Contest 1a

	A uniform meter stick of negligible mass is balanced on a knife edge with two masses placed at various positions on the meter stick.
(1)	Find the mark at the position of the knife edge when the meter stick is balanced with a 40 g mass at the 15 cm mark and a 60 g mass at the 60 cm mark. **Ans: 42 cm**
(2)	Find the mark at the position of the knife edge when the meter stick is balanced with a 20 g mass at the 20 cm mark and a 30 g mass at the 70 cm mark. **Ans: 50 cm**
(3)	Find the mark at the position of the knife edge when the meter stick is balanced with a 15 g mass at the 20 cm mark and a 35 g mass at the 60 cm mark. **Ans: 48 cm**

Contest 1b

(4)	The radius of curvature of a concave spherical mirror is 0.32 m. Find the magnitude of the lateral magnification produced by the mirror of an axial object placed 0.80 m from its vertex. **Ans: 0.25**
(5)	The radius of curvature of a concave spherical mirror is 0.25 m. Find the magnitude of the lateral magnification produced by the mirror of an axial object placed 0.75 m from its vertex. **Ans: 0.20**
(6)	The radius of curvature of a concave spherical mirror is 0.20 m. Find the magnitude of the lateral magnification produced by the mirror of an axial object placed 0.15 m from its vertex. **Ans: 2.0**

Contest 2a

(1)	Find the kinetic energy of a uniform sphere of mass 32 kg and radius 0.10 m rotating about a fixed axis passing through its center at an angular frequency of 5.0 rad s^{-1}. **Ans: 1.6 J**
(2)	Find the kinetic energy of the uniform sphere of mass 32 kg and radius 0.10 m when it rotates about the fixed axis passing through its center at an angular frequency of 2.5 rad s^{-1}. **Ans: 0.40 J**
(3)	Find the kinetic energy of a uniform sphere of mass 25 kg and radius 0.20 m rotating about a fixed axis passing through its center at an angular frequency of 3.0 rad s^{-1}. **Ans: 1.8 J**

Contest 2b

	A fixed quantity of an ideal gas undergoes an isothermal process.
(4)	Find the final pressure of the gas if its initial pressure is 200 kPa, its initial volume is 15 dm^3, and its final volume is 25 dm^3. **Ans: 120 kPa**
(5)	Find the final volume of the gas if its initial pressure is 220 kPa, its final pressure is 120 kPa, and its initial volume is 3.6 m^3. **Ans: 6. 6 m^3**
(6)	Find the initial pressure of the gas if its final pressure is 400 kPa, its initial volume is 10 dm^3, and its final volume is 25 dm^3. **Ans: 1000 kPa**

Contest 3a

(1)	Find the magnitude of the normal force on a 15 kg object at rest on a plane inclined at 30° to the horizontal. **Ans: 130 N**
(2)	Find the magnitude of the friction force on a 16 kg object at rest on a plane inclined at 30° to the horizontal. **Ans: 80 N**
(3)	Find the magnitude of the normal force on a 24 kg object at rest on a plane inclined at 60° to the horizontal. **Ans: 120 N**

(4)	Find the magnitude of the magnetic force on a 0.50 m section of a straight conductor carrying a current of 2.0 A that lies perpendicular to a uniform 0.60 T magnetic field. **Ans: 0.60 N**
(5)	Find the magnitude of the magnetic force on a 0.40 m section of a straight conductor carrying a current of 3.0 A that makes an angle of 30° to a uniform 0.80 T magnetic field. **Ans: 0.48 N**
(6)	Find the magnitude of the magnetic force on a 0.50 m section of a straight conductor carrying a current of 6.0 A that makes an angle of 30° to a uniform 2.0 T magnetic field. **Ans: 3.0 N**

Contest 4a

(1)	Find the frequency at which the impedance of a series RC circuit with $R = 5.0\ \Omega$ and $C = 5.0\ \mu F$ is $13\ \Omega$. **Ans: 2.7 kHz**
(2)	The impedance of an RC circuit with $R = 5.0\ \Omega$ is $13\ \Omega$ at 3.5 kHz. Find C. **Ans: 3.8 μF**
(3)	Find the frequency at which the impedance of a series RC circuit with $R = 4.0\ \Omega$ and $C = 5.0\ \mu F$ is $5.0\ \Omega$. **Ans: 11 kHz**

Contest 4b

(4)	The temperature of an object changes from 25 °C to 29 °C when it absorbs 320 J of heat. Find its temperature after it absorbs an additional 80 J of heat. **Ans: 30** °C
(5)	The temperature of another object changes from 20 °C to 28 °C when it absorbs 400 J of heat. Find its temperature after it rejects 50 J of heat. **Ans: 27** °C
(6)	The temperature of an object changes from 25 °C to 29 °C when it absorbs 320 J of heat. Find the quantity of heat it rejects when its temperature decreases from 29 °C to 20 °C. **Ans: 720 J**

Contest 5a

(1)	A battery has an emf of 12 V and an internal resistance of $0.5\ \Omega$. Find the terminal voltage of the battery when it supplies a current of 4 A. **Ans: $\mathbf{10}$ V**
(2)	A battery has an emf of 9 V and an internal resistance of $0.2\ \Omega$. Find the current the battery supplies when its terminal voltage is 8 V. **Ans: $\mathbf{5}$ A**
(3)	Find the internal resistance of a battery of emf 24 V whose terminal voltage is 22 V when it supplies a current of 8 A. **Ans: $\mathbf{0.25\ \Omega}$**

Contest 5b

(4)	Find the mean life of a radioactive element whose half-life is 1.5 s. **Ans:** $\mathbf{2.2\ s}$
(5)	Find the decay constant of a radioactive element whose half-life is 250 s. **Ans:** $\mathbf{2.8 \times 10^{-3}\ s^{-1}}$
(6)	Find the decay constant of a radioactive element whose half-life is 1200 s. **Ans:** $\mathbf{5.8 \times 10^{-4.}\ s^{-1}}$

Contest 6a

(1)	The magnitude of the electrostatic force a charged particle exerts on a 5.0 nC particle 0.20 m away from it is 18 N. Find the magnitude of the force it exerts on a 4.0 nC charge 0.30 m away. **Ans: 6. 4 N**
(2)	The magnitude of the electrostatic force a charged particle exerts on a 16 nC particle 0.40 m away from it is 270 N. Find the magnitude of the force it exerts on a 4.0 nC charge 0.30 m away. **Ans: 32 N**
(3)	The magnitude of the electrostatic force a charged particle exerts on a 5.0 nC particle 0.20 m away from it is 15 N. Find the magnitude of the force it exerts on a 7.0 nC charge 0.10 m away. **Ans: 84 N**

Contest 6b

(4)	The refractive index of calcium sulfate is 1.8 at a wavelength of 10 μm. Find the speed of 10 μm light in calcium sulfate. **Ans:** $\mathbf{1.7 \times 10^{8}\ m\ s^{-1}}$
(5)	The refractive index of calcium sulfate is 1.2 at a wavelength of 23.8 μm. Find the speed of 23.8 μm light in calcium sulfate. **Ans:** $\mathbf{2.5 \times 10^{8}\ m\ s^{-1}}$
(6)	The refractive index of calcium sulfate is 2.5 at a wavelength of 9.02 μm. Find the speed of 9.02 μm light in calcium sulfate. **Ans:** $\mathbf{1.2 \times 10^{8}\ m\ s^{-1}}$

Contest 7a

	The flow rate of water at the inlet of a horizontal pipe of nonuniform cross-section is $800\ \mathrm{cm^3\ s^{-1}}$. The diameter of the inlet is 50 cm.
(1)	Find the speed of water at the inlet of the pipe. **Ans: $\mathbf{0.41}$ cm $\mathbf{s^{-1}}$**
(2)	Find the speed of water at a section where the diameter of the pipe is 40 cm. **Ans: $\mathbf{0.64}$ cm $\mathbf{s^{-1}}$**
(3)	Find the speed of water at a section where the diameter of the pipe is 60 cm. **Ans: $\mathbf{0.28}$ cm $\mathbf{s^{-1}}$**

Contest 7b

(4)	Two springs each of spring constant $500\ \mathrm{N\ m^{-1}}$ are connected in parallel. Find the extension produced by a 40 N force applied to the parallel springs. **Ans: $\mathbf{0.04}$ m**
(5)	A spring of spring constant $450\ \mathrm{N\ m^{-1}}$ is connected in parallel with a spring of spring constant $350\ \mathrm{N\ m^{-1}}$. Find the extension produced by a 200 N force applied to the parallel springs. **Ans: $\mathbf{0.25}$ m**
(6)	A spring of spring constant $450\ \mathrm{N\ m^{-1}}$ is connected in parallel with a spring of spring constant $750\ \mathrm{N\ m^{-1}}$. Find the extension produced by a 24 N force applied to the parallel springs. **Ans: $\mathbf{0.02}$ m**

Contest 8a

(1)	A 3 kg object moving at 12 m s^{-1} collides head-on with and becomes attached to a stationary 1 kg object. Find the speed of the objects after the collision. **Ans: 9 m s^{-1}**
(2)	A 5 kg object collides head-on with and becomes attached to a stationary 3 kg object and the two objects take off at 15 m s^{-1} after the collision. Find the speed of the incoming object. **Ans: 24 m s^{-1}**
(3)	A 4 kg object collides head-on with and becomes attached to a stationary 3 kg object and the two objects take off at 8 m s^{-1} after the collision. Find the speed of the incoming object. **Ans: 14 m s^{-1}**

Contest 8b

(4)	Find the resistance of a resistor which dissipates 500 W when the current through it is 1 A. **Ans: 500 Ω**
(5)	Find the resistance of a resistor which dissipates 50 W when the current through it is 5 A. **Ans: 2 Ω**
(6)	Find the power dissipated by a 10 Ω resistor when the current through it is 2 A. **Ans: 40 W**

Contest 9a

(1)	The magnitude of the impedance of a series ac circuit is 85 Ω. Find the magnitude of the reactance in the circuit if the resistance in it is 36 Ω. **Ans: 77 Ω**
(2)	Find the magnitude of the impedance of a series ac circuit whose resistance is 420 Ω and whose reactance has a magnitude of 65 Ω. **Ans: 425 Ω**
(3)	Find the magnitude of the impedance of a series ac circuit whose resistance is 28 Ω and whose reactance has a magnitude of 45 Ω. **Ans: 53 Ω**

Contest 9b

(4)	Find the magnitude of the force that stops a 16 kg object moving at 6.0 m s^{-1} in 4.0 s. **Ans: 24 N**
(5)	Find the time in which a 75 N force stops a 5 kg object moving at 3 m s^{-1}. **Ans: 0.2 s**
(6)	Find the magnitude of the force that stops a 10 kg object moving at 5 m s^{-1} in 0.1 s. **Ans: 500 N**

Contest 10a

(1)	The work done by an ideal gas in an isobaric process is 800 J. Find the final volume of the gas if its initial volume is 0.2 m^3 and the pressure of the gas is 1600 Pa. **Ans: 0. 7 m^3**
(2)	The work done by an ideal gas in an isobaric process is 200 J. Find the pressure of the gas if its volume changes from 0.1 m^3 to 0.6 m^3 in the process. **Ans: 400 Pa**
(3)	Find the work done by an ideal gas in an isobaric process in which its volume changes from 0.6 m^3 to 0.8 m^3 at a pressure of 4000 Pa. **Ans: 600 J**

Contest 10b

	The magnitude of the electrostatic force a charged particle exerts on a 5.0 nC particle 0.20 m away from it is 72 N.
(4)	Find the magnitude of the force the charge exerts on a 5.0 nC charge 0.30 m away. **Ans: 32 N**
(5)	Find the magnitude of the force the charge exerts on a 2.0 nC charge 0.40 m away. **Ans: 7.2 N**
(6)	Find the magnitude of the force the charge exerts on a 15 nC charge 0.60 m away. **Ans: 24 N**

Contest 11a

(1)	An object is placed 0.15 m from the vertex of a concave spherical mirror of focal length 0.30 m. How far is the image from the vertex of the mirror? **Ans: 0. 30 m**
(2)	An object is placed 0.30 m from the vertex of a concave spherical mirror of focal length 0.50 m. How far is the image from the vertex of the mirror? **Ans: 0. 75 m**
(3)	An object is placed 0.15 cm from the vertex of a concave spherical mirror of focal length 0.60 m. How far is the image from the vertex of the mirror? **Ans: 0. 20 m**

Contest 11b

(4)	Find the energy stored by a 15 μF capacitor when the potential difference across it is 4 V. **Ans: 120 μJ**
(5)	Find the capacitance of the capacitor which stores 80 mJ of energy when the potential difference across it is 5 V. **Ans: 6.4 mF**
(6)	Find the energy stored by a 16 μF capacitor when the potential difference across it is 5 V. **Ans: 200 μJ**

Contest 12a

	Find the power developed when the point of application of the constant force $\boldsymbol{F}$ moves with velocity $\boldsymbol{v}$.
(1)	$\boldsymbol{F} = (8.0\hat{\boldsymbol{\imath}} + 5.0\hat{\boldsymbol{\jmath}})$ N and $\boldsymbol{v} = (6.0\hat{\boldsymbol{\imath}} - 3.0\hat{\boldsymbol{\jmath}})\ \mathrm{m\ s^{-1}}$. **Ans: 33 W** $$P = \boldsymbol{F} \cdot \boldsymbol{v} = 48\ \mathrm{W} - 15\ \mathrm{W} = 33\ \mathrm{W}$$
(2)	$\boldsymbol{F} = (7.0\hat{\boldsymbol{\imath}} - 3.0\hat{\boldsymbol{\jmath}})$ N and $\boldsymbol{v} = (4.0\hat{\boldsymbol{\imath}} + 5.0\hat{\boldsymbol{\jmath}})\ \mathrm{m\ s^{-1}}$. **Ans: 13 W**
(3)	$\boldsymbol{F} = (9.0\hat{\boldsymbol{\imath}} - 6.0\hat{\boldsymbol{\jmath}})$ N and $\boldsymbol{v} = (4.0\hat{\boldsymbol{\imath}} + 6.0\hat{\boldsymbol{\jmath}})\ \mathrm{m\ s^{-1}}$. **Ans: 0**

(4)	A projectile launched horizontally with a speed of 5 m s^{-1} from the top of a vertical post on level ground falls 10 m from the post. How high is the post? **Ans: 20 m**
(5)	A projectile is launched horizontally with a speed of 10 m s^{-1} from the top of an 80 m high building on level ground. How far from the foot of the building does the projectile fall? **Ans: 40 m**
(6)	A projectile is launched horizontally from the top of a 20 m high post on level ground. What must the launch speed be for the projectile to fall 36 m from the foot of the post? **Ans: 18 m $\mathbf{s^{-1}}$**

Contest 13a

(1)	A 0.2 kg particle of charge -5 μC initially moving at constant velocity enters a uniform 400 kV m^{-1} electric field. Find the magnitude of the acceleration of the particle. **Ans: $\mathbf{10\ m\ s^{-2}}$**
(2)	A 0.2 kg particle of charge 4 μC initially moving at constant velocity enters a uniform 100 kV m^{-1} electric field. Find the magnitude of the acceleration of the particle. **Ans: $\mathbf{2\ m\ s^{-2}}$**
(3)	A particle of charge 6 μC moves with an acceleration of magnitude 36 m s^{-2} when it enters a uniform 300 kV m^{-1} electric field. Find the mass of the particle. **Ans: $\mathbf{0.05\ kg}$**

(4)	A 5 kg object is at rest on a plane inclined at 45° to the horizontal. Find the magnitude of the friction force on the object. **Ans: 35 N**
(5)	A 5 kg object is at rest on a plane inclined at 60° to the horizontal. Find the magnitude of the normal force on the object. **Ans: 25 N**
(6)	A 20 kg object is at rest on a plane inclined at 30° to the horizontal. Find the magnitude of the friction force on the object. **Ans: 100 N**

Contest 14a

	Take $\sqrt{8.314} \cong 2.88$.
(1)	Determine the root-mean-square speed for an ideal gas of molar mass 32.0×10^{-3} kg mol^{-1} at 300 K. **Ans: $\mathbf{483}$ m s^{-1}**
(2)	Determine the root-mean-square speed for an ideal gas of molar mass 36.0×10^{-3} kg mol^{-1} at 300 K. **Ans: $\mathbf{455}$ m s^{-1}**
(3)	Determine the root-mean-square speed for an ideal gas of molar mass 4.00×10^{-3} kg mol^{-1} at 270 K. **Ans: $\mathbf{1.30}$ km s^{-1}**

	Find the magnetic force on the given charge q moving with velocity $\boldsymbol{v}$ in the given magnetic field $\boldsymbol{B}$.
(4)	$q = 2.5\ \text{C}$, $\boldsymbol{v} = 2.0\hat{\boldsymbol{\imath}}\ \text{m s}^{-1}$, $\boldsymbol{B} = 1.0\hat{\boldsymbol{\jmath}}\ \text{T}$ **Ans: $\mathbf{5.0}\ \hat{\boldsymbol{k}}$ N**
(5)	$q = 3\ \text{C}$, $\boldsymbol{v} = 4\hat{\boldsymbol{\imath}}\ \text{m s}^{-1}$, $\boldsymbol{B} = 0.5\hat{\boldsymbol{k}}\ \text{T}$ **Ans: $\mathbf{-6}\ \hat{\boldsymbol{\jmath}}$ N**
(6)	$q = 2.5\ \text{C}$, $\boldsymbol{v} = 4\hat{\boldsymbol{\imath}}\ \text{m s}^{-1}$, $\boldsymbol{B} = 1.0\hat{\boldsymbol{\imath}}\ \text{T}$ **Ans: 0**

Contest 28a

(1)	A three-particle system consists of a 2 kg particle at $3\hat{\boldsymbol{\imath}}$ m, a 3 kg particle at $8\hat{\boldsymbol{\jmath}}$ m, and a 3 kg particle at $-2\hat{\boldsymbol{\imath}}$ m. Find the center of mass of the system. **Ans: $3\hat{\boldsymbol{\jmath}}$ m**
(2)	Another three-particle system consists of a 3 kg particle at $2\hat{\boldsymbol{\imath}}$ m, a 2 kg particle at $\hat{\boldsymbol{\jmath}}$ m, and a 4 kg particle. Find the position of the 4 kg particle if the center of mass of the system is $(2\hat{\boldsymbol{\imath}} + 2\hat{\boldsymbol{\jmath}})$ m. **Ans: $(3\hat{\boldsymbol{\imath}} + 4\hat{\boldsymbol{\jmath}})$ m**
(3)	Yet another three-particle system consists of a 1 kg particle at $15\hat{\boldsymbol{\imath}}$ m, a 2 kg particle at $6\hat{\boldsymbol{\jmath}}$ m, and a 2 kg particle at $-\hat{\boldsymbol{\jmath}}$ m. Find the center of mass of the system. **Ans: $(3\hat{\boldsymbol{\imath}} + 2\hat{\boldsymbol{\jmath}})$ m**

Contest 28b

	An ac circuit consists of a 3000 Ω resistor in series with a 600 mH inductor and a 50 nF capacitor.
(4)	Find the reactance of the circuit at an angular frequency of 10,000 rad s^{-1}. **Ans: 4000 Ω = 4 kΩ**
(5)	Find the tangent of the phase angle between voltage across the circuit and the current in it at an angular frequency of 10,000 rad s^{-1}. **Ans: 4/3**
(6)	Find impedance of the circuit at an angular frequency of 10,000 rad s^{-1}. **Ans: 5000 Ω = 5 kΩ**

	The thermal conductivity of copper is $385\ \mathrm{W\ m^{-1}\ K^{-1}}$.
(7)	What is the rate of heat flow across a straight 1.0 m long insulated copper rod of cross-sectional area $5.0\ \mathrm{cm^2}$ with a 40 K temperature difference across its ends? **Ans: $\mathbf{7.7}$ W**
(8)	Find the temperature difference across a straight 2.0 m long insulated copper rod of cross-sectional area $16\ \mathrm{cm^2}$ through which heat flows at a rate of 77 W. **Ans: $\mathbf{250}$ K**
(9)	Find the rate of heat flow across a straight 5.0 m long insulated copper rod of cross-sectional area $2.0\ \mathrm{cm^2}$ with a 50 K temperature difference across its ends? **Ans: $\mathbf{0.77}$ W**

Contest 29a

(1)	A physical pendulum consists of a uniform rod of length L and mass M that is pivoted at one end in a region where the acceleration due to gravity is g. Give an expression for the period of the pendulum. **Ans:** $\boldsymbol{T = 2\pi\sqrt{2L/3g}}$
(2)	The physical pendulum consisting of a uniform rod of length L and mass M is pivoted a distance $L/4$ from its center of mass. Give an expression for the period in this case. **Ans:** $\boldsymbol{2\pi\sqrt{7L/12g}}$
(3)	The physical pendulum consisting of a uniform rod of length L and mass M is now pivoted a distance $L/3$ from its center of mass. Give an expression for the period in this case. **Ans:** $\boldsymbol{2\pi\sqrt{7L/12g}}$

(4)	A flat square loop of side 4.0 cm lies in the xy-plane. Determine the magnitude of magnetic flux through the loop produced by the uniform magnetic field $\boldsymbol{B} = (-8.0\ \text{T})\hat{\boldsymbol{\imath}} + (2.0\ \text{T})\hat{\boldsymbol{k}}$. **Ans: $\mathbf{3.2 \times 10^{-3}}$ Wb**
(5)	A flat square loop of side 5.0 cm lies in the xz-plane. Determine the magnitude of magnetic flux through the loop produced by the uniform magnetic field $\boldsymbol{B} = (-8.0\ \text{T})\hat{\boldsymbol{\imath}} + (3.0\ \text{T})\hat{\boldsymbol{k}}$. **Ans: 0**
(6)	Another flat rectangular loop of sides 4.0 cm by 3.0 cm lies in the yz-plane. Determine the magnitude of magnetic flux through the loop produced by the uniform magnetic field $\boldsymbol{B} = (-8.0\ \text{T})\hat{\boldsymbol{\imath}} + (2.0\ \text{T})\hat{\boldsymbol{k}}$. **Ans: $\mathbf{9.6 \times 10^{-3}}$ Wb**

	An ideal gas is made up of monatomic molecules of molar mass 18.0×10^{-3} kg mol^{-1}.
(7)	Find the temperature at which the mean speed of gas molecules is 800 m s^{-1}. **Ans: 544 K**
(8)	Find the temperature at which the root-mean-square speed of gas molecules is 800 m s^{-1}. **Ans: 462 K**
(9)	Find the temperature at which the most probable speed of gas molecules is 810 m s^{-1}. **Ans: 710 K**

Contest 30a

(1)	An object moving at 3.2 m s^{-1} directly towards a wall bounces off at 2.4 m s^{-1} after striking the wall. Find the coefficient of restitution for the collision between the object and the wall. **Ans: $\mathbf{3/4 = 0.75}$**
(2)	The coefficient of restitution for the collision between an object moving at 5.0 m s^{-1} directly towards a stationary object is 0.80. Find the velocity after the collision of the incoming object if the stationary object takes off at 3.6 m s^{-1} after the collision. **Ans: $\mathbf{-0.40\ m\ s^{-1}}$**
(3)	An object bounces off a wall at 5.0 m s^{-1} after striking it directly. Find the incident speed of the object if the coefficient of restitution for the collision is 0.5. **Ans: $\mathbf{10\ m\ s^{-1}}$**

Contest 30b

	An incompressible fluid of density 800 kg m^{-3} flows in a horizontal pipe. The flow is steady and laminar. At a point where the fluid pressure is 120 kPa, the fluid speed is 2.00 m s^{-1}.
(4)	Find the pressure at a point where the fluid speed is 3.00 m s^{-1}. **Ans: 118 kPa**
(5)	Find the pressure at a point where the fluid speed is 1.00 m s^{-1}. **Ans: 121 kPa**
(6)	Find the pressure at a point where fluid speed is 4.00 m s^{-1}. **Ans: 115 kPa**

(7)	When the brakes of a 720 kg vehicle moving at 8.00 m s^{-1} are applied, the vehicle stops after travelling 6.00 m. What is the average net force that stops the vehicle? **Ans: $\mathbf{3.84}$ kN**
(8)	The average net force that stops a 560 kg vehicle moving at 2.0 m s^{-1} is 4.0 kN when the brakes are applied. Find the time the vehicle takes to stop after the brakes are applied. **Ans: $\mathbf{0.28}$ s**
(9)	A 640 kg vehicle moving at 5.0 m s^{-1} is stopped by an average net force of 2.5 kN when its brakes are applied. Find the distance the vehicle moves before coming to rest. **Ans: $\mathbf{3.2}$ m**

Contest 31a

(1)	The extension of a vertical spring supported at one end is 2.5 cm when an object is suspended from its free end. Find the angular frequency of oscillations of the object when it is displaced downward and released. **Ans: $\mathbf{20\ rad\ s^{-1}}$**
(2)	One end of a spring whose other end is fixed is attached to a 5 kg block on a smooth horizontal surface. The extension of the spring is 16 mm when a 200 N horizontal force pulls on the block. Find the angular frequency of oscillations of the block when released. **Ans: $\mathbf{50\ rad\ s^{-1}}$**
(3)	A mass attached to the lower end of a vertical spring fixed at the other end oscillates at an angular frequency of 100 rad s^{-1}. Find the extension of the spring when the mass is at rest. **Ans: 1 mm**

Contest 31b

(4)	A thin lens with a focal length of $+0.20$ m is placed 0.10 m from an object. Find the image distance and state its type. **Ans: $\mathbf{0.20}$ m, virtual**
(5)	Find the position and nature of the image produced by a lens of focal length -0.20 m of a real object 0.10 m from the lens. **Ans: $\mathbf{0.067}$ m, virtual**
(6)	Find the position and nature of the image produced by a lens of focal length $+0.22$ m of a real object 0.33 m from the lens. **Ans: $\mathbf{0.66}$ m, real**

Contest 31c

	A sphere with a black surface is at a temperature of 400 K.
(7)	Find as a proper fraction the ratio of the net rate of heat loss of the sphere in a large container at 300 K to the rate in one at 200 K. **Ans: 35/48**
(8)	Find as a proper fraction the ratio of the net rate of heat loss of the sphere in a large container at 300 K to the rate in one at 100 K. **Ans: 35/51**
(9)	Find as a proper fraction the ratio of the net rate of heat loss of the sphere in a large container at 200 K to the rate in one at 100 K. **Ans: 16/17**

Contest 32a

(1)	A uniform solid sphere initially at rest rolls without slipping down an inclined plane from a height of 7 m on the plane. Find the speed of the sphere at the bottom of the plane. **Ans: 10 m $\mathbf{s^{-1}}$**
(2)	A uniform hollow spherical shell initially at rest rolls without slipping down an inclined plane from a height of 3 m on the plane. Find the speed of the sphere at the bottom of the plane. **Ans: 6 m $\mathbf{s^{-1}}$**
(3)	A uniform solid sphere of radius 0.050 m initially at rest rolls without slipping down an inclined plane from a height of 0.28 m on the plane. Find the angular speed of the sphere at the bottom of the plane. **Ans: 40 rad $\mathbf{s^{-1}}$**

	The refractive index of some transparent materials is given by $n = A + B/\lambda^2$ for wavelengths λ in the visible spectral range. For fused silica, $A = 1.458$ and $B = 0.00354\ \mu\text{m}^2$.
(4)	Find the refractive index of fused silica at $\lambda = 0.500\ \mu\text{m}$. **Ans: $\mathbf{1.472}$**
(5)	Find the refractive index of fused silica at $\lambda = 0.400\ \mu\text{m}$. **Ans: $\mathbf{1.480}$**
(6)	Find the refractive index of fused silica at $\lambda = 0.300\ \mu\text{m}$. **Ans: $\mathbf{1.497}$**

(7)	The velocity of a -2 C charged particle is $(3\text{ m s}^{-1})\hat{\boldsymbol{\imath}}$ at a point where the electric field is $(2\text{ N C}^{-1})\hat{\boldsymbol{\jmath}}$ and the magnetic flux density is $(-2\text{ T})\hat{\boldsymbol{\jmath}}$. Find the electromagnetic force on the particle. **Ans:** $\left(-\boldsymbol{4\hat{\jmath}}+\boldsymbol{12\hat{k}}\right)$ **N**
(8)	The velocity of another -2 C charged particle is $(4\text{ m s}^{-1})\hat{\boldsymbol{\imath}}$ at a point where the electric field is $(3\hat{\boldsymbol{\imath}}-2\,\hat{\boldsymbol{\jmath}})\text{ N C}^{-1}$ and the magnetic flux density is $(2\text{ T})\boldsymbol{i}$. Find the electromagnetic force on the particle. **Ans:** $(-\boldsymbol{6\hat{\imath}}+\boldsymbol{4\hat{\jmath}})$ **N**
(9)	The velocity of a 2 C charged particle is $(1\text{ m s}^{-1})\hat{\boldsymbol{\jmath}}$ at a point where the electric field is $(3\text{ N C}^{-1})\hat{\boldsymbol{\jmath}}$ and the magnetic flux density is $(3\text{ T})\hat{\boldsymbol{k}}$. Find the electromagnetic force on the particle. **Ans:** $(\boldsymbol{6\hat{\imath}}+\boldsymbol{6\hat{\jmath}})$ **N**

Contest 33a

(1)	A solid 250 kg sphere of radius 0.20 m rolls at 5.0 rad s^{-1} while sliding at 2.0 m s^{-1}. Find the kinetic energy of the sphere. **Ans: 550 J**
(2)	A hollow 4.0 kg spherical shell of radius 0.20 m rolls at 5.0 rad s^{-1} while sliding at 8.0 m s^{-1}. Find the kinetic energy of the spherical shell. **Ans: 130 J**
(3)	A solid 20.0 kg sphere of radius 0.200 m rolls at 2.50 rad s^{-1} while sliding at 4.00 m s^{-1}. Find the kinetic energy of the sphere. **Ans: 161 J**

Contest 33b

	Give the atomic number and the mass number of the nuclide produced after the given decay steps.
(4)	$^{232}_{93}$Np decays by β^+ emission to a nuclide that decays by α emission. **Ans: Mass number 228, atomic number 90**
(5)	$^{214}_{84}$Po decays by alpha emission to a nuclide that also decays by alpha emission. **Ans: Mass number 206, atomic number 80**
(6)	$^{237}_{93}$Np decays by alpha emission to a nuclide that decays by β^- emission. **Ans: Mass number 233, atomic number 92**

	A particle of charge-to-mass ratio q/m moves with speed v perpendicular to a uniform magnetic field of magnitude B.
(7)	Find the radius of the particle's path for $q/m = 2.0\ \mathrm{C\ kg^{-1}}$, $v = 15\ \mathrm{m\ s^{-1}}$, and $B = 0.30$ T. **Ans: 25 m**
(8)	Find the radius of the particle's path for $q/m = 5.0\ \mathrm{C\ kg^{-1}}$, $v = 36\ \mathrm{m\ s^{-1}}$, and $B = 0.40$ T. **Ans: 18 m**
(9)	For $q/m = 2.0\ \mathrm{C\ kg^{-1}}$ and $v = 2.8\ \mathrm{m\ s^{-1}}$, find the value of B for which the radius of the particle's path is 2.0 m. **Ans: 0. 70 T**

Contest 34a

	A cylinder of mass 0.200 kg has a moment of inertia of 0.0250 kg m^2 about its axis.
(1)	Find the kinetic energy of the cylinder when it slides at 4.00 m s^{-1} while rolling at 2.00 rad s^{-1}. **Ans: $\mathbf{1.65}$ J**
(2)	Find the kinetic energy of the cylinder when it slides at 3.00 m s^{-1} while rolling at 3.00 rad s^{-1}. **Ans: $\mathbf{1.01}$ J**
(3)	Find the kinetic energy of the cylinder when it slides at 8.00 m s^{-1} while rolling at 20.0 rad s^{-1}. **Ans: $\mathbf{11.4}$ J**

	The Wien wavelength displacement law constant is 2.90×10^{-3} m K and the Stefan-Boltzmann constant is 5.67×10^{-8} W m^{-2} K^{-4}.
(4)	Find the temperature at which the wavelength for peak spectral intensity in a blackbody spectrum occurs at 580 nm. **Ans: 5000 K**
(5)	Find the temperature at which the wavelength for peak spectral intensity in a blackbody spectrum occurs at 2900 nm. **Ans: 1000 K**
(6)	Find the temperature at which the wavelength for peak spectral intensity in a blackbody spectrum occurs at 3480 nm. **Ans: 833 K**

(7)	A pure sine wave current of amplitude 2 A and angular frequency 100 rad s^{-1} flows through a series RL circuit with $R = 3\ \Omega$ and $L = 40$ mH. What is the voltage amplitude across the circuit? **Ans: 10 V**
(8)	A pure sine wave voltage of amplitude 40 V and angular frequency 500 rad s^{-1} is applied across a series RC circuit with $R = 30\ \Omega$ and $C = 50\ \mu$F. Find the current amplitude in the circuit. **Ans: 0.8 A**
(9)	A pure sine wave current of amplitude 5.0 A and angular frequency 24 rad s^{-1} flows through a series RL circuit with $R = 5.0\ \Omega$ and $L = 0.50$ H. What is the voltage amplitude across the circuit? **Ans: 65 V**

(1)	Find the torque which changes the angular momentum of an object steadily from $(2\ \mathrm{kg\ m^2\ s^{-1}})\hat{\boldsymbol{\imath}}$ to $(4\ \mathrm{kg\ m^2\ s^{-1}})\hat{\boldsymbol{\jmath}}$ in 2 s. **Ans:** $(-\hat{\boldsymbol{\imath}} + 2\hat{\boldsymbol{\jmath}})$ **N m**
(2)	A constant torque equal to $(18\ \mathrm{N\ m})\hat{\boldsymbol{\jmath}}$ acts on an object whose initial angular momentum is $(6\hat{\boldsymbol{\imath}} - 12\hat{\boldsymbol{\jmath}})\ \mathrm{kg\ m^2\ s^{-1}}$. Find the angular momentum of the object after 2 s. **Ans:** $(\mathbf{6}\hat{\imath} + \mathbf{24}\hat{\jmath})\ \mathbf{kg\ m^2\ s^{-1}}$
(3)	Find the torque which changes the angular momentum of an object steadily from $(10\ \mathrm{kg\ m^2\ s^{-1}})\hat{\boldsymbol{\imath}}$ to $(15\ \mathrm{kg\ m^2\ s^{-1}})\hat{\boldsymbol{\jmath}}$ in 5 s. **Ans:** $(-\mathbf{2}\hat{\boldsymbol{\imath}} + \mathbf{3}\hat{\boldsymbol{\jmath}})$ **N m**

(4)	Find the shortest wavelength that can be produced by an x-ray tube operated with 87.0 kV between the electron emitter and the target. **Ans: 14.3 pm**
(5)	Find the shortest wavelength that can be produced by an x-ray tube operated with 45.0 kV between the electron emitter and the target. **Ans: 27.6 pm**
(6)	Find the voltage between the electron emitter and the target of an x-ray tube at which the shortest wavelength that can be produced is 25.0 pm. **Ans: 49.6 kV**

	The Wien wavelength displacement law constant is 2.90×10^{-3} m K and the Stefan-Boltzmann constant is 5.67×10^{-8} W m^{-2} K^{-4}.
(7)	A sphere of surface area 0.20 m^2 and emissivity of unity is maintained at a temperature of 200 K. Find the rate of radiant energy emission by the spherical surface. **Ans: 18 W**
(8)	A disc whose total surface area is 0.30 m^2 has an emissivity of 0.80. Find the rate of radiant energy emission by the disc surface when it is at a temperature of 100 K. **Ans: 1.4 W**
(9)	The rate of radiant energy emission from an object of surface area 0.50 m^2 is 34 W when the temperature of the object is 200 K. Find the emissivity of the surface of the object. **Ans: 0.75**

Contest 36a

	Find the maximum speed a vehicle can have without skidding on a banked curve in a road with the given properties.
(1)	A curve of radius $30\sqrt{3}$ m in a frictionless road banked at $60°$. **Ans: $\mathbf{30\ m\ s^{-1}}$**
(2)	A curve of radius $10\sqrt{3}$ m in a frictionless road banked at $30°$. **Ans: $\mathbf{10\ m\ s^{-1}}$**
(3)	A curve of radius 16.9 m in a frictionless road banked at $45°$. **Ans: $\mathbf{13\ m\ s^{-1}}$** Accept $13.0\ \mathrm{m\ s^{-1}}$.

(4)	Determine the radius of the Bohr orbit whose quantum number $n = 4$. **Ans: 846 pm**
(5)	Find the quantum number for the Bohr orbit whose radius is 4.2849 nm. **Ans: 9**
(6)	Find the radius of the Bohr orbit whose quantum number $n = 3$. **Ans: 476 pm**

	An initially uncharged 5.0 μF capacitor is connected to a 20 V battery through a 200 kΩ resistor.
(7)	Find the charge on the capacitor 1.0 s after the connection is made. **Ans: 63 μC**
(8)	Find the charging current 1.0 s after the connection is made. **Ans: 37 μA**
(9)	Find the charge on the capacitor 2.0 s after the connection is made. **Ans: 86 μC**

Contest 37a

(1)	Find the acceleration of the center of mass of a uniform solid sphere rolling without slipping down a plane inclined at 30° to the horizontal. **Ans: $\mathbf{7\ m\ s^{-2}}$**
(2)	Find the acceleration of the center of mass of a uniform hollow spherical shell rolling without slipping down a plane inclined at 30° to the horizontal. **Ans: $\mathbf{3\ m\ s^{-2}}$**
(3)	Find the acceleration of the center of mass of a uniform hollow cylindrical shell open at both ends rolling without slipping down a plane inclined at 30° to the horizontal. **Ans: $\mathbf{2.5\ m\ s^{-2}}$**

Contest 37b

	A lens maker uses ZnSe to make thin spherical lenses for use in the infrared.
(4)	The refractive index of ZnSe is 2.40 at 10.6 μm. Find the focal length of a plano-convex lens designed for use in ambient air at that wavelength whose curved surface has a radius of curvature of magnitude 70.0 cm. **Ans: $\mathbf{50.0}$ cm**
(5)	The refractive index of ZnSe is 2.50 at 0.920 μm. Find the focal length of a plano-concave lens designed for use in ambient air at that wavelength whose curved surface has a radius of curvature of magnitude 120 cm. **Ans: $\mathbf{-80.0}$ cm**
(6)	The refractive index of ZnSe is 2.44 at 2.60 μm. Find the focal length of a biconvex lens designed for use in ambient air at that wavelength whose curved surfaces each has a radius of curvature of magnitude 144 cm. **Ans: $\mathbf{50.0}$ cm**

	A uniformly charged sphere of radius R carries a total charge Q.
(7)	Find the ratio of the magnitude of the electric field at a point a distance $R/4$ from the center of the sphere to that on the surface of the sphere. **Ans: $1/4$**
(8)	Find the ratio of the magnitude of the electric field at a point a distance $R/2$ from the center of the sphere to that on the surface of the sphere. **Ans: $1/2$**
(9)	Find the ratio of the magnitude of the electric field at a point a distance $2R$ from the center of the sphere to that on the surface of the sphere. **Ans: $1/4$**

Contest 38a

(1)	The magnetic susceptibility of a paramagnetic substance is 2.10×10^{-5} at 47 °C. Find the magnetic susceptibility of the substance at 27 °C. **Ans: $\mathbf{2.24 \times 10^{-5}}$**
(2)	Find the magnetic susceptibility at 67 °C of the paramagnetic substance whose magnetic susceptibility is 2.10×10^{-5} at 47 °C. **Ans: $\mathbf{1.98 \times 10^{-5}}$**
(3)	The magnetic susceptibility of another paramagnetic substance is 2.60×10^{-4} at 17 °C. Find the magnetic susceptibility of the substance at 87 °C. **Ans: $\mathbf{2.09 \times 10^{-4}}$**

	A spherical solar system object has a radius of 476 km and a mass of 9.47×10^{20} kg. Ignore rotation of the object.
(4)	Estimate the surface gravity of the object. **Ans: $\mathbf{0.279}$ m s^{-2}** Accept 0.28 m s^{-2}
(5)	The mean distance of the object from the sun is 4.14×10^8 km. Estimate the mean kinetic energy of the object. Take the mass of the sun as 2.0×10^{30} kg. **Ans: $\mathbf{1.5 \times 10^{29}}$ J**
(6)	Estimate the escape velocity from a point 29 km above the surface of the object. **Ans: $\mathbf{500}$ m s^{-1}**

Contest 38c

(7)	A stopped organ pipe has a fundamental frequency of 210 Hz on a day the speed of sound in air is 350 m s^{-1}. Find the length of the pipe. **Ans: $\mathbf{0.417}$ m**
(8)	Another stopped organ pipe has a fundamental frequency of 280 Hz on the same day the speed of sound in air is 350 m s^{-1}. Find the length of the pipe. **Ans: $\mathbf{0.313}$ m**
(9)	Find the fundamental frequency of a stopped organ pipe of length 0.490 m on a day the speed of sound is 345 m s^{-1}. **Ans: $\mathbf{176}$ Hz**

Contest 39a

(1)	The scalar potential in a region is given by $V = \frac{1}{2}kx^2$ where k is constant. Find the electric field in the region. **Ans:** $\boldsymbol{-kx\hat{\imath}}$
(2)	The scalar potential in another region is given by $V = A + Bx$ where A and B are constants. Find the electric force on a charge q in the region. **Ans:** $\boldsymbol{-qB\hat{\imath}}$
(3)	The scalar potential in yet another region is given by $V = V_0\cos(kz)$ where V_0 and k are constants. Find the electric field in the region. **Ans:** $\boldsymbol{kV_0\sin(kz)\,\hat{k}}$

Contest 39b

(4)	What is the average translational kinetic energy of a molecule in an ideal gas at 17.0 ℃? **Ans:** $\mathbf{6.00 \times 10^{-21}\ J}$
(5)	What is the temperature at which the average translational kinetic energy of an ideal gas molecule is 6.50×10^{-21} J? **Ans:** $\mathbf{314\ K = 41}$ ℃
(6)	Find the average translational kinetic energy of a molecule in an ideal gas at 37.0 ℃. **Ans:** $\mathbf{6.42 \times 10^{-21}\ J}$

	The speed of sound on a certain afternoon is $345\ \mathrm{m\ s^{-1}}$.
(7)	Find the frequency of the third harmonic of an open organ pipe of length $0.392\ \mathrm{m}$. **Ans: $\mathbf{1.32\ kHz}$**
(8)	Find the frequency of the third overtone of an open organ pipe of length $0.392\ \mathrm{m}$. **Ans: $\mathbf{1.76\ kHz}$**
(9)	Find the frequency of the third harmonic of a stopped organ pipe of length $0.392\ \mathrm{m}$. **Ans: $\mathbf{660\ Hz}$**

Contest 40a

(1)	Name the particle emitted by a nuclide that decays by electron capture. **Ans: <u>Electron</u> neutrino**
(2)	Name the particle emitted in the decay of a nuclide by internal conversion. **Ans: <u>Atomic</u> electron**
(3)	Name the fundamental force that is responsible for beta decay processes. **Ans: Weak force**

	An excited hydrogen atom is slightly heavier than a hydrogen atom in its ground state. Find the mass difference between a hydrogen atom in the states with the given principal quantum numbers.
(4)	$n = 5$ and $n = 9$ **Ans: $\mathbf{6.7 \times 10^{-37}}$ kg** Accept 6.69×10^{-37} kg.
(5)	$n = 2$ and $n = 5$ **Ans: $\mathbf{5.1 \times 10^{-36}}$ kg** Accept 5.08×10^{-36} kg or 5.09×10^{-36} kg.
(6)	$n = 1$ and $n = 2$ **Ans: $\mathbf{1.8 \times 10^{-35}}$ kg** Accept 1.82×10^{-35} kg.

Contest 40c

	Total charge Q is uniformly distributed throughout the volume of a sphere of radius R.
(7)	What is the electric potential a distance $R/4$ from the center of the sphere in SI units? **Ans: $\boldsymbol{47Q/128\pi\epsilon_0 R}$**
(8)	What is the electric potential at the center of the sphere in SI units? **Ans: $\boldsymbol{3Q/8\pi\epsilon_0 R}$**
(9)	What is the electric potential a distance $R/2$ from the center of the sphere in SI units? **Ans: $\boldsymbol{11Q/32\pi\epsilon_0 R}$**