SJPO 2026

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22 May 2026

The questions have been reordered in this LaTeX document.
This document has been written independently of IPS.

Question 1

Which of the following is a unit vector? ($\hat{\mathbf{i}}, \hat{\mathbf{j}}, \hat{\mathbf{k}}$ are standard unit vectors in the x, y, z directions respectively.)

(a) $\hat{\mathbf{i}} + \hat{\mathbf{j}}$

(b) $\hat{\mathbf{i}} \cdot \hat{\mathbf{i}}$

(c) $\hat{\mathbf{i}} \times \hat{\mathbf{i}}$

(d) $(\hat{\mathbf{i}} \times \hat{\mathbf{j}}) \times \hat{\mathbf{k}}$

(e) $(\hat{\mathbf{i}} \times \hat{\mathbf{j}}) \times \hat{\mathbf{i}}$

Question 2

Chris stands still while watching a man walk at speed u towards a moving mirror. Surprisingly, Chris sees that the image of the man remains stationary. What must be the speed and direction of motion of the mirror?

(a) $u/2$ away from the man

(b) $u/2$ towards the man

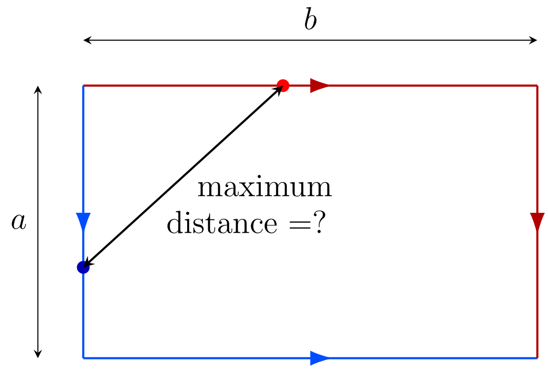
(c) u away from the man

(d) u towards the man

(e) $2u$ away from the man

Question 3

Two runners start on the same corner of a rectangular track (e.g. upper-left corner) of sides a and b, with $a < b$. They begin running towards the opposite corner of the track at the same speed through two different paths around the track. What is the maximum distance reached between the two runners?



(a) a

(b) b

(c) $a\sqrt{2}$

(d) $b\sqrt{2}$

(e) $\sqrt{a^2 + b^2}$

Question 4

Shuhao stands straight with height $h = 175\,\text{cm}$. He casts a shadow of length $l = 300\,\text{cm}$ on the ground. What is the angle of the Sun above the horizon?

(a) $30°$

(b) $36°$

(c) $45°$

(d) $54°$

(e) $60°$

Question 5

A bubble of uniform density ρ_b and volume V is deep within a fluid of uniform density ρ_f. What is the total change in potential energy of the system if the bubble rises by a small height h?

(a) $\rho_b V g h$

(b) $\rho_f V g h$

(c) $(\rho_b - \rho_f) V g h$

(d) $(\rho_f - \rho_b) V g h$

(e) $(\rho_b + \rho_f) V g h$

Question 6

A block is released from rest on an inclined ramp, and slides down the ramp with acceleration $a > 0$. The ramp has coefficients of static and kinetic friction μ_s and μ_k respectively. What is the smallest possible value of a?

(a) $(1 - \mu_k) g$

(b) $(\mu_s - \mu_k) g$

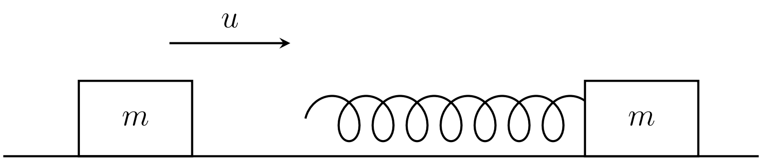
(c) $\dfrac{\mu_s}{\sqrt{1 + \mu_s{}^2}} g$

(d) $\dfrac{\mu_k}{\sqrt{1 + \mu_s{}^2}} g$

(e) $\dfrac{\mu_s - \mu_k}{\sqrt{1 + \mu_s{}^2}} g$

Question 7

A block of mass m is launched with speed u towards an ideal spring of force constant k, which is attached to another block of equal mass m. Both blocks are free to slide on a frictionless horizontal surface. What is the maximum compression of the spring?



(a) $\dfrac{u}{2}\sqrt{\dfrac{m}{k}}$

(b) $\dfrac{u\sqrt{2}}{2}\sqrt{\dfrac{m}{k}}$

(c) $\dfrac{u\sqrt{3}}{2}\sqrt{\dfrac{m}{k}}$

(d) $\dfrac{u\sqrt{6}}{2}\sqrt{\dfrac{m}{k}}$

(e) $u\sqrt{\dfrac{m}{k}}$

Question 8

A droplet falls through a tree and collides with a leaf every vertical distance h. Each collision causes the droplet to lose half of its speed. After falling through a large distance, the droplet achieves steady state. What is the terminal speed reached by the droplet? Neglect air resistance.

(a) $\sqrt{gh}$

(b) $\sqrt{2gh}$

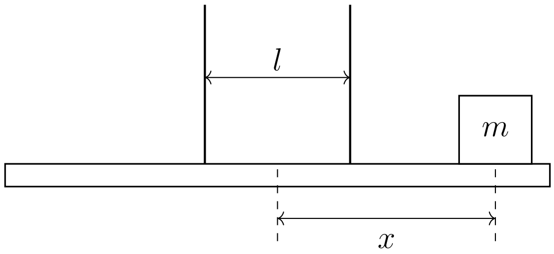
(c) $\sqrt{\frac{2}{3}gh}$

(d) $\sqrt{\frac{8}{3}gh}$

(e) $\sqrt{8gh}$

Question 9

A long uniform rod of mass M is held horizontal by two strings, attached symmetrically to the rod at distance l apart. A small block of mass m initially rests on the rod's centre. It is then slowly moved towards the right. At what distance x between the block and the rod's centre does one of the strings start to become slack?



(a) $\frac{l}{2}\frac{M+m}{m}$

(b) $\frac{l}{2}\frac{M-m}{m}$

(c) $\frac{l}{2}\frac{M+m}{M}$

(d) $\frac{l}{2}\frac{m}{M+m}$

(e) $\frac{l}{2}\frac{M}{M+m}$

Question 10

Consider a spring-mass system of mass m and force constant k that experiences a linear damping force $-bv$, where $b > 0$ is a constant damping coefficient. The equation of motion can be written as

$$ma + bv + kx = 0$$

Which of the following statement(s) correctly describe/describes the motion of the mass?

I. The period of oscillations depends on m and k, but not b.

II. The rate of decay of oscillations depends on b, but not m and k.

III. Critical damping can only take place for one specific value of b (given a fixed m and k).

(a) I only

(b) III only

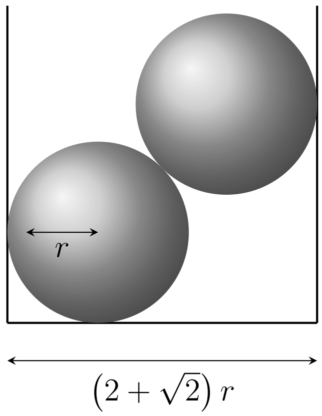
(c) I and II

(d) I and III

(e) II and III

Question 11

A box of base width $(2+\sqrt{2})r$ is placed on a horizontal ground. Two identical spheres of mass m and radius r are packed inside it. What is the force exerted between the two spheres? Assume all surfaces are smooth.



(a) mg

(b) $2mg$

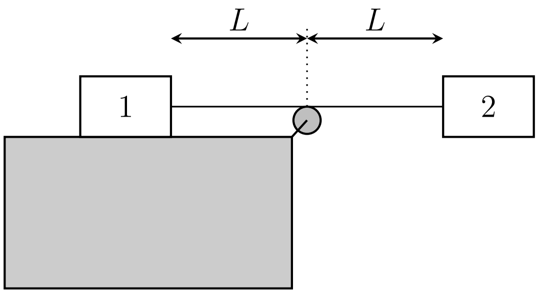
(c) $\dfrac{mg}{2}$

(d) $mg\sqrt{2}$

(e) $\dfrac{\sqrt{2}}{2}mg$

Question 12

Two blocks of equal masses are connected by an inextensible string passing over a light pulley at the edge of a table. Block 1 is on the table, while block 2 is suspended freely. Both blocks are initially held at equal horizontal distances from the pulley. The system is then released from rest. Which statement is true about the motion of the blocks? Neglect friction and air resistance.



(a) Both blocks remain at rest as their masses are equal.

(b) Block 1 reaches the pulley before block 2 strikes the table.

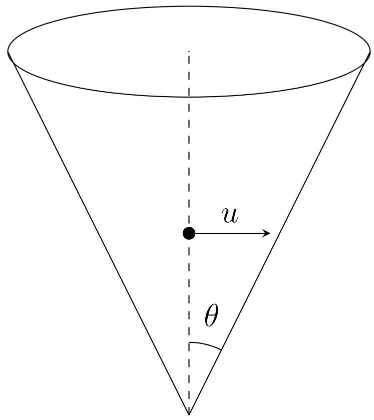
(c) Block 1 reaches the pulley after block 2 strikes the table.

(d) Block 1 reaches the pulley and block 2 strikes the table at the same time.

(e) Not enough information to determine which event occurs first.

Question 13

A particle is held above the tip of an inverted hollow cone of half-angle θ. The particle is projected with a horizontal speed u such that it bounces back and forth indefinitely between the two sides of the cone symmetrically. What is the period of its motion? Neglect air resistance and assume all collisions are elastic.



(a) $\dfrac{u}{g}\sin\theta$

(b) $\dfrac{2u}{g}\sin\theta$

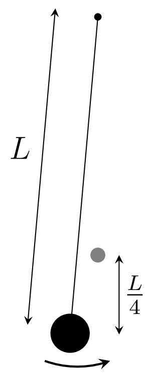
(c) $\dfrac{4u}{g}\sin\theta$

(d) $\dfrac{u}{g}\tan\theta$

(e) $\dfrac{4u}{g}\tan\theta$

Question 14

A pendulum of mass m and length L swings in the vertical plane. At the lowest point of its motion, the string catches on a peg located at a distance $L/4$ above the mass. If the tension in the string just before hitting the peg is $T = 3mg$, what is the tension in the string right after hitting the peg? Neglect air resistance.



(a) $\frac{3}{4}mg$

(b) $\frac{3}{2}mg$

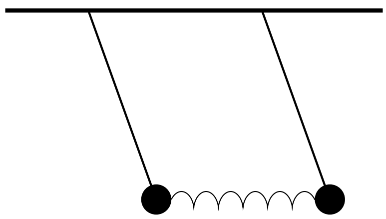
(c) $3mg$

(d) $\frac{5}{2}mg$

(e) $9mg$

Question 15

Two identical pendulums, each with mass m and length l, are connected by a spring of force constant k. The two pendulums are set in the normal mode where they oscillate **in phase** with each other. What is the period of their oscillations?



(a) $2\pi\sqrt{\dfrac{l}{g}}$

(b) $2\pi\sqrt{\dfrac{m}{k}}$

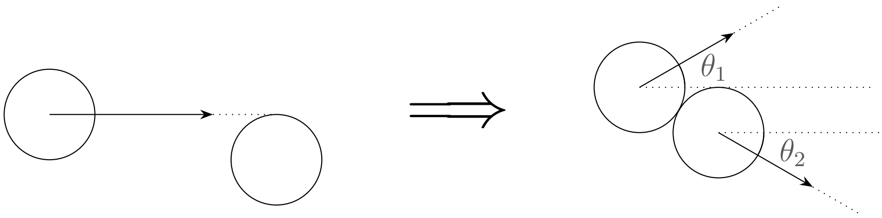
(c) $2\pi\sqrt{\dfrac{l}{g}+\dfrac{m}{k}}$

(d) $\dfrac{2\pi}{\sqrt{\frac{g}{l}+\frac{k}{m}}}$

(e) $\dfrac{2\pi}{\sqrt{\frac{g}{l}+\frac{2k}{m}}}$

Question 16

Two identical billiard balls undergo a side-on elastic collision on a frictionless table, where one ball strikes another stationary ball off-centre. The moving ball is deflected by an angle $\theta_1 = 75°$. What is the deflection angle θ_2 of the other ball?



(a) 15°

(b) 30°

(c) 45°

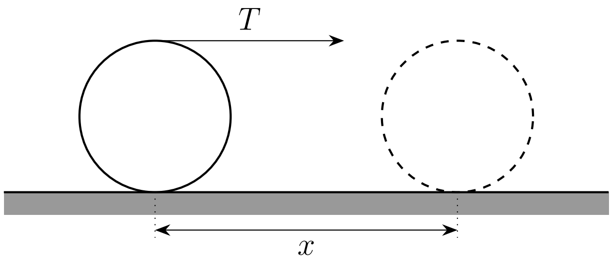
(d) 60°

(e) 75°

Use the information below to answer Questions 17 and 18.

A uniform solid cylinder lies on rough horizontal ground. A string wrapped around the cylinder is pulled at the top with constant horizontal tension T. The cylinder rolls without slipping, moving a distance x forward.

(The moment of inertia of a uniform solid cylinder of mass m and radius r is $I = \frac{1}{2}mr^2$ about its central axis.)



Question 17

What is the magnitude of the friction exerted on the cylinder by the ground?

(a) 0

(b) $\dfrac{1}{4}T$

(c) $\dfrac{1}{3}T$

(d) $\dfrac{1}{2}T$

(e) T

Question 18

What is the work done by the tension T?

(a) 0

(b) $\dfrac{1}{2}Tx$

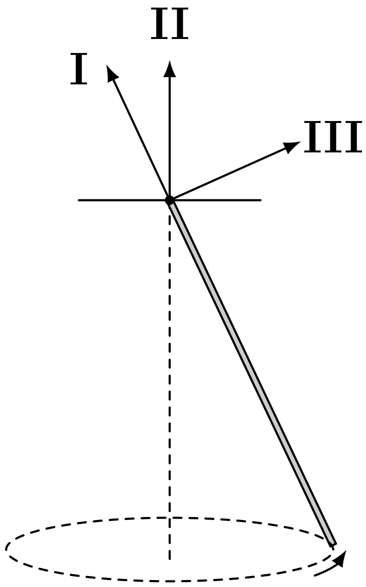
(c) Tx

(d) $\dfrac{3}{2}Tx$

(e) $2\,Tx$

Question 19

A thin stick is pivoted at its top end and is set to swing rigidly in uniform circular motion about the vertical axis. What are the directions of its angular velocity $\vec{\omega}$ and its angular momentum $\vec{L}$?



(a) $\vec{\omega}$ in direction **I** and $\vec{L}$ in direction **I**

(b) $\vec{\omega}$ in direction **II** and $\vec{L}$ in direction **I**

(c) $\vec{\omega}$ in direction **II** and $\vec{L}$ in direction **II**

(d) $\vec{\omega}$ in direction **II** and $\vec{L}$ in direction **III**

(e) $\vec{\omega}$ in direction **III** and $\vec{L}$ in direction **II**

Question 20

A mass is placed on the edge of a horizontal turntable of radius R and coefficient of static friction μ_s. Starting from rest (at time $t = 0$), the turntable begins to rotate at a constant angular acceleration α. At what time t does the mass slip off the turntable?

(a) $\dfrac{\mu_s g}{R\alpha}$

(b) $\left(\dfrac{\mu_s g}{R\alpha^2}\right)^{1/2}$

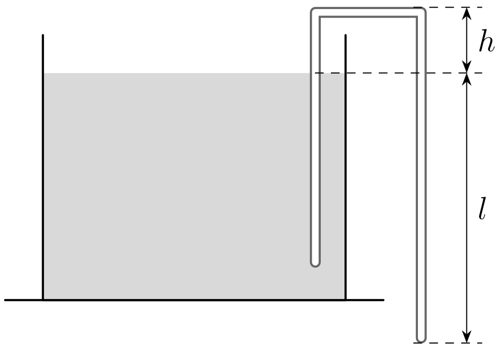
(c) $\left(\dfrac{\mu_s g}{R\alpha^2} - \dfrac{1}{\alpha}\right)^{1/2}$

(d) $\left(\dfrac{{\mu_s}^2 g^2}{R^2\alpha^2} - 1\right)^{1/2}$

(e) $\left(\dfrac{{\mu_s}^2 g^2}{R^2\alpha^4} - \dfrac{1}{\alpha^2}\right)^{1/4}$

Question 21

A siphon is a seemingly gravity-defying device that can empty a tank of fluid by causing fluid to flow up, then down, and out of the siphon. In this setup, the siphon reaches a maximum height h above the fluid surface, and minimum height l below the fluid surface. Let P_0 be the atmospheric pressure and ρ be the fluid density. What is the maximum height h for which the siphon will work? Assume that the siphon has a uniform diameter and that the tank is very large.



(a) $\dfrac{P_0}{\rho g}$

(b) $\dfrac{P_0}{2\rho g}$

(c) $\dfrac{P_0}{\rho g} - l$

(d) $\dfrac{P_0}{2\rho g} - l$

(e) There is no maximum height; the siphon will always work for any h.

Question 22

A tiny dust particle is at rest in space at a large distance r from the Earth. Due to Earth's gravitational attraction, the dust particle begins moving in a straight line towards the Earth. The Earth has mass M and radius R, with $r \gg R$. What is the time taken for the dust particle to reach the Earth?

(a) $\sqrt{\dfrac{2r}{g}}$

(b) $\sqrt{\dfrac{2r^3}{GM}}$

(c) $\dfrac{\pi}{2\sqrt{2}}\sqrt{\dfrac{r^3}{GM}}$

(d) $\pi\sqrt{\dfrac{r^3}{GM}}$

(e) $2\pi\sqrt{\dfrac{r^3}{GM}}$

Question 23

A mass is initially held at a height h above the Earth's surface, with the Sun directly overhead. The mass is then released. What is the minimum height h such that the mass proceeds to rise towards the Sun instead of falling back towards the Earth?

Data:

- Mass of Sun $M_S = 1.99 \times 10^{30}\,\text{kg}$
- Mass of Earth $M_E = 5.97 \times 10^{24}\,\text{kg}$
- Radius of Sun $R_S = 6.96 \times 10^5\,\text{km}$
- Radius of Earth $R_E = 6.37 \times 10^3\,\text{km}$
- Distance between the centres of the Sun and Earth $d_{SE} = 1.50 \times 10^8\,\text{km}$

(a) $4.43 \times 10^2\,\text{km}$

(b) $2.59 \times 10^4\,\text{km}$

(c) $2.53 \times 10^5\,\text{km}$

(d) $1.49 \times 10^6\,\text{km}$

(e) $7.50 \times 10^7\,\text{km}$

Question 24

A satellite of mass m is in a circular orbit of radius r around a planet of mass M. It can be shown that its kinetic energy and potential energy are given by

$$\text{Kinetic energy} = \frac{GMm}{2r}$$
$$\text{Potential energy} = -\frac{GMm}{r}$$

Suppose that the satellite's engine is suddenly shut down. As a result of resistive forces, how do the radius of the orbit and the linear speed of the satellite change over time?

(a) Radius decreases and speed decreases.

(b) Radius decreases and speed increases.

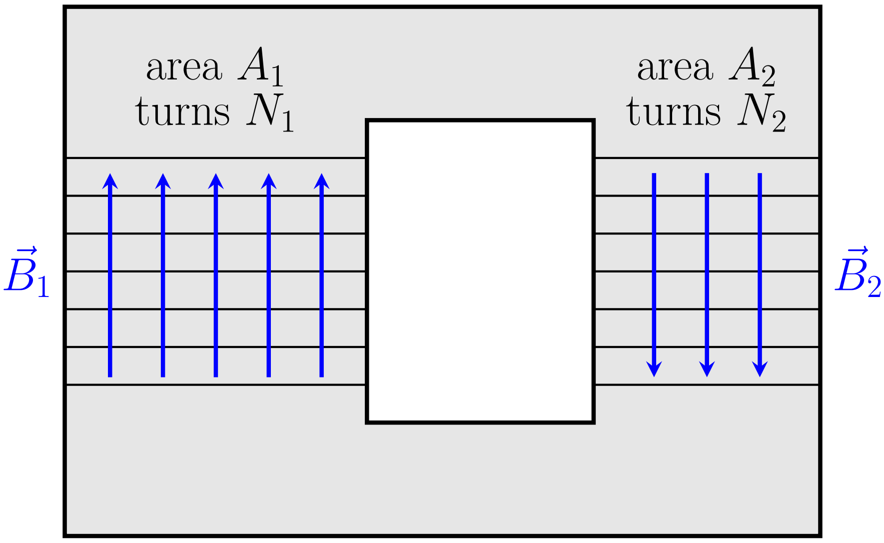
(c) Radius increases and speed decreases.

(d) Radius increases and speed increases.

(e) Radius remains unchanged and speed decreases.

Question 25

Consider a transformer with an **ideal** magnetic core. Each side of the core has different areas A_1 and A_2, wrapped by coils of N_1 and N_2 turns respectively. If the average magnetic fields on each side of the core are B_1 and B_2 respectively, what is the ratio B_1/B_2?



(a) 1

(b) $\dfrac{A_1}{A_2}$

(c) $\dfrac{A_2}{A_1}$

(d) $\dfrac{A_1 N_1}{A_2 N_2}$

(e) $\dfrac{A_2 N_2}{A_1 N_1}$

Question 26

A non-ideal voltmeter of internal resistance R_V and a non-ideal ammeter of internal resistance R_A are connected **in series** to an ideal battery. When a certain resistor is connected in parallel with the voltmeter, the voltmeter reading decreases by a factor of 2, while the ammeter reading increases by a factor of 4. What is the ratio R_V/R_A?

(a) 2

(b) 3

(c) 4

(d) 6

(e) 8

Question 27

Two capacitors start out with different charges. The first capacitor has capacitance C and initial charge $3Q$, while the second capacitor has capacitance $2C$ and initial charge Q. The two capacitors are then connected in series to an ideal battery of voltage V. What is the final charge on the first capacitor (with capacitance C)?

(a) $\frac{2}{3}CV$

(b) $3CV$

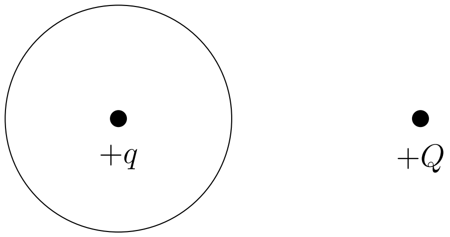
(c) $\frac{2}{3}CV + \frac{2}{3}Q$

(d) $\frac{2}{3}CV + Q$

(e) $\frac{2}{3}CV + 3Q$

Question 28

A point charge $+q$ is placed at the centre of a neutral, conducting spherical shell. Another point charge $+Q$ is placed outside the shell. Which of the following statements is true about the net forces experienced by each charge?



(a) Both charges experience a net force, and they have equal magnitudes.

(b) Both charges experience a net force, and they have different magnitudes.

(c) Both charges experience no net force.

(d) $+Q$ experiences no net force, but $+q$ experiences a net force.

(e) $+q$ experiences no net force, but $+Q$ experiences a net force.

Question 29

A charged sphere of radius R has a hollow core of radius c at its centre, but is otherwise solid with its charge distributed uniformly across the remaining solid. Which option correctly describes the electric field strength E at a distance r from the centre of the sphere, where $c \leq r \leq R$?

(a) $E \propto r$

(b) $E \propto \dfrac{1}{r^2}$

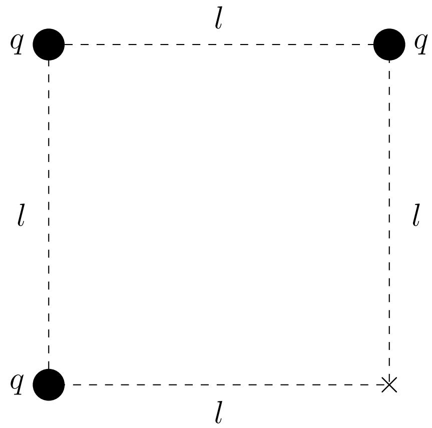
(c) $E \propto \dfrac{1}{r^2} - \dfrac{1}{c^2}$

(d) $E \propto r - \dfrac{c^3}{r^2}$

(e) $E \propto r - \dfrac{R^3}{r^2}$

Use the information below to answer Questions 30 and 31.

Three identical charges, each with charge q, are placed on three corners of a square of length l.



Question 30

What is the magnitude of the electric field at the fourth corner?

(a) $\dfrac{3q}{4\pi\varepsilon_o l^2}$

(b) $\dfrac{5q}{8\pi\varepsilon_o l^2}$

(c) $\dfrac{q}{4\pi\varepsilon_o l^2}\left(\sqrt{2}+\dfrac{1}{\sqrt{2}}\right)$

(d) $\dfrac{q}{4\pi\varepsilon_o l^2}\left(\sqrt{2}+\dfrac{1}{2}\right)$

(e) $\dfrac{q}{4\pi\varepsilon_o l^2}\left(\sqrt{2}+1\right)$

Question 31

What is the energy required to place another charge q at the fourth corner? Assume that this new charge started infinitely far away.

(a) $\frac{3q^2}{4\pi\varepsilon_0 l}$

(b) $\frac{3q^2}{8\pi\varepsilon_0 l}\sqrt{2}$

(c) $\frac{q^2}{4\pi\varepsilon_0 l}\left(\sqrt{2}+\frac{1}{2}\right)$

(d) $\frac{q^2}{4\pi\varepsilon_0 l}\left(\sqrt{2}+4\right)$

(e) $\frac{q^2}{4\pi\varepsilon_0 l}\left(2+\frac{\sqrt{2}}{2}\right)$

Question 32

A positive charge q moving through a vacuum at speed v meets a plane electromagnetic wave propagating in the **opposite** direction. The maximum electric field in the electromagnetic field is E. What is the maximum force experienced by the charge?

(a) qE

(b) $qE\left(1+\frac{v}{c}\right)$

(c) $qE\left(1-\frac{v}{c}\right)$

(d) $qE\left(1+\frac{v^2}{c^2}\right)$

(e) $qE\left(1-\frac{v^2}{c^2}\right)$

Question 33

A long solenoid has n turns per unit length and current I. What is the magnetic field at the **end** of the solenoid along its axis?

Hint: Consider the superposition of the magnetic field.

(a) $\frac{1}{4}\mu_0 nI$

(b) $\frac{1}{2}\mu_0 nI$

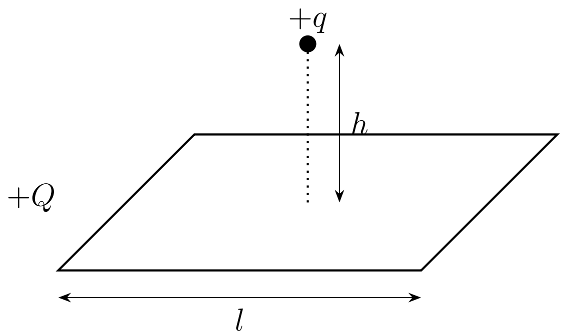
(c) $\mu_0 nI$

(d) $2\mu_0 nI$

(e) $4\mu_0 nI$

Question 34

A plane of mass m and uniformly distributed charge $+Q$ is repelled by a stationary point charge $+q$. The plane is a square with side l, and the charge is at a perpendicular distance h from the plane's centre, with $h \ll l$. What is the initial acceleration of the plane?



(a) $\dfrac{qQ}{4\pi m\varepsilon_0 l^2}$

(b) $\dfrac{qQ}{4\pi m\varepsilon_0 h^2}$

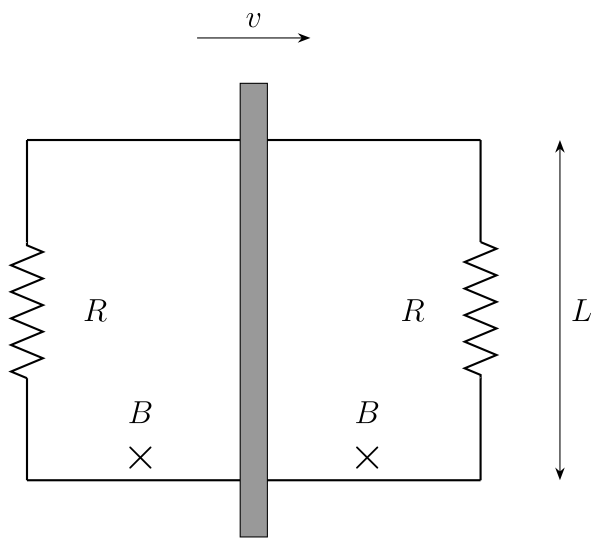
(c) $\dfrac{qQ}{m\varepsilon_0 l^2}$

(d) $\dfrac{qQ}{m\varepsilon_0 h^2}$

(e) $\dfrac{qQh}{4\pi m\varepsilon_0 (l^2+h^2)^{3/2}}$

Question 35

A movable conducting rod is placed in the middle of a square metal frame of side L, dividing it into two halves of resistance R each. There is a uniform magnetic field B perpendicular to the frame. What is the force required to move the rod across the frame at a constant speed v? Assume the rod is frictionless and has negligible resistance.



(a) 0

(b) $\dfrac{B^2L^2v}{2R}$

(c) $\dfrac{B^2L^2v}{R}$

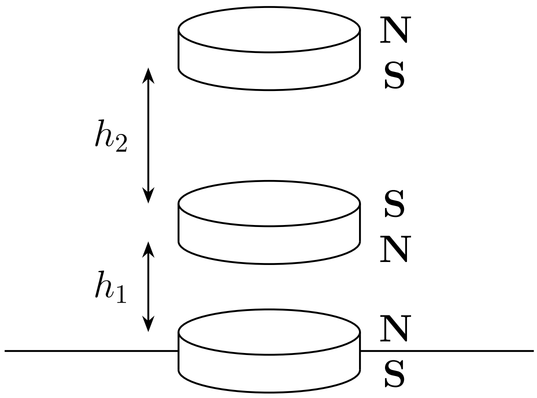
(d) $\dfrac{2B^2L^2v}{R}$

(e) $\dfrac{4B^2L^2v}{R}$

Question 36

The magnetic force between two disc magnets separated by distance r is given by $F \propto r^{-n}$, which is either attractive between unlike poles or repulsive between like poles. Note that n is an unknown constant.

Three identical disc magnets levitate above each other at equilibrium. The first magnet rests on the ground, the second magnet floats at a height $h_1 = 9\,\text{cm}$ above the first, and the third magnet floats at a height $h_2 = 11\,\text{cm}$ above the second. Based on this information, what is the best **approximated** value of n?



(a) 1

(b) 2

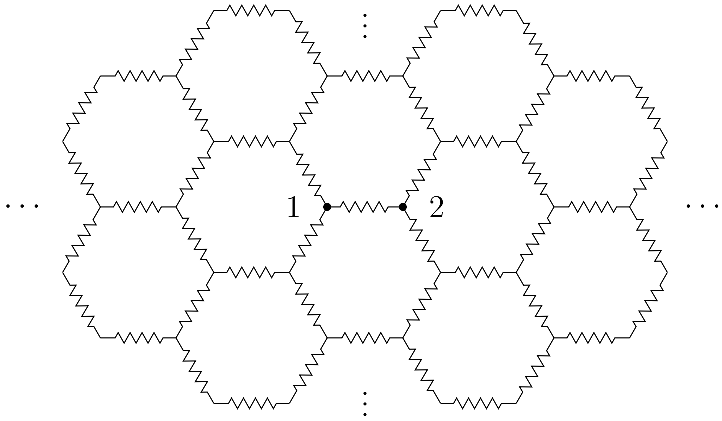
(c) 3

(d) 4

(e) 5

Question 37

Consider an infinite hexagonal grid of identical resistors, each with resistance R. Find the effective resistance across any one resistor (e.g. the resistance between nodes 1 and 2 labelled below).



(a) $\frac{1}{36}R$

(b) $\frac{1}{9}R$

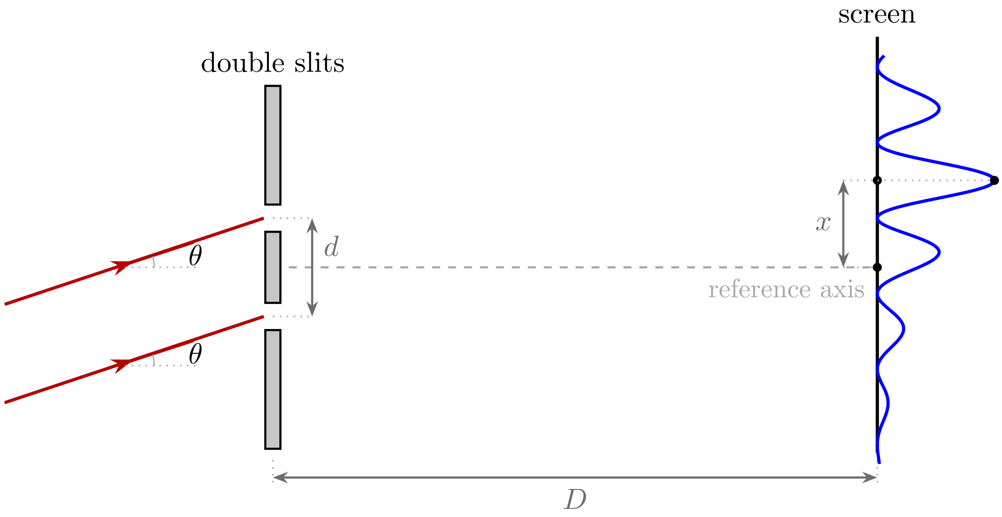
(c) $\frac{1}{6}R$

(d) $\frac{1}{3}R$

(e) $\frac{2}{3}R$

Question 38

A "bad" double-slit experiment is set up with the light sources misaligned by the same angle θ. As a result, the central bright fringe is some distance x away from the true centre of the screen. What is this distance x, in terms of the distance d between slits, the distance D between slits and the screen (where $D \gg d$), and the wavelength λ of light?



(a) d

(b) $D \cos\theta$

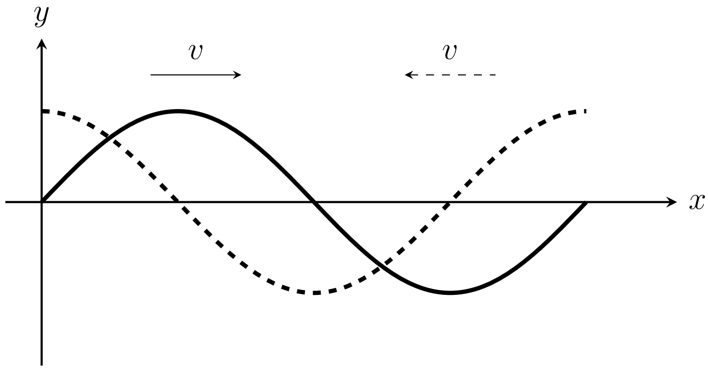
(c) $D \tan\theta$

(d) $\dfrac{\lambda D}{d} \sin\theta$

(e) $\dfrac{\lambda D}{d} \tan\theta$

Question 39

Two identical waves of period T are travelling in opposite directions (e.g. counter-propagating waves). Their displacements at time $t = 0$ are shown below. What is the earliest time $t > 0$ when constructive interference and destructive interference next occur?



(a) Constructive interference at $t = \frac{1}{8}T$ and destructive interference at $t = \frac{3}{8}T$.

(b) Constructive interference at $t = \frac{3}{8}T$ and destructive interference at $t = \frac{1}{8}T$.

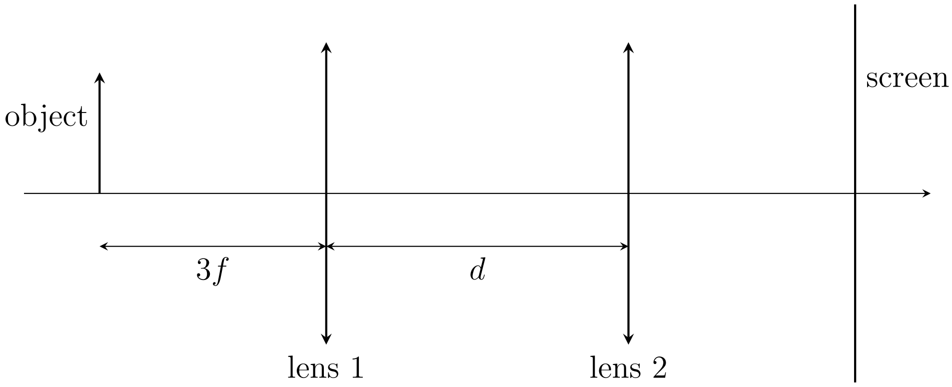
(c) Constructive interference at $t = \frac{1}{4}T$ and destructive interference at $t = \frac{1}{4}T$.

(d) Constructive interference at $t = \frac{1}{4}T$ and destructive interference at $t = \frac{3}{4}T$.

(e) Constructive interference at $t = \frac{3}{4}T$ and destructive interference at $t = \frac{1}{4}T$.

Question 40

Two identical converging lenses of focal length f are placed a distance d apart. An object is placed at a distance $3f$ from the first lens. What is the minimum distance d such that the second lens can form a real image on the screen?



(a) f

(b) $\frac{3}{2}f$

(c) $2f$

(d) $\frac{5}{2}f$

(e) $3f$

Question 41

Brian fills an empty bottle of height $h = 29\,\mathrm{cm}$ from a water tap. Brian has "perfect pitch" and listens to the sound produced by the water filling the bottle. What is the dominant pitch he hears when the bottle is filled to depth $h/4$? The speed of sound in air is $c = 340\,\mathrm{m\,s^{-1}}$.

(a) G4 (392 Hz)

(b) G5 (784 Hz)

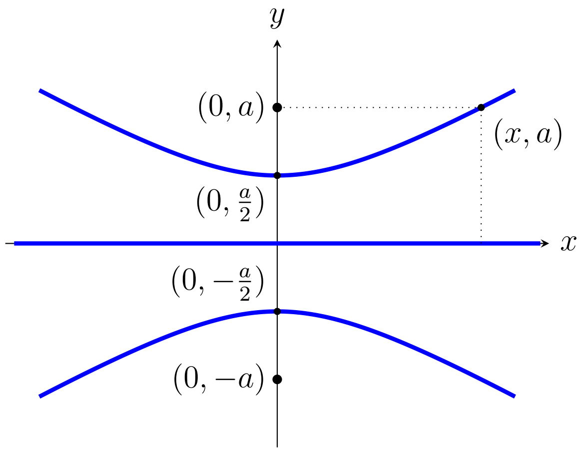
(c) G6 (1568 Hz)

(d) D6 (1175 Hz)

(e) D7 (2349 Hz)

Question 42

Two coherent light sources positioned at points $(0, -a)$ and $(0, a)$ interfere to produce "bright" lines of maximum intensity, which can be shown to be hyperbolas. One such hyperbola passes through points $\left(0, \frac{a}{2}\right)$ and (x, a). What is the value of x?



(a) $\dfrac{a}{2}$

(b) a

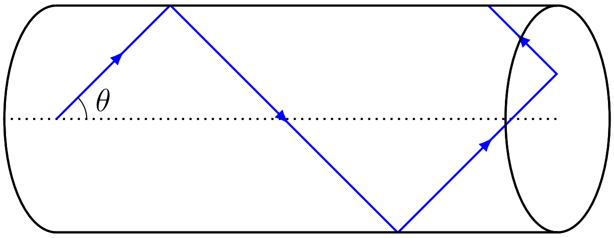
(c) $\dfrac{3a}{2}$

(d) $2a$

(e) $4a$

Question 43

A light ray travels inside a cylinder of refractive index $n = 1.5$ at an angle θ from its axis. The light ray can hit the sides or ends of the cylinder. For what range of values of θ will the light ray never exit the cylinder into the air outside?



(a) $\theta < 42°$

(b) $\theta < 48°$

(c) $\theta > 42°$

(d) $\theta > 48°$

(e) $42° < \theta < 48°$

Question 44

Consider a point source emitting sound waves radially **outwards**. The displacement $y(r, t)$ of air molecules at a distance r from the speaker and at a time t is given by

$$y(r, t) = A(r)\cos(kr + \omega t)$$

Let the speed of sound be c. Which of the following statements is true about the forms of $A(r)$ and ω?

(a) $A(r) \propto \frac{1}{r}$, $\omega = ck$

(b) $A(r) \propto \frac{1}{r}$, $\omega = -ck$

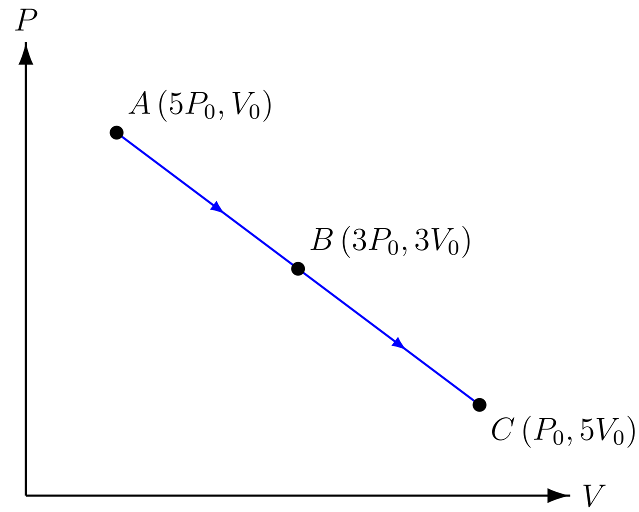
(c) $A(r) \propto \frac{1}{r^2}$, $\omega = ck$

(d) $A(r) \propto \frac{1}{r^2}$, $\omega = -ck$

(e) $A(r) = \text{constant}$, $\omega = ck$

Question 45

A monatomic ideal gas undergoes a process that is described by a straight line on the $P-V$ diagram, going through points $A(5P_0, V_0)$, $B(3P_0, 3V_0)$ and $C(P_0, 5V_0)$. What is the direction of heat flow during the $A \to B$ and $B \to C$ parts of the process?



(a) $A \to B$: Heat absorbed, $B \to C$: Heat absorbed

(b) $A \to B$: Heat absorbed, $B \to C$: Heat released

(c) $A \to B$: Heat released, $B \to C$: Heat absorbed

(d) $A \to B$: Heat released, $B \to C$: Heat released

(e) None of the above

Question 46

An engine manufacturer makes the claim that the engine they have developed will, on each cycle, take 100 J of heat out of boiling water at 100 °C, do mechanical work of 80 J, and exhaust 20 J of heat at 10 °C. What, if anything, is wrong with this claim?

(a) The heat exhausted must always be greater than the work done according to the second law of thermodynamics.

(b) This engine violates the first law of thermodynamics as $100\,\mathrm{J} + 20\,\mathrm{J} \neq 80\,\mathrm{J}$.

(c) An engine would operate by taking in heat at the lower temperature and exhausting heat at the higher temperature.

(d) The efficiency of this engine is greater than the ideal Carnot cycle efficiency.

(e) There is nothing wrong with this claim because $100\,\mathrm{J} = 20\,\mathrm{J} + 80\,\mathrm{J}$.

Question 47

A box of dimensions $1\,\mathrm{m} \times 1\,\mathrm{m} \times 1\,\mathrm{m}$ contains oxygen gas (molecular mass $= 32\,\mathrm{g\,mol^{-1}}$) at room temperature ($300\,\mathrm{K}$) and pressure $10^5\,\mathrm{Pa}$. Obtain the best estimation of the **total** number of collisions between molecules and the walls of the box every second.

(a) $10^{22}\,\mathrm{s^{-1}}$

(b) $10^{24}\,\mathrm{s^{-1}}$

(c) $10^{26}\,\mathrm{s^{-1}}$

(d) $10^{28}\,\mathrm{s^{-1}}$

(e) $10^{30}\,\mathrm{s^{-1}}$

Question 48

Two chambers contain equal masses of gas X. One chamber contains pure ideal gas X in monatomic form at temperature T_1, while the other chamber contains pure ideal gas X_2 in diatomic form at temperature T_2. The two chambers are now connected, allowing the gases to mix without heat exchange with the surroundings. What is the final temperature of the mixed gas?

Hint: Total internal energy of the gas system is conserved.

(a) $\dfrac{T_1 + T_2}{2}$

(b) $\dfrac{3T_1 + 5T_2}{8}$

(c) $\dfrac{5T_1 + 3T_2}{8}$

(d) $\dfrac{5T_1 + 6T_2}{11}$

(e) $\dfrac{6T_1 + 5T_2}{11}$

Question 49

The average surface temperature of the Earth is $T = 15\,°\mathrm{C}$. Suppose that the Sun-Earth distance were reduced by $10\,\%$. Estimate the new average surface temperature of the Earth.

(a) $16\,°\mathrm{C}$

(b) $19\,°\mathrm{C}$

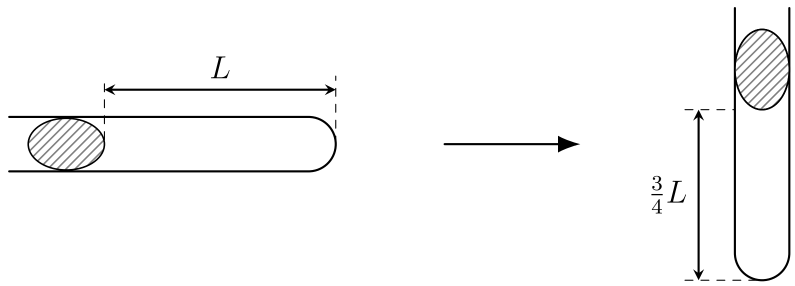
(c) $31\,°\mathrm{C}$

(d) $47\,°\mathrm{C}$

(e) $83\,°\mathrm{C}$

Question 50

A column of monatomic ideal gas is trapped by a droplet in a capillary tube of cross sectional area A. The tube is initially horizontal, and the gas column has length L. The tube is now quickly brought vertical, and the gas column comes to rest at a new length of $\frac{3}{4}L$. Let P_0 be the atmospheric pressure. Assuming that the tube and the droplet are perfect thermal insulators, what is the mass of the droplet?



(a) $0.33\dfrac{P_0 A}{g}$

(b) $0.62\dfrac{P_0 A}{g}$

(c) $1.33\dfrac{P_0 A}{g}$

(d) $1.62\dfrac{P_0 A}{g}$

(e) $1.67\dfrac{P_0 A}{g}$