{th} mark on the $12\ \mathrm{cm}$ long cathetus scale. This point is known as the point of coincidence. Thus, the measured length of the stick ℓ is

$$\ell = m \times (\Delta x / \cos\theta) - n \times (\Delta x),$$

where $\Delta x = 1.20\ \mathrm{cm}$, $\cos\theta = 12/13$, whereas m and n are integers obeying $m > n$. The least count $\ell_{\min}$ is

$$\ell_{\min} = (m-n)_{\min} \times (13/12 - 1) \times 1.20\ \mathrm{cm} = 0.10\ \mathrm{cm}.$$

Answer 31. (E) $m = 0.03\ \mathrm{g}$.

Hint. Read the slope from the graph ($\mathrm{d}x/\mathrm{d}v = -\sqrt{3}\ \mathrm{s}$) and then apply Newton's second law. Namely,

$$m\frac{\mathrm{d}v}{\mathrm{d}t} = -b\frac{\mathrm{d}x}{\mathrm{d}t} \Rightarrow m = -b\frac{\mathrm{d}x}{\mathrm{d}v}.$$

Answer 32. (D) $f \in (12, 15)\ \mathrm{cm}$

Hint. Let object and virtual image distance be u and $|v| = -v$, respectively. f is focal length of the thin lens of which diameter is $d = 4\ \mathrm{cm}$. The distance between the lens and the tape measures $u = 5\ \mathrm{cm}$, while ℓ is the unknown lens distance from the camera. The lens magnification is defined as $m = |v|/u$. Then, following thin lens-maker's equation and angular sizes, respectively:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \text{ and } \frac{md_1}{|v| + \ell} = \frac{d_2}{u + \ell} = \frac{d}{\ell},$$

where $d_1 \approx 3.40\ \mathrm{cm}$ and $d_2 \approx 4.90\ \mathrm{cm}$. Finally,

$$f = \frac{ud}{d_2 - d_1} \approx 13.33\ \mathrm{cm}.$$