Question(1p) 1. A vigorous debate over whether light is a wave or a particle goes back many centuries. In the 17th century, an English physicist, the father of gravitational theory and so much more, believed that light was composed of a stream of corpuscles. He was so greatly revered as a scientist that it was nearly impossible for anyone to dispute his theory. On the continental side of Europe, however, a most notably Dutch physicist and the father of wave theory, one of the contemporaries of the English physicist, thought that light was a wave vibrating in some sort of a vacuum medium (ether). There was evidence for both pictures. The English and Dutch physicists are respectively known as

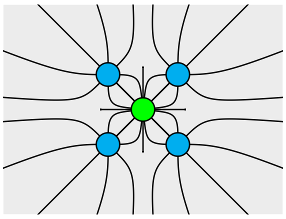
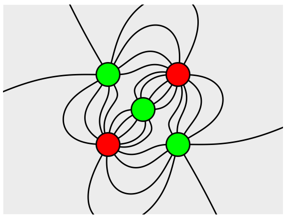
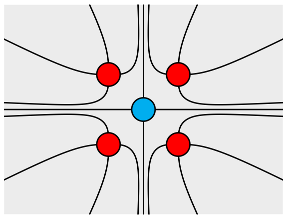
(A) Isaac Newton and Johannes Diderik van der Waals.
(B) Christiaan Huygens and Henry Cavendish.
(C) Henry Cavendish and Johannes Diderik van der Waals.
(D) Thomas Young and Christiaan Huygens.
(E) Isaac Newton and Christiaan Huygens.

Question(1p) 2. Speed of sound in empty space is equal to

(A) 3×10^8 m/s.
(B) a positive temperature-dependent value.
(C) 340 m/s.
(D) a positive pressure-dependent value.
(E) 0 m/s, oftentimes considered undefined.

Question(1p) 3. Consider three types of point-like electric charges of equal magnitude, coloured red, green, and blue. Each type bears its own sign, $+$ or $-$. Some arbitrary planar configurations of their electric field lines are exemplified by the three diagrams. Detect a choice of the type-related signs that fits the diagrams.

(A) ⊖ ⊕ ⊖
(B) ⊕ ⊖ ⊖
(C) ⊖ ⊖ ⊕
(D) ⊖ ⊕ ⊕
(E) ⊕ ⊕ ⊖

Question(1p) 4. It is a pure non-flammable substance. At ambient pressure, its one gram of mass gives out nearly 334 joules of heat while condensing into a solid at the transition temperature below which the volume expands by nearly $0.11\ \mathrm{cm}^3$. The substance seems most certainly to be

(A) lithium.
(B) mercury.
(C) water.
(D) hydrogen.
(E) helium.

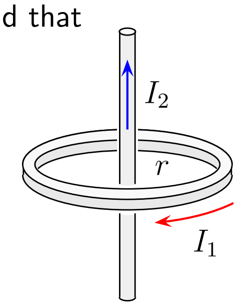
Question(1p) 5. A bright spot sometimes appearing at either side of the sun, often on a luminous ring as shown in the photograph, known since the ancient age by name as *parahelion* or *sundog*, originates from the

(A) sunlight scattering by the aperture blades of the camera.
(B) sunlight refraction/reflection by tiny ice crystals in the atmosphere.
(C) sunlight scattering by car pollution particles in the atmosphere.
(D) sunlight refraction/reflection by the camera lens.
(E) appreciable solar oblateness in the asphericity of the Sun as a star.

Question$^{(1p)}$ 6. The rain is failing vertically downwards. A man walking on the road with a speed constant both in magnitude and direction holds his umbrella tilted. Now, suddenly the rain stops and there is afternoon sun just above the head. In order to protect himself from sun-rays, he holds the umbrella vertical. The reason hidden behind this is most likely due to the fact that

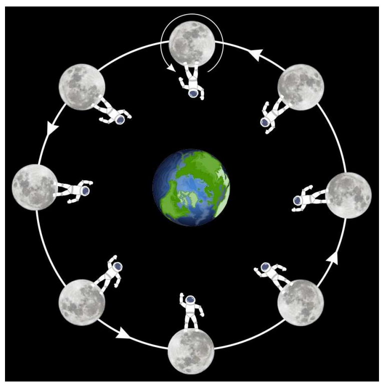
(A) the sun-rays spread out from the sun radially.
(B) the speed of light is much higher than the speed of man.
(C) the light is behaving as a wave, not as a particle.
(D) the velocity vector of light is observed invariant in all inertial frames.
(E) the light is behaving as a particle, not as a wave.

Question$^{(1p)}$ 7. A wired ring of radius r is maintained a constant electric current I_1 flowing in the given circular sense. See the figure right below. An infinite straight wire, supplied with a constant electric current I_2 in the given direction, is exactly placed along ring's symmetry axis. If one measures both character and magnitude of magnetostatic force (F) between the ring and straight wire, then it is found that



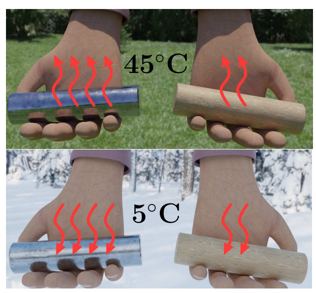
(A) F is repulsive, r-independent, and proportional to the $I_1 \cdot I_2$ product.
(B) F is attractive, r-independent, and proportional to the $I_1 \cdot I_2$ product.
(C) $F = 0$.
(D) F is attractive, r-dependent, and proportional to the $I_1 \cdot I_2$ product.
(E) F is repulsive, r-dependent, and proportional to the $I_1 \cdot I_2$ product.

Question$^{(1p)}$ 8. *Far side* of the Moon, a rather suitable term than the *dark side* which leads to all kinds of misconceptions, refers to the Moon's hemisphere that is facing away from the Earth. Following the figure, that hemisphere is only dark to us as it can never be viewed from the Earth because the



(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.
(B) Moon is tidally locked to Earth's gravity so that it orbits the Earth clockwise and spins anti-clockwise at the same period of nearly a month.
(C) Moon is tidally locked to Earth's gravity so that it orbits the Earth and spins at the same period of a day, both anti-clockwise.
(D) Moon is tidally locked to Earth's gravity so that it orbits the Earth clockwise and spins anti-clockwise at the same period of a day.
(E) sunlight does not, in fact, shine equally upon all sides of the Moon, leaving thus one side behind darker than the other.

Question$^{(2p)}$ 9. Let's study the skin sensation intensity of how cold/warm a bar of metal or a bar of wood is. A healthy person with an invariable metabolic body temperature undertakes two independent experiments, as shown in the photos: the first at summer's $(45°\mathrm{C})$ and the second at winter's ambient temeparture $(5°\mathrm{C})$. Prior to being touched, the two bars have been left for a long time outside. As soon as they are picked up all together, the metal bar (right hand) appears warmer in the first case and colder in the second, as compared to the wood bar (left hand). Which of the following statements explains best such behaviour?



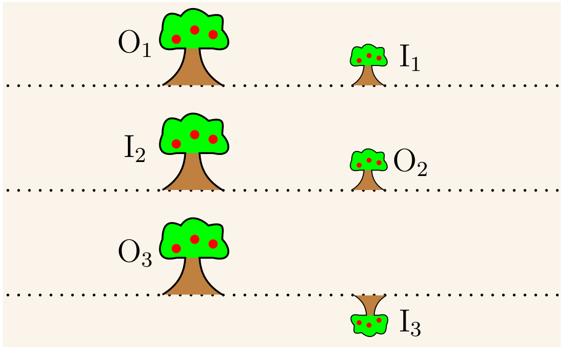
(A) Right-hand skin is rather thermally sensitive than the left-hand skin.
(B) Metal conducts heat significantly faster than wood.
(C) Unlike wood, metal never thermalises to the environmental temperatures.
(D) Wood conducts heat significantly faster than metal.
(E) Left-hand skin is rather thermally sensitive than the right-hand skin.

Question(2p) 10. A light ray is refracted when crossing the boundary from one transparent medium of refractive index n_1 into another of refractive index n_2. Let the incident(refracted) ray makes an angle $\alpha_1(\alpha_2)$ with the normal of a plane tangent to the boundary. The speeds, wavelengths, and frequencies are $c_1(c_2)$, $\lambda_1(\lambda_2)$, and $\nu_1(\nu_2)$, respectively. Identify the statement that is **false**.

(A) $n_1 \geq n_2 \Rightarrow \lambda_1 \leq \lambda_2$
(B) $n_1 = n_2 \Rightarrow \alpha_1 = \alpha_2$
(C) $n_1 < n_2 \Rightarrow c_1 > c_2$
(D) $n_1 \neq n_2 \Rightarrow \nu_1 \neq \nu_2$
(E) $n_1 > n_2 \Rightarrow \alpha_1 < \alpha_2$

Question(2p) 11. Consider three situations of the image production $\mathrm{I_k}$ from its object $\mathrm{O_k}$ (drawn as a tree symbol) due to the ray refraction by one of the two thin lenses: converging () or diverging)(. Find the proper order of lens appearance in every case: $\mathrm{k} = 1, 2,$ and 3.

(A))($- \mathrm{O_1} - \mathrm{I_1}$ & $\mathrm{I_2} - \mathrm{O_2} -$ () & $\mathrm{O_3} -$ () $- \mathrm{I_3}$
(B) $\mathrm{O_1} - \mathrm{I_1} -$)(& () $- \mathrm{I_2} - \mathrm{O_2}$ & $\mathrm{O_3} -$ () $- \mathrm{I_3}$
(C) $\mathrm{O_1} - \mathrm{I_1} -$)(& $\mathrm{I_2} - \mathrm{O_2} -$ () & $\mathrm{O_3} -$)($- \mathrm{I_3}$
(D) $\mathrm{O_1} - \mathrm{I_1} -$)(& $\mathrm{I_2} - \mathrm{O_2} -$ () & $\mathrm{O_3} -$ () $- \mathrm{I_3}$
(E) $\mathrm{O_1} - \mathrm{I_1} -$ () & $\mathrm{I_2} - \mathrm{O_2} -$)(& $\mathrm{O_3} -$ () $- \mathrm{I_3}$



Question(2p) 12. Sketched below is a scheme of an induction cooker comprising: a voltage generator of alternating current (AC) supplying in an electric single-loop circuit a coil through which a rapidly changing magnetic field is formed to generate eddy currents in an electrically resistive iron-based fry-pan placed on a ceramic surface. If you were interested in understanding the underlying mechanisms of how such a cooker fully functions, which one among the offered laws below you most certainly would **not** apply?

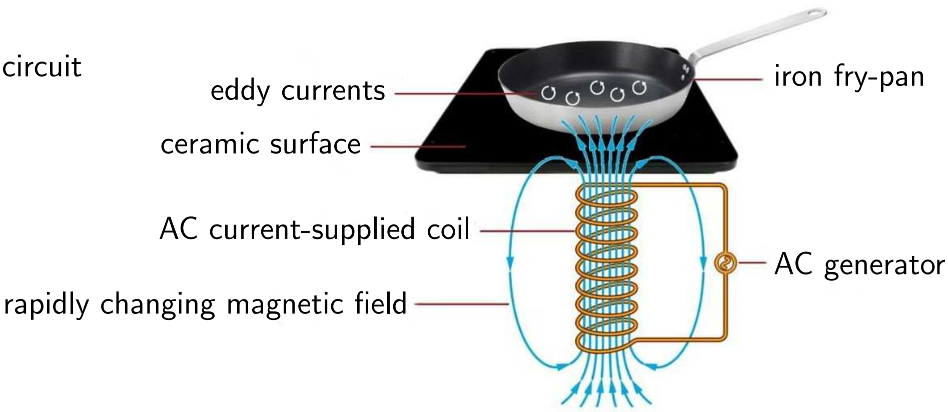
(A) Kirchhoff's nodal law in the circuit

(B) Faraday's law of induction

(C) Ohm's law

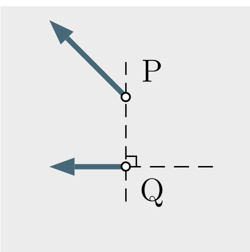
(D) Lenz's law

(E) Joule-Lenz law

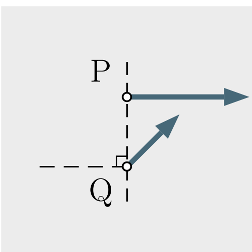


Question(2p) 13. Each of the following figures shows electric field vectors at two points P and Q in a two-dimensional electric field. In which figure can the illustrated field **not** be created by a single point charge?

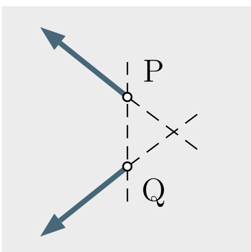
(A)



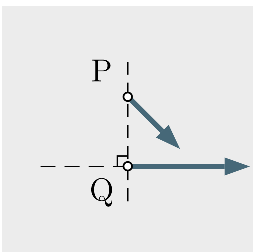
(B)



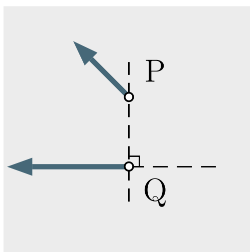
(C)



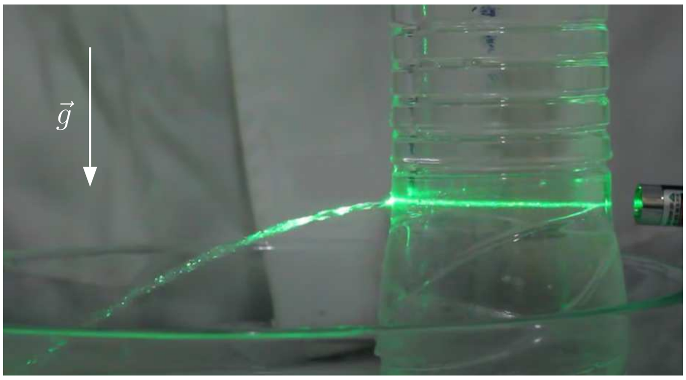
(D)



(E)

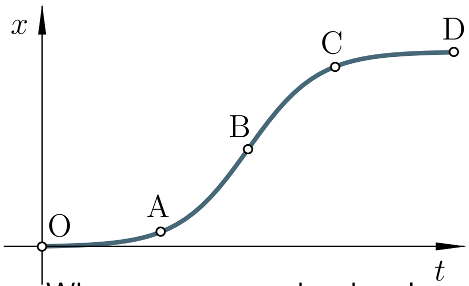


Question$^{(2p)}$ **14.** Take a transparent plastic bottle filled with water, as shown in the snapshot. There is a small hole near the base of the bottle which the water comes out through under gravity. Pass the green laser beam (on the right) behind the bottle in such a way that the beam travels through the filled bottle horizontally and comes out through the hole on the other side (on the left). The water stream flows out of the hole in free fall getting green in colour. The laser beam appears to bend along the stream because it



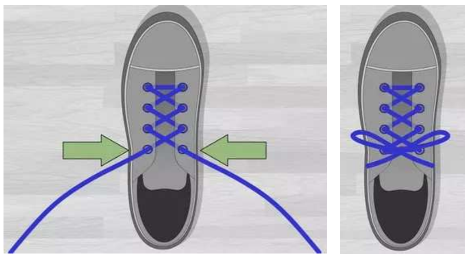
(A) is reflected internally multiple times inside the stream of water which is optically rarer than air.
(B) is entirely absorbed by the surrounding air, that is not the case with the water in the stream.
(C) is green in wavelength – a phenomenon which is inherent to none but this wavelength of light.
(D) must be as curved as the stream is due to the gravity, aligned with a theory proposed by Einstein.
(E) is reflected internally multiple times inside the stream of water which is optically denser than air.

Question$^{(2p)}$ **15.** Displacement versus time graph, $x(t)$, of a particle moving along a straight line is as shown in the figure. Select the alternative that is most likely **not** correct.



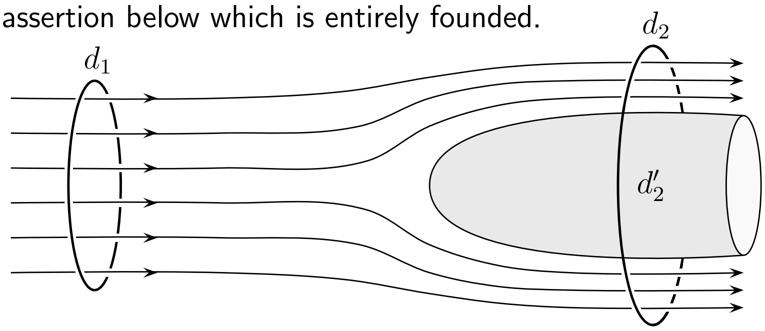
(A) Work done by all the force in region BC is negative.
(B) Work done by all the force in region $\mathrm{OA} \cup \mathrm{BD}$ is negative.
(C) Work done by all the force in region AC is zero.
(D) Work done by all the force in region $\mathrm{OA} \cup \mathrm{BD}$ is positive.
(E) Work done by all the force in region AB is positive.

Question$^{(2p)}$ **16.** Shoelaces make a superb example of a pulley system. When you tug on the shoe laces, they move through tiny holes (eyelets), which reverse the direction of the force and pull the shoe tightly around your foot. A small angle criss-cross lacing is taken in the figures. There are two columns of four eyelets, a distance ℓ apart, or equivalently four adjacent rows of the eyelet pair. Each end of the inextensible shoelace is pulled sidewise by 1.00 cm remaining taut in the eyelets upon the most common knot is tied. Then, ℓ uniformly alters into $\ell - \Delta\ell$, where



(A) $\Delta\ell \approx 0.50$ cm.
(B) $\Delta\ell \approx 0.75$ cm.
(C) $\Delta\ell \approx 1.00$ cm.
(D) $\Delta\ell \approx 0.25$ cm.
(E) $\Delta\ell \approx 1.25$ cm.

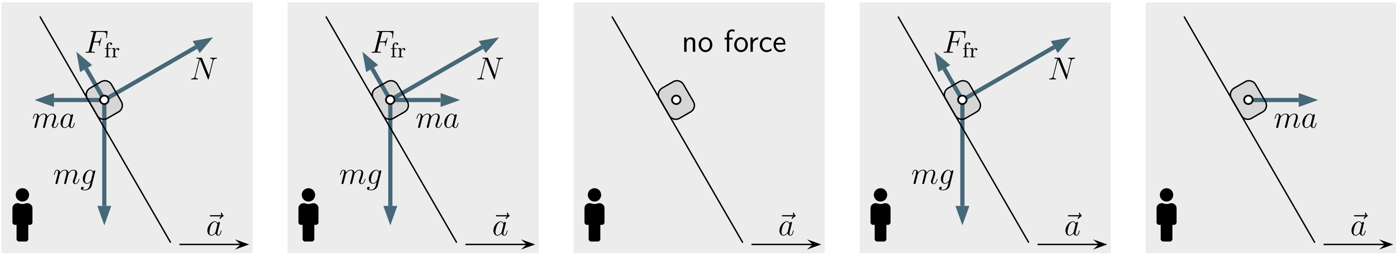
Question$^{(3p)}$ **17.** Figure illustrates induction lines of an axially symmetric tube-like magnetic field. In the left region of space, the field is homogeneous within a circular cross-section of diameter $d_1 = 3.5$ m. At this point, magnitudes of magnetic flux and its surface density are Φ_1 and B_1 (induction), respectively. In the right region of space, the magnetic field bypasses a non-magnetic obstacle from all sides following the axial symmetry until it becomes homogeneous again within a hollow circular cross-section of diameters $d_2' = 2$ m (inner) and $d_2 = 4$ m (outer). At this point, magnitudes of magnetic flux and its surface density are Φ_2 and B_2 (induction), respectively. Single out the sole assertion below which is entirely founded.



(A) $B_1 = B_2$ and $\Phi_1 = \Phi_2$.
(B) $B_1 < B_2$ and $\Phi_1 = \Phi_2$.
(C) $B_1 > B_2$ and $\Phi_1 > \Phi_2$.
(D) $B_1 > B_2$ and $\Phi_1 = \Phi_2$.
(E) $B_1 \geq B_2$ and $\Phi_1 < \Phi_2$.

Question(3p) 18. A block of mass m sits on a plane, and there is friction force (magnitude F_{fr}) between the block and the plane. The plane is accelerated to the right with uniform acceleration of magnitude $a \equiv |\vec{a}|$, in the laboratory inertial frame (🕴). If the block remains at the same position on the plane, which of the following pictures might show the correct free-body diagram of the real individual forces acting on the block, as viewed from the laboratory inertial frame? Gravity acts vertically down with acceleration g. Magnitude of the plane-block normal reaction force is denoted with N.

(A) (B) (C) (D) (E)



Question(3p) 19. You are provided with two identical bars of the same weight, painted with the same colour, one of which is a steel bar and the remaining one a permanent magnet. There is a way to distinguish between the two bars by inspecting the two T-shape configurations as shown: (1) and (2). Discriminating between the two bars is made possible because the configuration

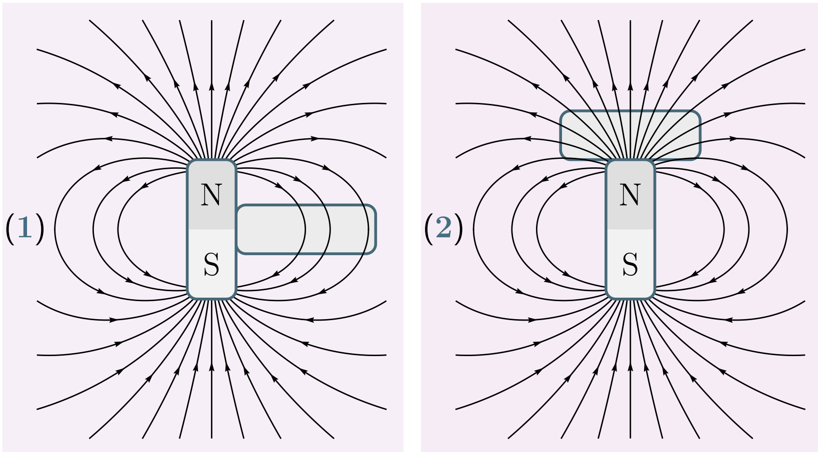
(A) (1) will switch to (2).

(B) (1) remains rather stable.

(C) (2) will switch to (1).

(D) (2) remains rather unstable.

(E) (1) is more probable than (2).



Question(3p) 20. A rod is fixed perpendicularly to the surface of an inclined plane of angle of elevation $\alpha = 30°$. The end of the light inextensible thread of a simple mathematical pendulum of length ℓ is attached to the top of the rod. The angle between the thread of the pendulum and the surface of the slope is $\beta = 45°$. What is the period T of the pendulum when it swings with small amplitude under the gravity of acceleration g, if friction is negligible?

(A) $T = 2\pi\sqrt{\ell\sqrt{3}/g}$

(B) $T = 2\pi\sqrt{g\sqrt{3}/\ell}$

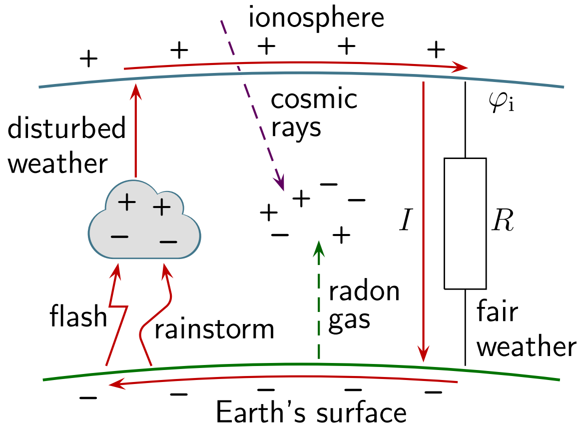
(C) $T = 2\pi\sqrt{\ell/g}$

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

(E) $T = 2\pi\sqrt{g\sqrt{2}/\ell}$

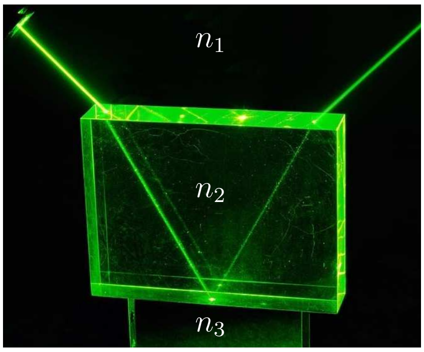
Question(3p) **21.** A well-established feature of our atmosphere is its global electric circuit, which refers to a ceaseless flow of electric current I around the planet. Earth's atmosphere can be modelled as a global capacitor, with the conducting layer in the upper atmosphere (ionosphere) and Earth's surface as the conducting plate, which are separated by the weakly conducting atmosphere in-between, having electric resistance R. Earth's thunderstorms repeatedly act as batteries to generate a large potential difference φ_i between the ionosphere and Earth's surface. Find the **false** statement among the following.

(A) Positive charges in the storm top flow upwards into the electrically conducting ionosphere.
(B) Measurements show that there are as many thunderstorms, active around the globe at any one time.
(C) Even if all the thunderstorms were suddenly switched off, the global capacitor would never discharge.
(D) Though weakly, the atmosphere conducts electricity as it gets ionized by cosmic rays, radon gas, and the like.
(E) Negative charges in the storm bottom are transferred down to Earth's surface through lightning and precipitation.



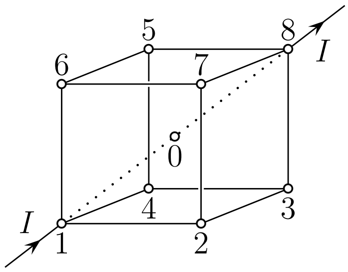
Question(3p) **22.** Monochromatic light travelling through three transparent substances follows a path shown in the photography. Arrange their indices of refraction in order from smallest to largest.

(A) $n_1 < n_3 < n_2$
(B) $n_3 < n_1 < n_2$
(C) $n_3 < n_2 < n_1$
(D) $n_1 < n_2 < n_3$
(E) $n_2 < n_1 < n_3$



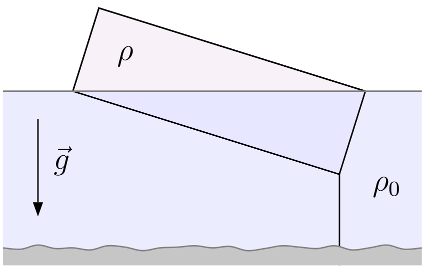
Question(3p) **23.** A cubic network is made of homogeneous resistance wire of uniform cross-section. Electric current of intensity I is conducted into vertex 1 through a long, straight wire directed towards the centre 0 of the cube, and it is conducted away through vertex 8 in the same way, as illustrated in the figure. What is the direction of the magnetic induction vector $\vec{B}_0$ at the centre 0 of the cube?

(A) $\vec{B}_0$ is parallel to $\overrightarrow{18}$.
(B) $\vec{B}_0$ is parallel to $\overrightarrow{47}$.
(C) Given $\vec{B}_0 = \vec{0}$ there is no direction.
(D) $\vec{B}_0$ is parallel to $\overrightarrow{25}$.
(E) $\vec{B}_0$ is parallel to $\overrightarrow{81}$.



Question(3p) **24.** A solid wooden plank of mass density ρ is floating on water of mass density ρ_0 in a large basin. It is tethered to the bottom of the basin by a string attached at mid-point of an edge of its bottom face, which causes it to float with a diagonal of one of its vertical cross-section coinciding with the level surface of the water, as shown in the figure. What is the relative density of the wood (ρ/ρ_0)?

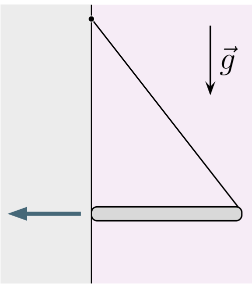
(A) $1/5$
(B) $1/2$
(C) $2/3$
(D) $1/3$
(E) $1/4$

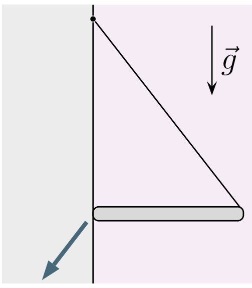


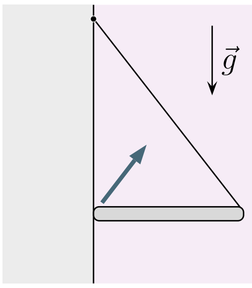
Question$^{(4p)}$ **25.** Boil water in a large pot on the stove at ambient conditions. Put some cool milk in a thin-walled cup (colored yellow in the figure), then immerse the cup into the boiling water ($100°C$) so that it does not touch the walls of the pot. Assume that the boiling point of milk is coincident with that of water and that the pot never runs out of water. Trace the alien out of the offered statements below, as concluded upon a very long period time.

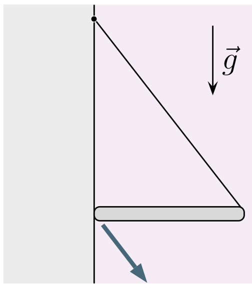
(A) There is no temperature difference between the water and milk.
(B) The milk temperature is 100 °C.
(C) No net heat flows as the cup and pot reach thermal equilibrium.
(D) Heat has previously flowed from the water into the cooler cup.
(E) The milk in the cup is boiling.

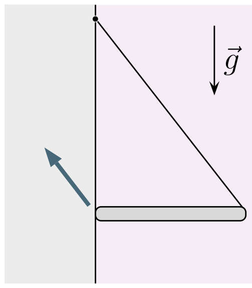
Question$^{(4p)}$ **26.** A uniform rod with a certain mass is supported at the left end by a non-smooth vertical wall, while being attached at the right end to a massless inextensible string. With help of some tension, the string connected to the wall holds the rod horizontally in static equilibrium. Gravity $\vec{g}$ acts vertically down. Which arrow best represents the direction of the reaction force exerted by the rod on the wall?

(A)


(B)


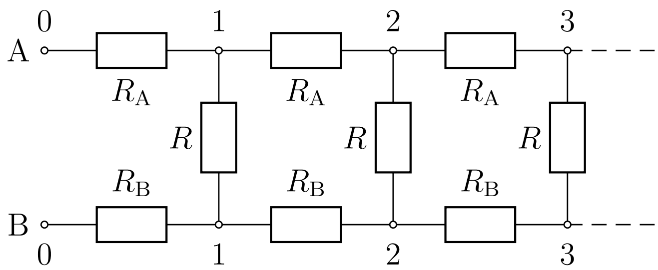
(C)


(D)


(E)


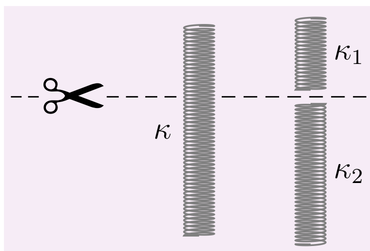
Question$^{(4p)}$ **27.** Determine the supplying voltage U_0 between the terminals A and B of the chain, consisting of an extremely large number of identical links from resistors with electric resistances $R_{\rm A}$, $R_{\rm B}$, and R (see scheme), if it is known that on R resistor in the link number 4 (counting from the side of the terminals A and B, the link number 0) the voltage is $U_4 = 240$ V, and on the resistor R in the link number 6 the voltage is $U_6 = 200$ V. Express the required value in volts and indicate as the answer its numerical value, rounded to one single decimal digit.

(A) $U_0 = 346.5$ V
(B) $U_0 = 345.6$ V
(C) $U_0 = 346.6$ V
(D) $U_0 = 345.1$ V
(E) $U_0 = 345.4$ V



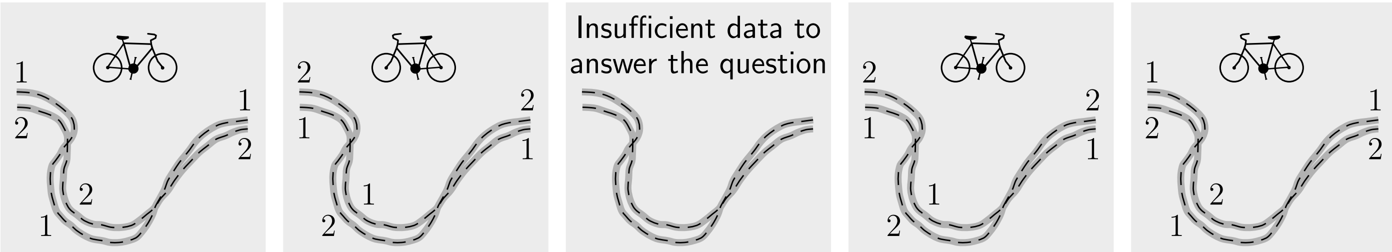
Question$^{(4p)}$ **28.** Consider an ideal elastic spring of force constant κ, as shown below. It is cut in two parts at its one-third length. Two ideal elastic springs are thus obtained with force constants κ_1 (the shorter spring) and κ_2 (the longer spring) expressed as

(A) $\kappa_1 = 3\kappa/2$ and $\kappa_2 = 3\kappa$.
(B) $\kappa_1 = \kappa$ and $\kappa_2 = \kappa$.
(C) $\kappa_1 = 3\kappa$ and $\kappa_2 = 3\kappa/2$.
(D) $\kappa_1 = \kappa/3$ and $\kappa_2 = 2\kappa/3$.
(E) $\kappa_1 = 4\kappa/3$ and $\kappa_2 = 4\kappa$.

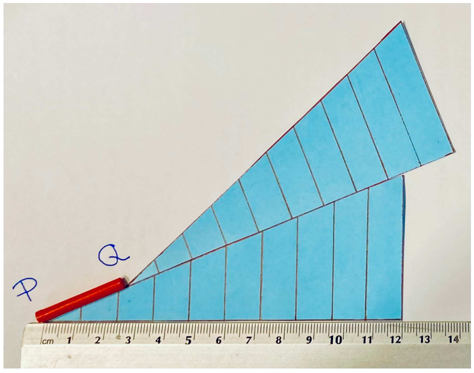


Question$^{(4p)}$ 29. Viewed from the air, the figures show a wet track of a bicycle on dry asphalt after the bicycle passed a puddle. Trail made by the front wheel is labelled with 1, while the trail made by the rear one is labelled with 2. The bike may have moved from the left to the right (🚲) or from the right to the left (🚲). Select the right figure.

(A) (B) (C) (D) (E)



Question$^{(4p)}$ 30. Consider a homemade vernier scale, as shown in the photo. We are interested in measuring the length of the red plastic stick PQ in the method used. If both inclines are identical forming a right-triangle geometry with cateti and hypotenuse of length: 12 cm (with ten parts of equal length), 5 cm, and 13 cm, respectively, then what is the least count of such a do-it-yourself instrument?



(A) 0.50 cm

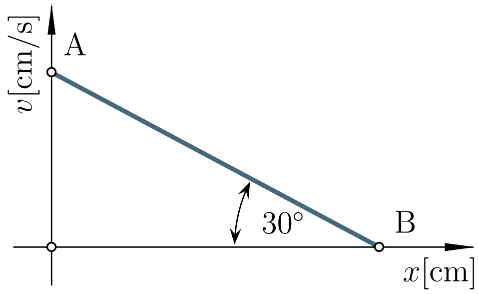
(B) 0.13 cm

(C) 0.12 cm

(D) 0.10 cm

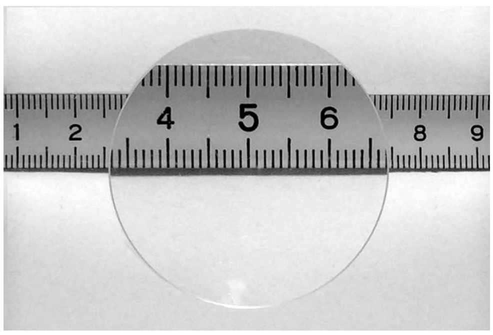
(E) 0.05 cm

Question$^{(4p)}$ 31. Velocity $v[\mathrm{cm/s}]$ versus displacement $x[\mathrm{cm}]$ linear graph of a particle moving along a straight line through a viscous medium, free of gravity, is shown in the figure. The moving particle experiences viscous drag given by expression $\vec{F} = -b\vec{v}$, where $\vec{v}$ is instantaneous velocity of the particle and constant $b = 10\sqrt{3}\ \mathrm{N} \cdot \mu\mathrm{s/m}$. The displacement x measures the traveling distance from the point of projection (A), before the particle terminates its motion (B). Estimate the value of particle mass m.



(A) $m = 0.01$ g.
(B) $m = 0.03$ mg.
(C) $m = 100$ μg.
(D) $m = 0.01$ mg.
(E) $m = 0.03$ g.

Question$^{(4p)}$ 32. The lens of the unknown focal length f has a diameter of 4.00 cm and is a distance 5.00 cm apart from the ruler tape, as shown in the photo. The cyphers on the ruler tape are expressed in centimeters. Estimate the range of values you are fairly sure the true value of f lies in.



(A) $f \in (19, 22)$ cm

(B) $f \in (10, 11)$ cm

(C) $f \in (15, 16)$ cm

(D) $f \in (12, 15)$ cm

(E) $f \in (16, 19)$ cm