You may use following physical constant if needed.
Velocity of light = $3.0\times10^{8}\ m\ s{-}1$
Plank Constant =$6.6\times10^{-34}\ J\ s$

1. A boat which has a speed of 5 km h^{-1} in still waters crosses a river of width 1 km along the shortest possible path in 15 minutes. The speed of the river in km h^{-1} is,
   (1) 1 (2) 3 (3) 4
   (4) $\sqrt{41}$ (5) 8

2. Air is blown into a soap bubble of radius r to double its radius. If the surface tension of the soap solution is S, the work done in the process is,
   (1) $8\pi r^2 S$ (2) $12\ \pi r^2 S$ (3) $16\ \pi r^2 S$
   (4) $20\ \pi r^2 S$ (5) $24\ \pi r^2 S$

3. A fast train moving at 40 ms^{-1} passes by a stationary observer, emitting a whistle of frequency 300 Hz. If the velocity of sound waves is 340 m s^{-1}, then the change in the apparent frequency of the sound, just before and just after the train passes by the observer, will be nearly
   (1) 32 Hz (2) 40 Hz (3) 72 Hz
   (4) 84 Hz (5) 96 Hz

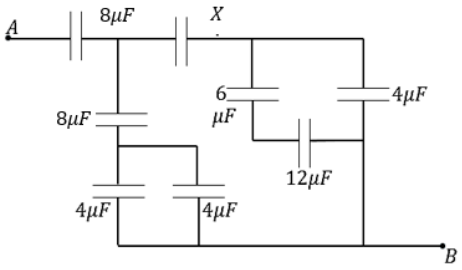
4. One end of a uniform rod of length 1 m is placed in boiling water, while the other end is placed in melting ice. A point P on the rod is maintained at a constant temperature of 80 °C. The mass of steam produced per second is equal to the mass of ice melted per second. If the specific latent heat of vaporization is 7 times the specific latent heat of fusion, the distance of P from the steam chamber must be,
   (1) 1/9 m (2) 1/8 m (3) 1/7 m
   (4) 1/10 m (5) 1/12 m

5. Consider the statements below regarding wave properties
   (A) The frequency and intensity do not change when waves existing in different planes are polarized
   (B) Any wave can refract and interfere
   (C) Standing waves and beats can be considered as an outcome of superposition of waves
   Which one is true?
   (1) A only (2) B only
   (3) C only (4) B and C only
   (5) All A, B and C

6. A sound source and an observer start from a same point and the sound source moves towards north while the observer moves towards east with the velocities $3\ ms^{-1}$ and $4\ ms^{-1}$ respectively. After the first second, if the observer feels a sound intensity level of $x\ dB$ how much more time will it be taken for it to be $(x-20)\ dB$.
   (1) 4 s (2) 5 s (3) 9 s
   (4) 10 s (5) 20 s

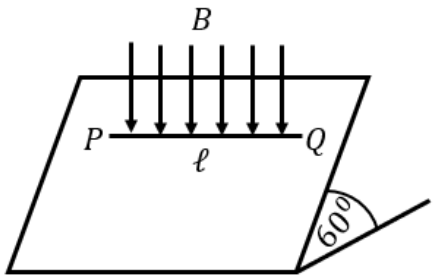
7. The capacitance in the circuit shown in the figure are given in μF. If the equivalence capacitance between A and B in the circuit is 4 μF the capacitance of X is

(1) 2 μF
(2) 4 μF
(3) 8 μF
(4) 16 μF
(5) 32 μF



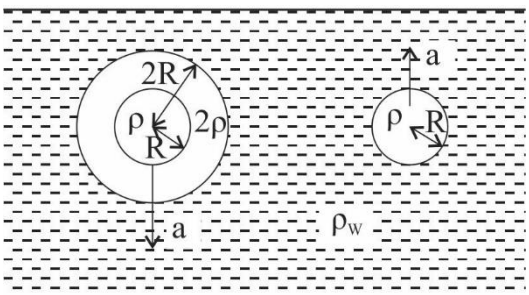
8. As shown in the figure a conductive horizontal rod PQ of length (l) 10 cm and mass 10 g is placed on a frictionless plane of angle 60^0 to the horizontal. There is a uniform vertical magnetic field with flux density B in the area. When a current of 1.73 A is going through the rod it will be at equilibrium under gravitational and magnetic forces. The direction of the current and value of B is

(1) Current PQ direction and 2.0 T
(2) Current QP direction and 1.0 T
(3) Current PQ direction and 1.0 T
(4) Current PQ direction and 4.0 T
(5) Current QP direction and 2.0 T



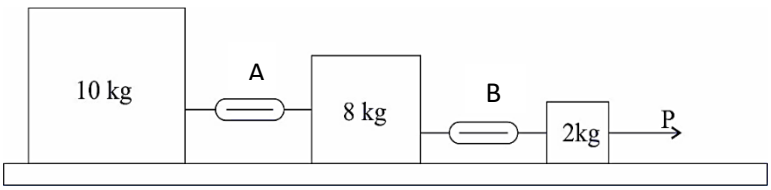
9. A sphere of radius R is made out of material of density ρ. A shell made of material of density 2ρ surrounds it so that the total radius is 2R. The compound object moves downwards in a liquid of density ρ_w with an acceleration a. A sphere of radius R made out of material of density ρ and without shell when released from the bottom of a liquid of density ρ_w will rise with acceleration a. When viscous forces are neglected $\frac{\rho}{\rho_w}$ will be.

(1) 5/8
(2) 11/14
(3) 7/11
(4) 12/7
(5) ½



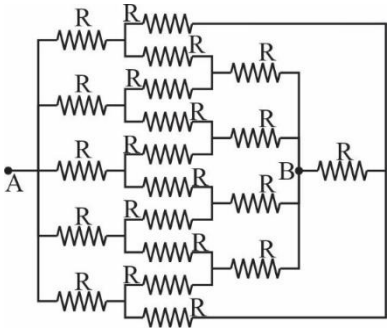
10. The figure shows a situation of three wooden boxes of masses 10 kg, 8 kg and 2 kg pulled together by a force P=100 N. The kinetic frictional coefficient between wooden blocks and the table is 0.2. If the all springs scales are massless, the ratio of the readings of spring scale A and the readings of spring scale B is

(6) 1:5
(1) 2:7
(2) 5:4
(3) 5:9
(4) 1:1



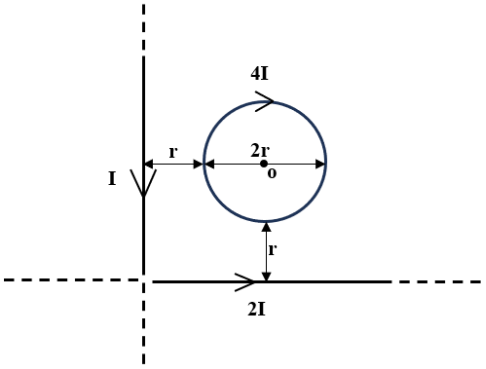
11. All the resistors shown in the figure is R. The equivalent resistance between A and B is,

(1) 10 R
(2) 5 R
(3) 2R
(4) R/2
(5) R/10



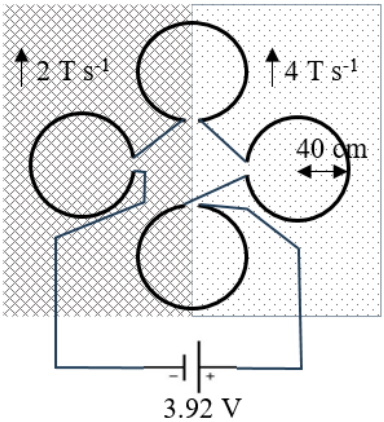
12. Current I and 2I flow in two infinite conducting wires and current 4I flows in circular loop with diameter 2r and n number of turns as shown in the figure. The resultant magnetic flux density at the center of the loop is

(1) $\frac{\mu_0 I}{2r}\left(\frac{5\pi n-3}{4\pi}\right)$
(2) $\frac{\mu_0 I}{2r}\left(\frac{8\pi n-3}{2\pi}\right)$
(3) $\frac{\mu_0 I}{2r}\left(\frac{5\pi n-4}{2\pi}\right)$
(4) $\frac{\mu_0 I}{2r\pi}\left(\frac{8\pi n-3}{2\pi}\right)$
(5) $\frac{\mu_0 I}{2r}\left(\frac{4\pi n}{2\pi}\right)$

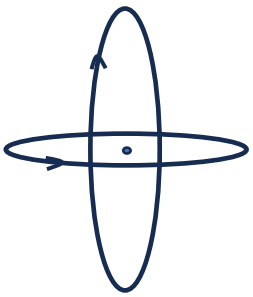


13. Four circular loops each with radius 40 cm and resistance 1 Ω are connected to a battery with EMF 3.92 V and zero internal resistance as shown in the figure. As shown in the figure the rate of increase of magnetic flux density is 2 T s^{-1} into the plane in one side and the rate of decrease of magnetic flux density is 4 T s^{-1} out of the plane on the other side. If the resistance in the other parts of the circuit is negligible, the current flow through the circuit is (Take $\pi = 3$)

(1) 0.10 A
(2) 0.15 A
(3) 0.25 A
(4) 0.50 A
(5) 1.46 A



14. Two charges with charge Q_1 and Q_2 rotate in circular paths with radii r_1 and r_2 and with angular velocities ω_1 and ω_2.Two circular paths are perpendicular to each other having same center. The magnetic flux density at the center is



(1) $\frac{\mu_0}{2}\sqrt{\frac{Q_1^4\omega_1^2}{r_1^2}+\frac{Q_2^4\omega_2^2}{r_2^2}}$

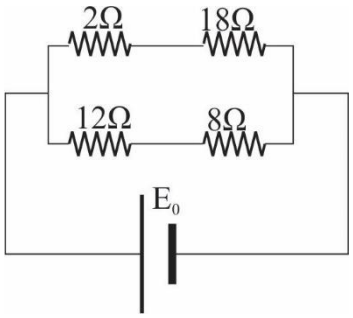
(2) $\frac{\mu_0}{4\pi}\sqrt{\frac{Q_1^2\omega_1^2}{r_1^2}+\frac{Q_2^2\omega_2^2}{r_2^2}}$

(3) $\frac{\mu_0}{2\pi}\sqrt{\frac{Q_1^2\omega_1^2}{r_1^3}+\frac{Q_2^2\omega_2^2}{r_2^3}}$

(4) $\frac{\mu_0}{4\pi}\sqrt{\frac{Q_1\omega_1}{r_1^2}+\frac{Q_2\omega_2}{r_2^2}}$

(5) $\frac{\mu_0}{4\pi}(\frac{Q_1^2\omega_1}{r_1^2}+\frac{Q_2^2\omega_2}{r_2^2})$

15. If the power dissipation by the 2 Ω resister shown in the figure is 10 W, the power dissipation by the 8 Ω resistor is



(1) 24 W

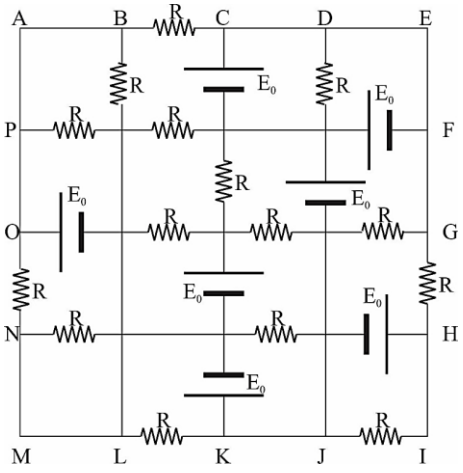
(2) 36 W

(3) 40 W

(4) 48 W

(5) 80 W

16. All the resistors shown in the figure is 10 Ω and electromotive force of all the batteries is E_0 = 6V. Internal resistance of each battery can be neglected. The potential difference between A and C is



(1) 6 V

(2) 12 V

(3) 18 V

(4) 24 V

(5) 36 V

17. The final temperature when mixing mass m from liquid A at 30 ºC and mass 2m from liquid B at 40 ºC is 36 ºC. The final temperature when mixing mass 2m from liquid B at 40 ºC and mass 3m from liquid C at 50 ºC is 45 ºC. The final temperature when mixing mass m from liquid A at 30ºC and mass 3m from liquid C at 50 ºC is, (Assume no heat is absorbed by the container and no heat loss to the environment)

(1) 38 ºC (2) 40 ºC (3) 42 ºC

(4) 45 ºC (5) 48 ºC

18. An object heated to 90 ºC, when cools under forced convection, takes 4 minutes to cool from 82 ºC to 78 ºC. How long will it take for the object to cool from 51 ºC to 49 ºC? The room temperature is 30 ºC.

(1) 4 minutes (2) 5 minutes (3) 6 minutes
(4) 7 minutes (5) 8 minutes

19. You have two thermometers one is correct and the other one is false. Both thermo meters are used to measure temperature of water at room temperature. The correct thermometer shows a value of 25 ºC and the false thermometer shows value of 26 ºC. When both thermometers are used to measure the boiling temperature of a liquid the correct thermometer shows a value of 75 ºC and the false thermometer shows value of 74 ºC. When both thermo meters are used to measure the temperature of another liquid false thermometer shows value of 60 ºC. The value shown in the correct thermometer is

(1) 57.42 ºC (2) 59.64 ºC (3) 60.42 ºC
(4) 61.40 ºC (5) 63.25 ºC

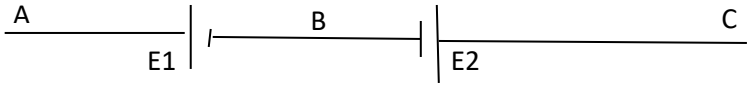
20. On a day that dew point is 25 ºC, the relative humidity of a closed room of volume 10 m^3 is 80% at 30 ºC. By turning on the air conditioner and 27 g water vapor is removed then the temperature of the room is 25 ºC and the relative humidity is 70%. Then the air conditioner is turned off and let the room's temperature come to 30 ºC without adding water vapor. The new relative humidity of the room is

(1) 50% (2) 52% (3) 54%
(4) 55% (5) 56%

21. Two wires, when connected in series, have an equivalent resistance of 18 Ω, and when connected in parallel, have an equivalent resistance of 4 Ω. Find their resistances.

(1) 10 Ω, 12 Ω (2) 12 Ω, 6 Ω. (3) 10 Ω, 6 Ω
(4) 12 Ω, 8 Ω. (5) 10 Ω, 8 Ω

22. Two cells of emfs E1 and E2 are connected as shown in the figure. When a potentiometer is connected between A and B, the balancing length of the potentiometer wire is 300 cm. On connecting the same potentiometer between A and C, the balancing length is 100 cm. The ratio of E1 and E2 is,



(1) 2:3 (2) 1:3 (3) 2:5
(4) 3:5 (5) 3:2

23. A Voltmeter has resistance 2000 Ω and reads 1 volt/division. The resistance that should be connected in series with the coil so that it reads 10 volts/ division is

(1) 2,000 Ω (2) 18,000 Ω (3) 20,000 Ω
(4) 21,000 Ω (5) 22,000 Ω

24. An object of mass *m* kg is taken from equator to the pole of the Earth. Radius, gravitational acceleration and rotation period of the Earth are R, g and 24 hours respectively. After moving from equator to pole of the Earth, weight of the object is

(1) remaining the same

(2) changed by $mg - \frac{4\pi^2 Rm}{(24\times3600)^2}$

(3) changed by $\frac{4\pi^2 Rm}{(24\times3600)^2}$

(4) changed by $mg + \frac{(24\times3600)^2 Rm}{4\pi^2}$

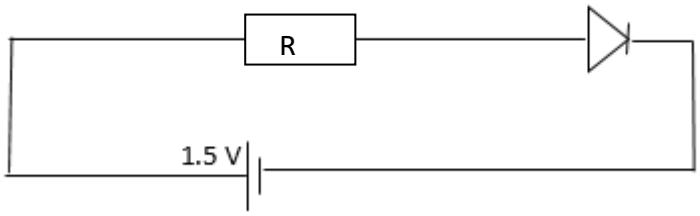
(5) changed by $2mg + \frac{4\pi^2 Rm}{(24\times3600)^2}$

25. In a common emitter amplifier, the load resistance is 5000 Ω and the input resistance is 1000 Ω. If the peak value of the signal voltage is 10 mV and the current gain is 50, then the peak value of the output voltage is.

(1) 1.25 V (2) 2.50 V (3) 3.75 V
(4) 5.00 V (5) 2.25 V

26. The diode used in the circuit shown in the figure has a constant voltage drop of 0.5 V at all currents and maximum power rating of 100 mW. The value of the resistor R, connected in series with the diode for obtaining maximum current should be

(1) 5.0 Ω
(2) 5.6 Ω
(3) 6.8 Ω
(4) 20.0 Ω
(5) 40.0 Ω



27. While a car is stopped at a traffic light in a rainy day, raindrops strike the roof of the car vertically. The area of the roof is 5.0 m^2. Each raindrop has a mass of 3.7×10^{-4} kg and speed of 2.5 ms^{-1} before impact and is at rest after the impact. If, on average at a given time, 150 raindrops strike each square meter, what is the impulse of the rain striking the car?

(1) 0.14 Ns (2) 0.45 Ns (3) 0.69 Ns
(4) 11.0 Ns (5) 21.0 Ns

28. A bicycle wheel of radius 0.70 m is rolling without slipping on a horizontal surface with an angular speed of 2.0 $revs^{-1}$. When the cyclist begins to uniformly apply the brakes, the bicycle stops in 5.0 s. How far did the bicycle travel during the 5.0 seconds of braking?

(1) 1.8 m (2) 8.8 m (3) 22.0 m
(4) 42.0 m (5) 44.0 m

29. A container containing 115 kg of an ideal gas has a volume of 6.5 m^3. If the gas exerts a pressure of 4.0×10^5 Pa, what is the *rms* speed of the molecules?

(1) 180 ms^{-1} (2) 260 ms^{-1} (3) 310 ms^{-1}
(4) 390 ms^{-1} (5) 420 ms^{-1}

30. A Carnot engine operates between hot and cold reservoirs with temperatures 527 °C and –73 °C, respectively. If the engine performs 1000 J of work per cycle, how much heat is extracted per cycle from the hot reservoir? Note the efficiency of a Carnot engine is given by $\eta = 1 - \frac{T_C}{T_H}$ where T_H and T_C are the absolute temperature of the hot and cold reservoirs.

(1) 878 J (2) 1163 J (3) 1333 J
(4) 1527 J (5) 2010 J

31. A source moving through water at 10.0 ms^{-1} generates water waves with a frequency of 5.0 Hz. The speed of these water waves relative to the water surface is 20.0 ms^{-1}. The source approaches an observer who is at rest in the water. The wavelength observed by the observer is,

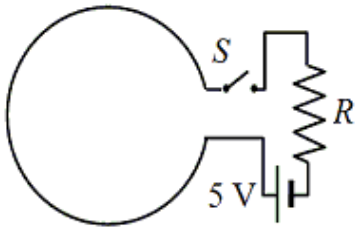
(1) 1.0 m (2) 2.0 m (3) 4.0 m
(4) 6.0 m (5) 8.0 m

32. A circular loop of wire with a diameter of 0.626 m is rotated in a uniform electric field to a position where the electric flux through the loop is a maximum. At this position, the electric flux is 7.50×10^5 N m^2 C^{-1}. What is the magnitude of the electric field?

(1) 1.07×10^6 N C^{-1} (2) 2.44×10^6 N C^{-1}
(3) 4.24×10^6 N C^{-1} (4) 6.00×10^6 N C^{-1}
(5) 8.88×10^5 N C^{-1}

33. The figure shows a circular, conducting loop that is connected to a 5.0 V battery and a switch *S*. Immediately after the switch *S* is closed, the current through the loop changes at a rate of 15 A s^{-1} and the emf induced in the loop has a magnitude of 5.0 V. The *self-inductance* of the coil is,

(1) 0.3 H
(2) 0.6 H
(3) 1.5 H
(4) 3.0 H
(5) 5.0 H



34. A distant space probe is programmed to emit a radio signal toward Earth at regular time intervals. One such pulse arrives on Earth 6.92 s after it is emitted from the probe. What is the approximate distance from the Earth to the probe?

(1) 7.40×10^{10} m (2) 3.50×10^{10} m
(3) 8.76×10^9 m (4) 6.94×10^9 m
(5) 2.08×10^9 m

35. A ray of light originates in medium **A** and is incident upon medium **B**. For which one of the following pairs of indices of refraction for **A** and **B (**n_A and n_B) is total internal reflection *not possible*?

(1) 1.12, 1.06 (2) 1.36, 1.00
(3) 1.26, 1.15 (4) 2.54, 1.63
(5) 1.28, 1.36

36. The de Broglie wave length of a neutron of mass $m = 1.67 \times 10^{-27}$ kg that has a speed of 5.0 ms^{-1} is given by

(1) 79 nm (2) 162 nm (3) 395 nm
(4) 529 nm (5) 1980 nm

37. A beam of 4.5 MeV neutrons is directed at a tissue sample of mass 0.030 kg. Each second, 1.5×10^6 neutrons strike the sample. If the relative biological effectiveness of these neutrons is 7.0, what biologically equivalent dose (in rem) is received by the sample in 65 seconds?

(1) 0.23 rem (2) 0.55 rem (3) 1.6 rem
(4) 19 rem (5) 33 rem

38. Determine the amount of energy released in the following reaction:
$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He}$. Use the following information for your calculation:
$^{2}_{1}\mathrm{H}$ has a mass of 2.014 102 u, $^{4}_{2}\mathrm{He}$ has a mass of 4.002 603 u, and 1 u = 931.5 MeV.

(1) 0.20 MeV (2) 23.8 MeV (3) 11.9 MeV
(4) 257 MeV (5) 7480 MeV

39. In the medical diagnostic technique known as positron emission tomography (PET), a positron and an electron annihilate each other and two γ–ray photons are emitted. The angle between the momentum vectors of the two photons is?

(1) 0° (2) 45° (3) 90°
(4) 180° (5) 270°

40. Assume the intensity of the sound made by a jet engine at a distance d is 4.0×10^{-2} Wm^{-2}. If there are three jets A, B and C, each at distances d, 2d and 4d from a person respectively what is the sound level at the point the person is at?

(1) 103 dB (2) 105 dB (3) 107 dB
(4) 109 dB (5) 111 dB

41. Two cars (A and B), each emitting sound with 100 Hz, are running towards a point P in a flat empty land. The velocity of the two cars is 10 m s^{-1} and they are at a same distance from the point P at any given time. The angle the two cars made looking from point P (APB angle) is 60°. What is the beat frequency heard by the driver in car B? Speed of sound 330 m s^{-1}.

(1) 0 Hz (2) 1 Hz (3) 2 Hz
(4) 3 Hz (5) 6 Hz

42. Water at boiling point is in a boiler without a cover on outer surface is connected to a heater of ratings 40 Ω, 200 V. When it is working under a 100 V potential difference, the rate of releasing water vapor is M_1 kg s^{-1}. When the same heater is working under a 200 V potential difference, the rate of releasing water vapor is M_2 kg s^{-1}. The latent heat of evaporation of water is,

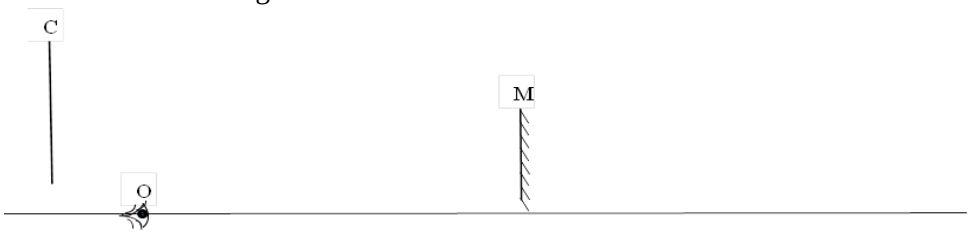
(1) $\frac{750}{M_2-M_1}$ (2) $\frac{1500}{M_2-M_1}$ (3) $\frac{600}{M_1-M_2}$
(4) $\frac{500}{M_2-M_1}$ (5) $\frac{150}{M_1-M_2}$

43. Which one of the following energy values would be characteristic of a *thermal neutron*? Assume Boltzmann's constant is 8.617×10^{-5} eVK^{-1} and room temperature is 27 °C.

(1) 0.04 MeV (2) 3 eV
(3) 0.03 eV (4) 0.4 eV
(5) 100 eV

- **Use the following information for Questions 44 & 45**

A sight-testing chart (C) of dimensions (height × width) 120 cm × 80 cm is to be viewed by reflection in a plane mirror. An observer *O* is standing 2.75 m in front of a plane mirror (M), while the chart *C* hangs in a wall 3.25 m distance from M and behind him.



44. What is the smallest height of the mirror that can be used to observe the complete image of the chart?

(1) 0.33 m (2) 0.55 m (3) 0.76 m
(4) 1.01 m (5) 1.42 m

45. If the observer's eye and the lower edge of the chart are respectively 1.2 m and 1.5 m above the ground, what is the distance from the ground to the bottom edge of the mirror?

(1) 0.74 m (2) 1.14 m (3) 1.34 m
(4) 1.64 m (5) 1.68 m

- **Write the relevant answer for question numbers 46 to 50 in the blank space on the answer sheet.**

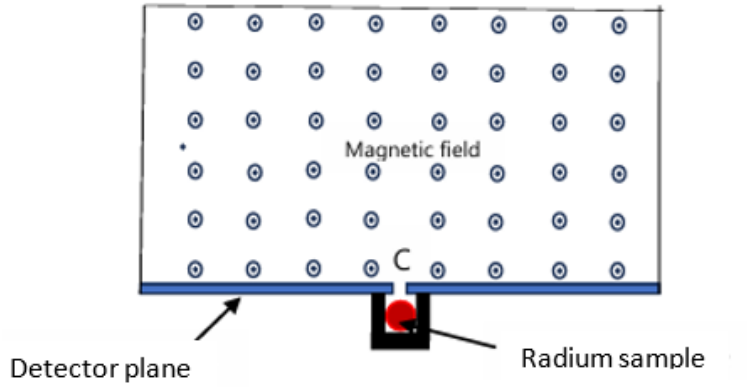
46. Rutherford's well-known gold foil experiment involved bombarding a thin gold leaf with alpha particles, allowing him to estimate the diameter of the gold nucleus. What is the radius of a gold nucleus ($^{197}_{79}Au$) in nanometers if an alpha particle with an initial energy of 0.500 MeV undergoes a head-on collision with the nucleus. Assume the closest approach between the gold nucleus and alpha particle. Consider the gold nucleus to remain at rest during the collision

47. A small radioactive source of ^{137}Cs is used in a laboratory. It has a strength of 1 μCi. What is the number of gamma rays emitted per second?

48. What is the Q-value for nuclear reaction (in Jules) $^{15}_{7}N + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{12}_{6}C$?
$^{15}_{7}N = 15.000109u, {}^{1}_{1}H = 1.007825u,\ {}^{4}_{2}He = 4.002603u,\ {}^{12}_{6}C = 12.000000u$
1u = 931.494 MeV.

- **Use the following information for the question numbers 49 and 50.**

A radioactive sample of $^{226}_{88}Ra$, which decays through α particle emission is placed very close to a cylindrical vacuum chamber with a particle detector plane whose cross-sectional view is shown in the figure below. There exists a uniform magnetic induction $\vec{B}$ in the direction as shown. The magnitude of this applied magnetic field is B = 1.5 T and the radius of the cylindrical chamber is 0.8 m. Take mass of the α particle, $m_\alpha = 6.645 \times 10^{-27}\, kg$. $e = 1.6 \times 10^{-19} C$



49. What is the maximum kinetic energy (in MeV) of the α particles that would be hitting the detector plane?

50. It was observed that the α particles emitted from the Radium source hits the detector plane at a distance 66.52 cm from the center of the chamber. What is the total energy E_t, emitted during the escape of the α-particle

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