SINGAPORE JUNIOR PHYSICS OLYMPIAD 2009
GENERAL ROUND

5 August, 2009

2:30 pm – 4:00 pm

Time Allowed: ONE hour THIRTY minutes

INSTRUCTIONS

1. This paper contains **50** multiple choice questions and **20** printed pages.
2. Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one that is best in each case and then shade the corresponding bubble on the answer sheet.
3. Only the answer sheet will be collected at the end of the test. Answers written anywhere else will not be marked.
4. Use 2B pencil only. Using any other type of pencil or pen may result in answers unrecognizable by the machine.
5. Answer all questions. Marks will **NOT** be deducted for wrong answers.
6. Scientific calculators are allowed in this test.
7. A table of information is given in page 2.

TABLE OF INFORMATION

$$
\begin{aligned}
\text{Acceleration due to gravity at Earth surface, } g &= 9.80 \text{ m/s}^2 \\
\text{Universal gravitational constant } G &= 6.67 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2) \\
\text{Universal gas constant, } R &= 8.31 \text{ J}/(\text{mol} \cdot \text{K}) \\
\text{Vacuum permittivity, } \epsilon_0 &= 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2) \\
\text{Vacuum permeability, } \mu_0 &= 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \\
\text{Atomic mass unit, } u &= 1.66 \times 10^{-27} \text{ kg} \\
\text{Speed of light in vacuum, } c &= 3.00 \times 10^{8} \text{ m/s} \\
\text{Charge of electron, } e &= 1.60 \times 10^{-19} \text{ C} \\
\text{Planck's constant, } h &= 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \\
\text{Mass of electron, } m_e &= 9.11 \times 10^{-31} \text{ kg} \\
\text{Mass of proton, } m_p &= 1.67 \times 10^{-27} \text{ kg} \\
\text{Boltzmann constant, } k &= 1.38 \times 10^{-23} \text{ J/K} \\
\text{Avogadro's number, } N_A &= 6.02 \times 10^{23} \text{ mol}^{-1} \\
\text{Standard atmosphere pressure} &= 1.01 \times 10^{5} \text{ Pa} \\
\text{Density of water} &= 1000 \text{ kg/m}^3 \\
\text{Lorentz Transformation: } x' &= \frac{x - ut}{\sqrt{1 - u^2/c^2}} \\
y' &= y \\
z' &= z \\
t' &= \frac{t - ux/c^2}{\sqrt{1 - u^2/c^2}}
\end{aligned}
$$

1. A flat disk with a mass of 0.50 kg is sent sliding along a frozen pond with an initial speed of 10 m/s. If the sliding frictional force exerted by the ice surface on the disc is a constant 0.50 N, in what distance will the disc come to rest?

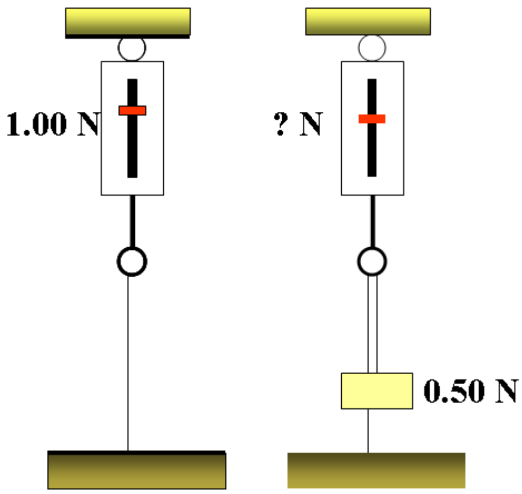
   (A) 28 m
   (B) 40 m
   (C) 47 m
   (D) 50 m
   (E) 55 m

2. Two projectiles are launched with identical speeds of 30 m/s and at angles 40° and 50° with the horizontal, respectively. The difference between the flight times of the two projectiles is closest to:

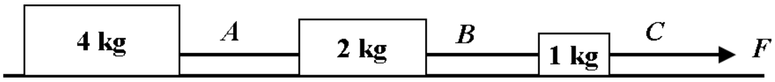
   (A) $\frac{2}{3}$ s
   (B) $\frac{3}{4}$ s
   (C) $\frac{4}{5}$ s
   (D) $\frac{5}{6}$ s
   (E) $\frac{6}{7}$ s

3. A spring balance is hung from the ceiling. An inextensible rope is attached to the hook of the spring balance, pulled tight so that the balance reads 1.00 N, and then anchored to the ground as seen in the first figure below. If an object with weight of 0.50 N is now hung on the hook (second figure), what will the balance read?

   (A) 0.50 N
   (B) 0.75 N
   (C) 1.00 N
   (D) 1.25 N
   (E) 1.50 N



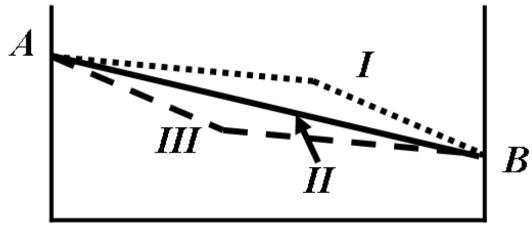
4. Three boxes are connected by stretchless strings and are pulled by a force F on a frictionless floor. Which string has to be the strongest so as not to break?



(A) A.
(B) B.
(C) C.
(D) They all have to be equally strong.
(E) It depends on the acceleration of the system.

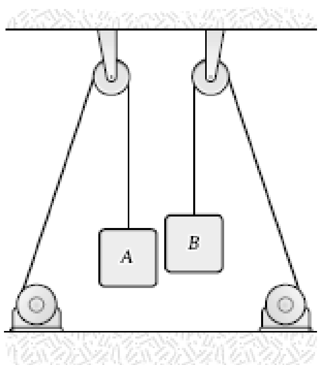
5. A marble rolls from A to B via one of the three possible paths I, II and III. By which path will it take the shortest time to reach B?

(A) I
(B) II
(C) III
(D) I and III both take the shortest.
(E) All take the same time.



6. Two equal masses are raised at constant velocity by ropes that run over pulleys as shown. Mass B is raised twice as fast as mass A. The magnitudes of the forces are F_A and F_B, while the power supplied is respectively P_A and P_B. Which of the following statements is correct?

(A) $F_B = F_A$; $P_B = P_A$.
(B) $F_B = F_A$; $P_B = 2P_A$.
(C) $F_B = 2F_A$; $P_B = P_A$.
(D) $F_B = 2F_A$; $P_B = 2P_A$.
(E) $F_B = 2F_A$; $P_B = 4P_A$.



7. A carnival Ferris wheel has a 15-m radius and completes five turns about its horizontal axis every minute. What is the acceleration of a passenger at his lowest point during the ride?

   (A) 0 m/s^2

   (B) 5.7 m/s^2 downward

   (C) 19 m/s^2 downward

   (D) 4.1 m/s^2 upward

   (E) 14 m/s^2 upward

8. A 30-year-old woman takes a trip on a rocket, leaving her 20-year-old brother behind. She travels at a speed of 0.8 c, and is gone 20 years, according to the younger brother. When she returns, how many years older/younger is she than her brother?

   (A) 8 years younger

   (B) 2 years younger

   (C) 2 years older

   (D) 8 years older

   (E) 10 years older

9. A car of rest length 5 m passes through a garage of rest length 4 m. Due to relativistic Lorentz contraction, the car is only 3 m long in the garage's rest frame. The doors on both ends of the garage, which opens automatically when the front of the car reaches them and close automatically when the car passes them. The opening or closing of each door requires a negligible amount of time. Which of the following statements is the best response to the question: "*Was the car ever inside a closed garage?*"

   (A) No, because the car is longer than the garage in all reference frames.

   (B) No, because the Lorentz contraction is not a "real" effect.

   (C) Yes, because the car is shorter than the garage in all reference frames.

   (D) Yes, because the answer to the question in the garage's frame must apply in all reference frames.

   (E) There is no unique answer to the question, as the order of door openings and closings depends on the reference frame.

10. A stopping potential of 0.50 V is required when a phototube is illuminated with monochromatic light of 490 nm wavelength. The wavelength of a different monochromatic illumination for which the stopping potential is 1.50 V is closest to

   (A) 350 nm.
   (B) 330 nm.
   (C) 380 nm.
   (D) 400 nm.
   (E) 450 nm.

11. The photoelectric effect is best explained with the assumption that

   (A) electrons are restricted to orbits of angular momentum $nh/(2\pi)$, where n is an integer.
   (B) electrons are associated with waves of wavelengths $\lambda = h/p$, where p is momentum.
   (C) light is emitted only when electrons jump between orbits.
   (D) light is absorbed in quanta of energy $E = hf$, where f is the frequency of light.
   (E) light behaves like a wave.

12. The total energy of a blackbody radiation source is collected for one minute and use to heat water. The temperature of the water increases from 20.0°C to 20.5°C. If the absolute temperature of the blackbody have doubled and the experiment is repeated, which of the following statements would be most nearly correct?

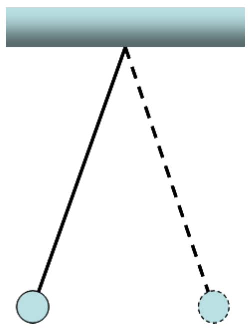
   (A) The temperature of the water would increase from 20°C to a final temperature of 21°C.
   (B) The temperature of the water would increase from 20°C to a final temperature of 24°C.
   (C) The temperature of the water would increase from 20°C to a final temperature of 28°C.
   (D) The temperature of the water would increase from 20°C to a final temperature of 36°C.
   (E) The water would boil within the one-minute time period.

13. At Earth's location, the intensity of sunlight is 1.5 kW/m^2. If no energy escapes Earth, by how much would Earth's mass increase in a day? (Radius of Earth is 6.37×10^6 m.)

(A) 8.5 kg/day
(B) 200 kg/day
(C) 1.3×10^3 kg/day
(D) 1.8×10^5 kg/day
(E) 7.3×10^5 kg/day

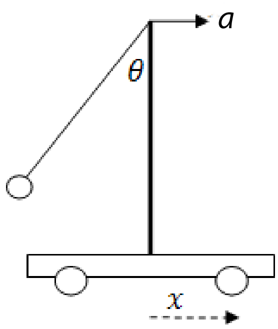
14. What is the period of a simple pendulum if the length of the cord is 67.0 cm and the pendulum bob has a mass of 2.4 kg?

(A) 0.259 s
(B) 1.63 s
(C) 3.86 s
(D) 16.3 s
(E) 24.3 s



15. A small bob with a mass of 250 g is suspended by a string from a clamp attached to a cart that is accelerating at a constant rate of $a = 2$ m/s^2 as it moves along a flat straight table as shown in the diagram below. Assuming the bob to be suspended motionless with respect to the cart, approximately what angle does the string make with the vertical?

(A) 11.5°
(B) 10.0°
(C) 78.5°
(D) 75.0°
(E) 11.0°



16. Identical springs with spring constant k are connected to identical masses of mass M in three different configurations as shown in Figures 1, 2 and 3 below. The periods of oscillations in the configurations are T_1, T_2 and T_3 respectively. Which statement is correct?

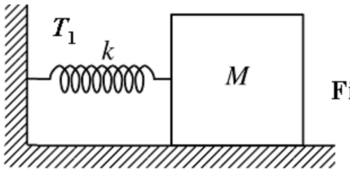


Figure 1

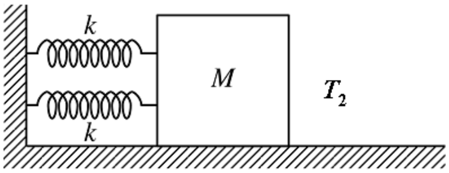


Figure 2

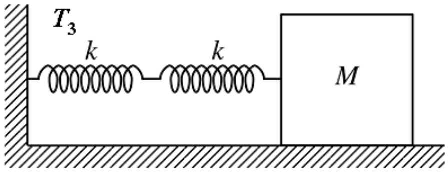
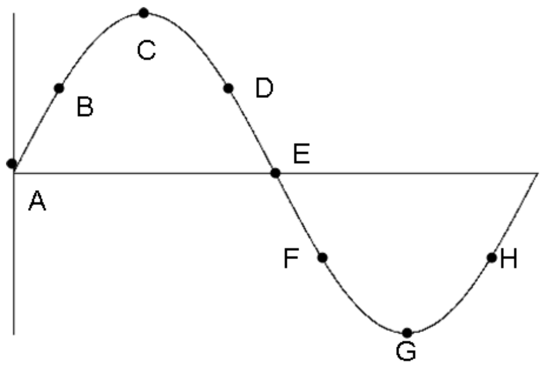


Figure 3

(A) $T_1 > T_2 > T_3$
(B) $T_2 > T_1 > T_3$
(C) $T_3 > T_1 > T_2$
(D) $T_1 = T_3 > T_2$
(E) $T_1 = T_2 = T_3$

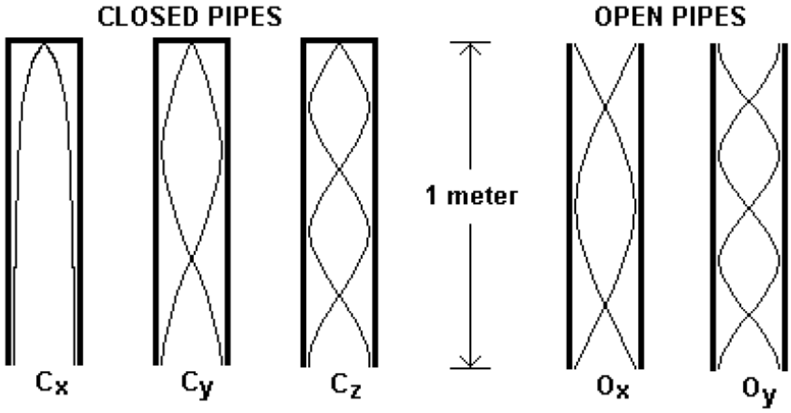
17. The figure shows a transverse wave at a particular instant in time. If we know that point F is moving downwards at that time, we can deduce that



(A) the wave is travelling towards the right.
(B) the point H is moving in the same direction as point F.
(C) C will reach the equilibrium position earlier that B.
(D) the acceleration at D at this point is the maximum.
(E) A is not moving at all.

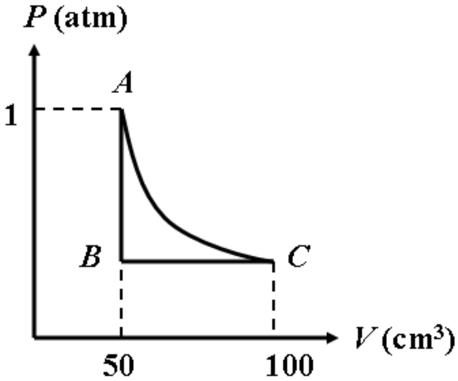
18. What is the length of the longest wavelength shown?

(A) 0.50 m
(B) 0.75 m
(C) 1.00 m
(D) 2.00 m
(E) 4.00 m



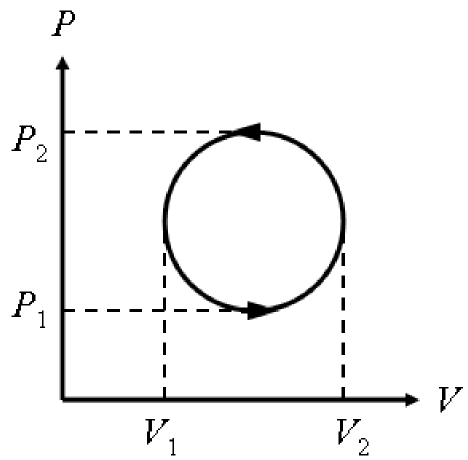
19. 0.02 moles of an ideal gas undergo a cycle consisting of an isochoric process, an isobaric process, and an isothermal process as shown below. Volumes and pressures at specific points are indicated on the axes. The pressure at point B is closest to:

(A) 1.0 atm
(B) 1.5 atm
(C) 0.2 atm
(D) 0.1 atm
(E) 0.5 atm



20. A thermodynamic system undergoes a cyclic process as shown in the figure below. The heat energy absorbed **by** the system over one complete cycle is:

(A) $\pi(P_2 - P_1)(V_1 - V_2)/4$
(B) $\pi(P_1 - P_2)(V_1 - V_2)/2$
(C) $\pi(P_2 - P_1)(V_2 - V_1)$
(D) $\pi(P_2 - P_1)V_2$
(E) $\pi P_2(V_2 - V_1)$



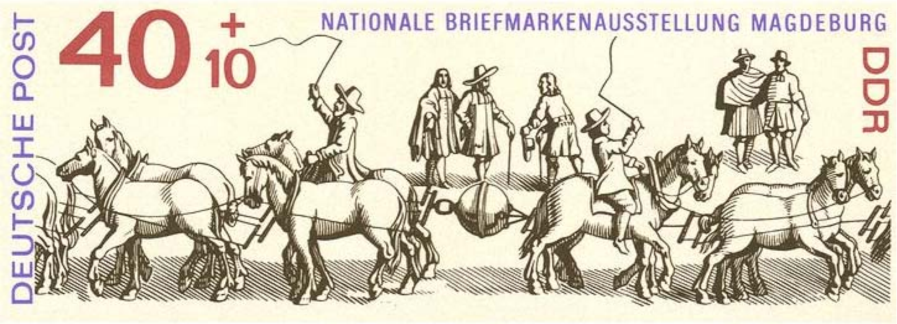
21. When a solid copper ball is heated, the largest percentage increase will occur in its:

(A) diameter
(B) area
(C) volume
(D) density
(E) The diameter, volume and area increases by same percentage

22. A 50.0 gram lead block (c = 128 J/kg·K), initially at 450°C, is dropped into an insulated cup containing 200 ml of 20°C water (c = 4190 J/kg·K). What is the final equilibrium temperature of the water?

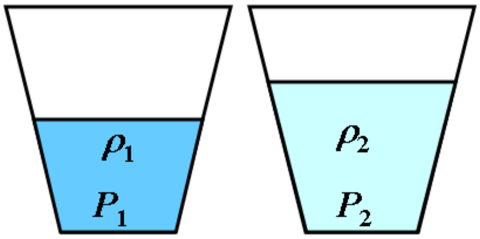
(A) 21.1°C
(B) 23.3°C
(C) 32.4°C
(D) 24.5°C
(E) 26.5°C

23. The German stamp below depicts the scene of the famous experiment conducted in 1650 by Otto von Guericke. The pair of hemispheres in the centre have diameter of 50 cm. What was the minimum force needed to separate the two hemispheres after the air was sucked out of the sphere?



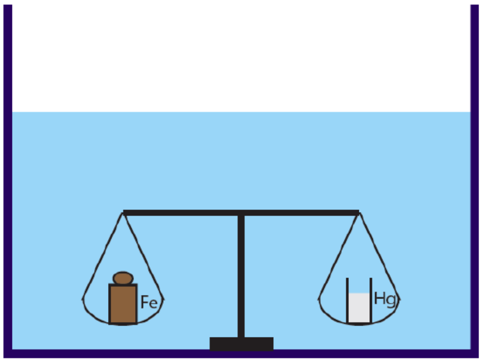
(A) 5000 N
(B) 10000 N
(C) 20000 N
(D) 40000 N
(E) 80000 N

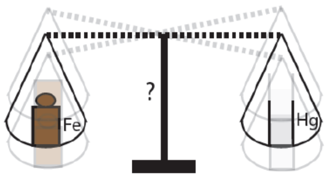
24. Two identical cups with the shape shown below contain same mass of two different types of liquid with densities $\rho_1 > \rho_2$. Which statement is correct about the pressure (P_1 and P_2) due to the liquids on the bottom of the cups?



(A) P_1 is always larger than P_2
(B) P_1 is always equal to P_2
(C) P_1 is always smaller than P_2
(D) P_1 may be larger than or equal to P_2
(E) P_1 may be smaller than or equal to P_2

25. Suppose the two plates of a balance scale are in equilibrium while the scale is kept under water (see figure). On one side is a 1 kg iron weight (Fe) and an unknown amount of mercury (Hg) on the other. If the density of iron is 7870 kg/m^3 and the density of mercury is 13550 kg/m^3, when you lift it out of the water





(A) the scale is still balanced.
(B) you can balance it again by adding 180 g to the plate on the left.
(C) you can balance it again by adding 97 g to the plate on the right.
(D) you can balance it again by adding 58 g on the right.
(E) you can balance it again by adding 29 g on the left.

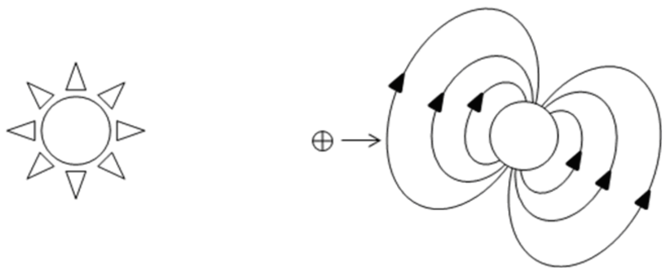
26. The approximate number of photons in a femtosecond (10^{-15}) pulse of 600 nm wavelength light from a 10-kW peak-power dye laser is

(A) 10^3
(B) 10^7
(C) 10^{11}
(D) 10^{15}
(E) 10^{18}

27. A beam of electrons is accelerated through a potential difference of 25 kV in an x-ray tube. The continuous x-ray spectrum emitted by the target of the tube will have a short wavelength limit of most nearly

(A) 0.01 nm
(B) 0.05 nm
(C) 0.2 nm
(D) 2.5 nm
(E) 5.0 nm

28. When a proton in the solar wind enters Earth's magnetic field as shown in the figure below, it



(A) follows a circular path.
(B) follows a linear path down into Earth's atmosphere.
(C) spirals to the north geomagnetic pole and down into Earth's atmosphere.
(D) spirals to the south geomagnetic pole and down into Earth's atmosphere.
(E) bounces back and forth, from pole to pole of Earth's magnetic field.

29. On March 13, 1989, the whole province of Quebec, Canada, suffered a blackout. This event was the result of a coronal mass ejection (CME) from the Sun, consisting primarily of electrons and protons. When the CME struck Earth, direct currents flowed through Quebec's power lines, causing a transformer failure. These currents occurred as a consequence of

(A) Ampere's law.
(B) Coulomb's law.
(C) Faraday's law.
(D) Gauss' law
(E) Ohm's law.

30. Three polarizing plates are stacked. The first and third are crossed; the one between has its polarizing direction at $45°$ to the polarizing direction of the other two. What fraction of the intensity of an originally unpolarized beam is transmitted by the stack?

    (A) 100%
    (B) 50%
    (C) 25%
    (D) 12.5%
    (E) 0%

31. The terminals of a 1.5-V battery are connected directly to each other in a short circuit, and a 30-A current flows through the circuit (Warning: A short circuit can be an extremely dangerous situation. Dont try it!). Now, a 4-Ω resistor is added to the circuit. What is the current flowing through the circuit?

    (A) 0 A
    (B) 0.370 A
    (C) 0.375 A
    (D) 0.380 A
    (E) 30 A

32. You are given a length of heating wire. When a potential difference of 120 V is applied across the full length of the wire, a power of 200 W is dissipated. Now, the wire is cut in half, and a potential difference of 120 V is applied across the length of each half, how much power is dissipated in total?

    (A) 100 W
    (B) 200 W
    (C) 400 W
    (D) 800 W
    (E) 1600 W

33. Light of wavelength 500 nm traveling with a speed 2.0×10^8 m/s in a certain medium enters another medium of refractive index 1.25 times that of the first medium. What are the wavelength and speed in the second medium?

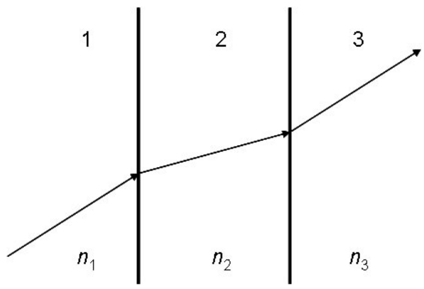
(A) 400 nm, 1.6×10^8 m/s
(B) 400 nm, 2.5×10^8 m/s
(C) 500 nm, 2.5×10^8 m/s
(D) 625 nm, 1.6×10^8 m/s
(E) 625 nm, 2.0×10^8 m/s

34. The critical angle for light going from medium X into medium Y is θ. The speed of light in medium X is v. The speed of light in medium Y is

(A) $v(1 - \cos\theta)$
(B) $v/\cos\theta$
(C) $v\cos\theta$
(D) $v/\sin\theta$
(E) $v\sin\theta$

35. A light ray passes through substances 1, 2 and 3, as shown below. The indices of refraction for these three substances are n_1, n_2 and n_3 respectively. Ray segments in 1 and 3 are parallel. From the directions of the ray, one can conclude that

(A) n_2 must be less than n_1
(B) n_2 must be less than n_3
(C) n_1 must be equal to 1.00
(D) n_3 must be the same as n_1
(E) all three indices must be the same



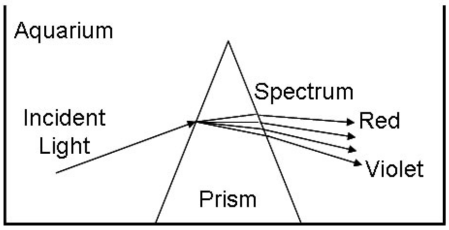
36. A concave mirror is used to form an image of the Sun on a white screen. If the lower half of the mirror were covered with an opaque card, the effect on the image on the screen would be

(A) negligible.
(B) to make the image less bright than before.
(C) to make the upper half of the image disappear.
(D) to make the lower half of the image disappear.
(E) to prevent the image from being focused.

37. Two thin lenses are placed 5 cm apart along the same axis and illuminated with a beam of light parallel to that axis. The first lens in the path of the beam is a converging lens of focal length 10 cm whereas the second is a diverging lens of focal length 5 cm. If the second lens is now moved towards the first, the emergent light

(A) remains parallel.
(B) remains convergent.
(C) remains divergent.
(D) changes from parallel to divergent.
(E) changes from convergent to divergent.

38. A beam of white light is incident on a triangular glass prism with an index of refraction of about 1.5 for visible light producing a spectrum. Initially, the prism is in a glass aquarium filled with air as shown below. If the aquarium is then filled with water with an index of refraction of 1.3, which of the following is true?



(A) No spectrum is produced.
(B) The spectrum produced is the same as that produced in air.
(C) The positions of the red and violet are reversed in the spectrum.
(D) The spectrum produced has greater separation between red and violet than that produced in air.
(E) The spectrum produced has less separation between red and violet than that produced in air.

39. A beam of light of wavelength λ is totally reflected at normal incidence by a plane mirror. The intensity of the light is such that photons hit the mirror at a rate n. Given that the Planck's constant is h, the force exerted on the mirror by this beam is

(A) $nh\lambda$
(B) nh/λ
(C) $2nh\lambda$
(D) $2n\lambda/h$
(E) $2nh/\lambda$

40. Red light is used in the darkroom for developing black and white photographic film. This is because

(A) red light can have no effect on the films since they are in black and white.
(B) red light has the lowest energy per photon in the visible range so it will have the least effect on the film.
(C) red light has the shortest wavelength in the visible spectrum and thus does not damage the film.
(D) red light has the highest frequency in the visible spectrum and it will have the least effect on the film.
(E) our eyes are more sensitive to red light and this makes working in low light levels efficient and practical.

41. Consider the following five transitions in a hydrogen atom:

n_i	n_f	Wavelength of the photon involved
2	1	λ_1
3	1	λ_2
4	1	λ_3
3	2	λ_4
4	2	λ_5

Which of the following statement is correct?

(A) $\lambda_3 = \lambda_4 + \lambda_5$
(B) $\lambda_1 > \lambda_2$
(C) λ_4 is the shortest of the five wavelengths.
(D) λ_5 is the longest of the five wavelengths.
(E) The transition corresponding to wavelength λ_3 represents the ionization of the atom.

42. As the atomic number increases the number of neutrons in the nucleus tends to

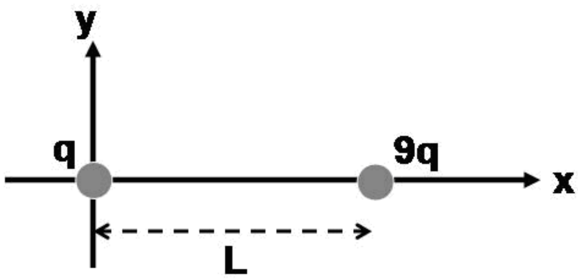
(A) decrease with respect to the number of protons.
(B) increase with respect to the number of protons.
(C) exactly match the number of protons.
(D) almost match the number of protons, but is strictly below.
(E) almost match the number of protons, but is strictly above.

43. Arrange the nuclei ${}^{2}_{1}$H, ${}^{4}_{2}$He, ${}^{56}_{26}$Fe and ${}^{207}_{82}$Pb, in order of increasing binding energy per nucleon.

(A) ${}^{2}_{1}$H, ${}^{4}_{2}$He, ${}^{56}_{26}$Fe, ${}^{207}_{82}$Pb
(B) ${}^{2}_{1}$H, ${}^{4}_{2}$He, ${}^{207}_{82}$Pb, ${}^{56}_{26}$Fe
(C) ${}^{207}_{82}$Pb, ${}^{2}_{1}$H, ${}^{4}_{2}$He, ${}^{56}_{26}$Fe
(D) ${}^{56}_{26}$Fe, ${}^{207}_{82}$Pb, ${}^{2}_{1}$H, ${}^{4}_{2}$He
(E) ${}^{207}_{82}$Pb, ${}^{56}_{26}$Fe, ${}^{2}_{1}$H, ${}^{4}_{2}$He

44. Point charges q (at $x = 0$) and $9q$ (at $x = L$) are a distance L apart. Where should a third charge Q be placed along the x axis so that the net force on ALL THREE charges vanishes? What is the required value of Q?

(A) At $x = L/9$ and $Q = -6q/16$
(B) At $x = L/4$ and $Q = -6q/16$
(C) At $x = L/4$ and $Q = -9q/16$
(D) At $x = L/3$ and $Q = -6q/16$
(E) At $x = L/3$ and $Q = -9q/16$



45. A resistor is made from a hollow cylinder of length L, inner radius a, and outer radius b. The interior of the cylinder is filled with a different material. Let r be the distance from the axis of the cylinder. The region $a < r < b$ is filled with material of resistivity ρ_1. The region $r < a$ is filled with material of resistivity ρ_2 where $\rho_2 = \rho_1/2$. Find the resistance R across both ends of this resistor.

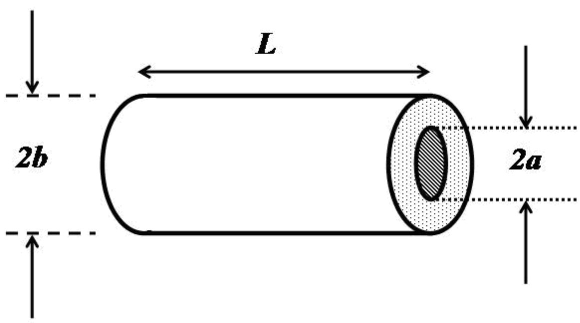
(A) $R = \dfrac{\rho_1 L}{\pi(b^2 - a^2)}$

(B) $R = \dfrac{\rho_1 L}{\pi(b^2 + a^2)}$

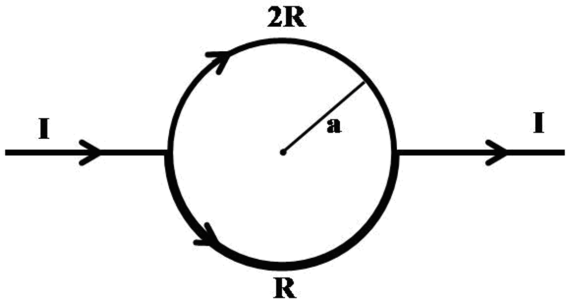
(C) $R = \dfrac{\rho_1 L}{2\pi}\dfrac{a^2 + b^2}{a^2(b^2 + a^2)}$

(D) $R = \dfrac{\rho_1 L}{2\pi}\dfrac{a^2 + b^2}{a^2(b^2 - a^2)}$

(E) $R = \dfrac{\rho_1 L}{\pi}\dfrac{a^2 + b^2}{a^2(b^2 - a^2)}$



46. Two wires are bent into semicircles of radius a as shown. If the upper half has resistance 2R Ω and the lower half has resistance R Ω, then find the magnetic field at the center of the circle in terms of the current I and radius a. What is the direction of this magnetic field?



(A) $\mu_0 I/(12a)$ into the plane of the paper.

(B) $\mu_0 I/(12a)$ out of the plane of the paper.

(C) $\mu_0 I/(6a)$ into the plane of the paper.

(D) $\mu_0 I/(4a)$ out of the plane of the paper.

(E) $\mu_0 I/(4a)$ into the plane of the paper.

47. Which of the following can be a unit for the energy possessed by a charged particle?

(I) keV (kilo-electronvolt)
(II) nJ (nanojoule)
(III) mW (milliwatts)

(A) I and II only

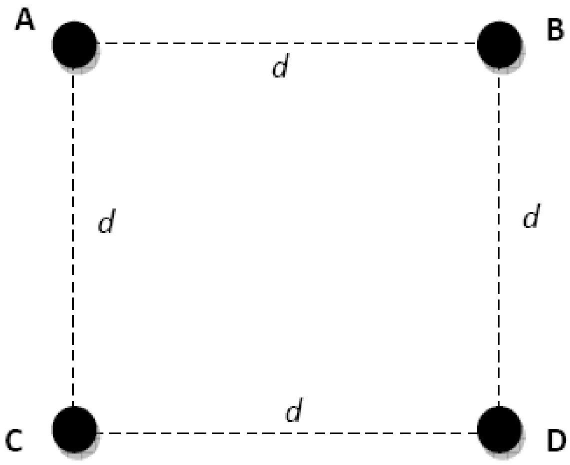
(B) I and III only

(C) I only

(D) II only

(E) I, II and III

The following diagram and description apply to Questions 48 and 49. The figure shows 4 identical metal spheres **A**, **B**, **C** and **D**.



Initially, **A** carries a charge of 8 nC and **B**, **C** and **D** do not carry any charge. The following then takes place in sequence. **A** is allowed to touch **B** and then returned to its original position. Then, **B** is allowed to touch **C** and then returned to its original position. Finally, **C** is allowed to touch **D** and then returned to its original position. (You may assume that the distance between the charges d is much greater than the dimensions of the spheres.)

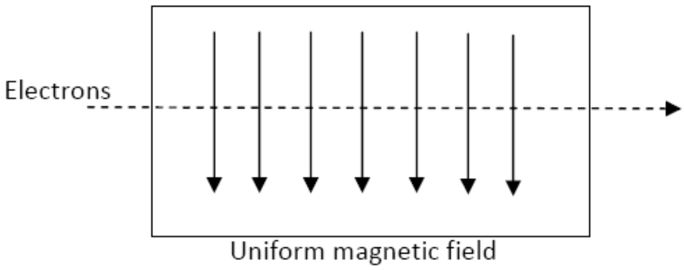
48. What is the charge residing on **C** at the end of the sequence of the events?

(A) 1 nC
(B) 2 nC
(C) 4 nC
(D) 8 nC
(E) 16 nC

49. At the end of the sequence of the events, what is the ratio of the force between **A** and **B** to the force between **C** and **D**?

(A) 1 : 1
(B) 2 : 1
(C) 4 : 1
(D) 8 : 1
(E) 16 : 1

50. A beam of electrons enters a region in which there are magnetic and electric fields. How should an electric field E be applied such that the beam passes straight through the region without deviation?



(A) Downwards along the plane of the paper

(B) Upwards along the plane of the paper

(C) Out of the plane of the paper

(D) Into the plane of the paper

(E) Electrons are not affected by magnetic fields so no application of any field is necessary.

END OF PAPER.