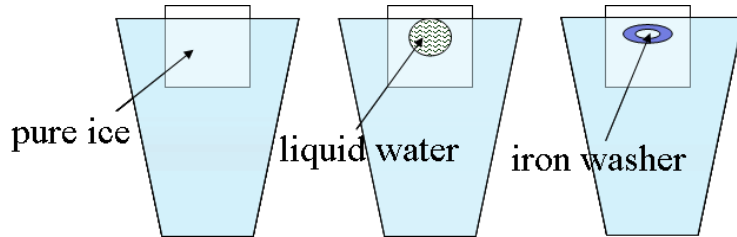


**SINGAPORE JUNIOR PHYSICS OLYMPIAD  
GENERAL ROUND**

1. This paper comprises 19 printed pages (inclusive of cover page.)
2. Indicate all answers in the optical mark sheet provided using a 2B pencil.  
There may be 4 or 5 options to each question.
3. Scientific calculators are allowed in this examination.
4. You are to start and stop the paper as instructed.

## SINGAPORE JUNIOR PHYSICS OLYMPIAD

1. A piece of pure ice, one with unfrozen water, and one with an embedded iron washer float on water filled to the rim of the glasses. What happens to the water level when the ice completely melts?



- A) No change    No change    No change  
B) No Change    Overflows    Overflows  
C) No change    No change    Overflows  
D) No change    No change    Drops
2. A horse exerts a force  $F$  on a cart, causing the cart to move with increasing speed. What force does the cart exert on the horse?
- A) Zero  
B)  $F$   
C) Greater than  $F$   
D) Less than  $F$
3. Which one of the following lists the four fundamental forces of nature in order of increasing strength?
- A) Gravitational, weak, electromagnetic, strong  
B) Weak, electromagnetic, strong, gravitational  
C) Electromagnetic, weak, gravitational, strong  
D) Weak, gravitational, electromagnetic, strong
4. The apparent weight of a girl in an elevator is greatest when the elevator
- A) moves downward at constant speed.  
B) moves upward at constant speed.  
C) moving downward with decreasing speed.  
D) moving upward with decreasing speed.

SINGAPORE JUNIOR PHYSICS OLYMPIAD

5. The frictional force of the floor on a large suitcase is least when the suitcase is
- A) pushed by a force parallel to the floor.
  - B) dragged by a force parallel to the floor.
  - C) pulled by a force directed at an angle above the floor.
  - D) pushed by a force directed at an angle into the floor.
6. A man pushes against a rigid, immovable wall. Which of the following statement is the most accurate statement concerning this situation?
- A) The man can never exert a force on the wall that exceeds his weight.
  - B) If the man pushes on the wall with a force of 200 N, we can be sure that the wall is pushing back with a force of exactly 200 N on him.
  - C) Since the wall cannot move, it cannot exert any force on the man.
  - D) The man cannot be in equilibrium since he is exerting a net force on the wall.
7. An object is moving to the right in a straight line with a constant speed. Which of the following statements **must be** correct?
- A) There are no forces acting on the object.
  - B) There is a larger number of forces acting on the object to the right than to the left.
  - C) There is only one force acting on the object and it is acting to the right.
  - D) The momentum of the object is pointing to the right.
8. A rock is thrown vertically upwards with initial speed  $u$ . Assume a friction force proportional to  $-\mathbf{v}$ , where  $\mathbf{v}$  is the velocity of the rock, and neglect the upthrust exerted by air. Which of the following is correct?
- A) The acceleration of the rock is always equal to  $\mathbf{g}$ .
  - B) The acceleration of the rock is equal to  $\mathbf{g}$  only at the top of the flight.
  - C) The acceleration of the rock is always less than  $\mathbf{g}$ .
  - D) The speed of the rock upon return to its starting point is  $u$ .

SINGAPORE JUNIOR PHYSICS OLYMPIAD

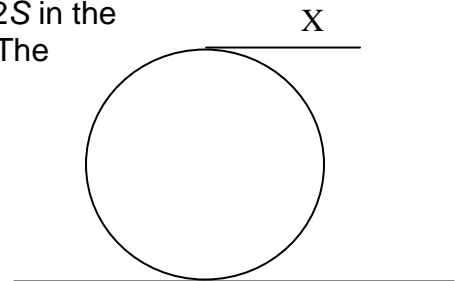
9. A solid ball weighs 5.0 N in air and 3.0 N submerged in water. If the ball weighs 2.0 N submerged in an unknown liquid, the specific gravity of the unknown liquid is most nearly

- A) 0.66
- B) 1.00
- C) 1.25
- D) 1.50
- E) 1.75

10. A large truck and a small car collided near Bukit Timah road one day and the two vehicles were stuck together. Which vehicle has undergone a larger change in momentum?

- A) The car.
- B) The truck.
- C) The momentum change was the same for both vehicles.
- D) One cannot tell which vehicle was larger without knowing the final velocity of the combined mass.
- E) One cannot tell which vehicle was larger without knowing the masses of the truck and the car.

11. A large spool of rope lies on the ground. See the diagram to the right. The end, labeled X, is pulled a distance  $2S$  in the horizontal direction. The spool rolls without slipping. The distance the spool's center of mass moves is



- A)  $4S$
- B)  $S$
- C)  $S/2$
- D)  $S/3$
- E)  $S/4$

12. A particle moves at a constant speed in a circular path with a radius of 2.06 cm. If the particle makes four revolutions each second, what is the magnitude of its acceleration?

- A)  $20 \text{ m/s}^2$
- B)  $18 \text{ m/s}^2$
- C)  $13 \text{ m/s}^2$
- D)  $15 \text{ m/s}^2$
- E)  $24 \text{ m/s}^2$

13. Ali throws a crumpled piece of paper upwards in air. It moves freely under gravity with some air resistance. Assuming constant air resistance and that the stone return to point where it is projected,

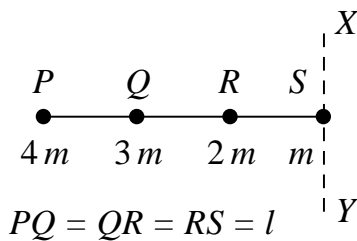
- (I) It takes less time to move upwards than it takes to move downwards.
- (II) It travels less distance upwards than it travels downwards.
- (III) The speed at the top of its trajectory is zero.
- (IV) The speed when it returns to the point of projection is less than the speed when it is projected.

- A) Only statements (I), (II) and (IV) are correct
- B) Only statements (I), (II) and (III) are correct.
- C) Only statements (I), (III) and (IV) are correct.
- D) Only statements (III) and (IV) are correct.
- E) None of the choice given in (I) to (IV) is true.

14. A puck moves with uniform acceleration on a straight air track (frictionless). It passes two points A and B with speed  $2 \text{ ms}^{-1}$  and  $8 \text{ ms}^{-1}$  respectively. If the puck passes through the two points within a time of 0.1 s, the distance between A and B is

- A) 20 cm
- B) 30 cm
- C) 40 cm
- D) 50 cm
- E) 60 cm

15.

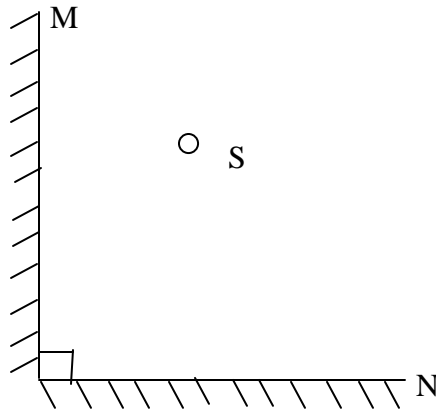


$PQRS$  is a light, rigid rod with masses attached to it as shown in the diagram. The moment of inertia of the system about  $XY$  is

- A)  $6 \text{ m l}^2$
- B)  $10 \text{ m l}^2$
- C)  $14 \text{ m l}^2$
- D)  $50 \text{ m l}^2$
- E)  $60 \text{ m l}^2$

16. The following diagram shows two mirrors placed  $90^\circ$  with respect to each other. An object placed at S will result in \_\_\_\_\_ images of S.

- A) 2
- B) 3
- C) 4
- D) 5
- E) Infinite



17. The following statements refers to a comparison between an amount of water with mass  $m$ , an amount of ice with mass  $m$  and an amount of steam with mass  $m$ , all at the triple point of water.

- i) All the amounts have the same number of molecules
- ii) The molecular kinetic energies of the ice, water and steam are the same.
- iii) Each of the three amounts contain the same amount of internal energy.

Which of the above statements are true?

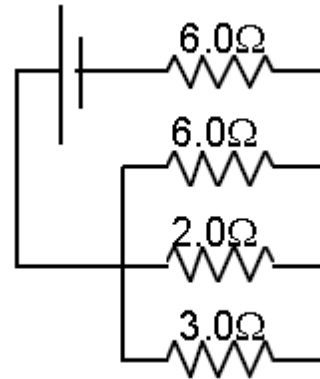
- A) (i) only
- B) (i) and (ii) only
- C) (i) and (iii) only
- D) (ii) and (iii) only
- E) All of the above

18. A 700-MW electric power plant has an efficiency of 25%. It loses its waste heat in large cooling towers by evaporating a fine mist of water. If all the waste heat went only into the evaporation of water, how many tons of water would be evaporated per day?

(Latent heat of vaporization of water =  $2.26 \times 10^6$  J/kg)

- A) 100,000
- B) 80,000
- C) 50,000
- D) 30,000
- E) 25,000

19. In the electrical circuit shown to the right, the current through the  $2.0\ \Omega$  resistor is  $3.0\ \text{A}$ . The emf of the battery is about



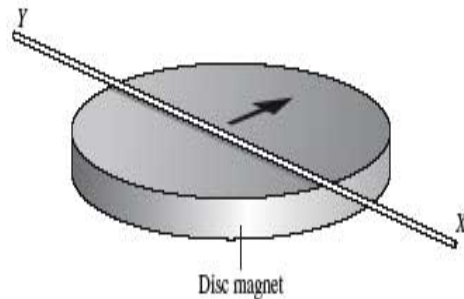
- A)  $51\ \text{V}$
- B)  $42\ \text{V}$
- C)  $36\ \text{V}$
- D)  $24\ \text{V}$
- E)  $21\ \text{V}$

20. Consider the following household appliances powered by the  $240\text{-V}$  mains supply. Which appliance has the greatest electrical resistance?

- A) A  $3\ \text{kW}$  heater.
- B) A  $1\ \text{kW}$  heater.
- C) A  $1\ \text{kW}$  iron.
- D) A  $100\ \text{W}$  incandescent bulb.
- E) A  $25\ \text{W}$  incandescent bulb.

21. A disc magnet has its poles on its opposing flat surfaces. An insulated copper wire was placed on the disc magnet as shown in the diagram.

The instant the wire was connected to a DC battery, the wire was observed to move in the direction of the arrow.



Which statement describes the direction of the magnetic field and the direction for the current is consistent with the observation?

- A) The field was vertically upwards and the current was from X to Y.
- B) The field was vertically upwards and the current was from Y to X.
- C) The field was in the direction of the arrow and the current was from X to Y
- D) The field was in the direction of the arrow and the current was from Y to X.
- E) None of the above statement is consistent.

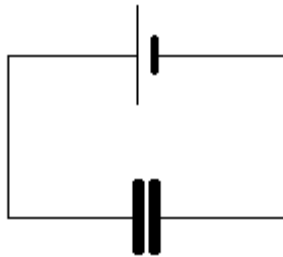
SINGAPORE JUNIOR PHYSICS OLYMPIAD

22. A particle of mass  $6.0 \times 10^{-8} \text{ kg}$  and charge  $+7.2 \mu\text{C}$  is travelling due east. It enters perpendicularly a magnetic field whose magnitude is  $3.0 \text{ T}$ . After entering the field, the particle completes one-half of a circle and exits the field travelling due west. How much time does the particle spend travelling in the magnetic field?
- A)  $8.7 \times 10^{-3} \text{ s}$   
B)  $0.017 \text{ s}$   
C)  $8.7 \text{ s}$   
D)  $17 \text{ s}$   
E) Time cannot be determined due to insufficient information.
23. A resistor has a resistance  $R$ , and a battery has an internal resistance  $r$ . When the resistor is connected across the battery, ten percent less power is dissipated in  $R$  than would be dissipated if the battery had no internal resistance. The ratio  $r/R$  is
- A) 2.2  
B) 0.90  
C) 0.11  
D) 0.10  
E) 0.054
24. Three identical resistors are connected in parallel. The equivalent resistance increases by  $700 \Omega$  when one resistor is removed and connected in series with the remaining two, which are still in parallel. The resistance of each resistor is
- A)  $300 \Omega$   
B)  $382 \Omega$   
C)  $600 \Omega$   
D)  $700 \Omega$   
E)  $2100 \Omega$

25. Two particles each have a mass of  $6.0 \times 10^{-3} \text{ kg}$ . One has a charge of  $+5.0 \times 10^{-6} \text{ C}$ , and the other has a charge of  $-5.0 \times 10^{-6} \text{ C}$ . They are initially held at rest at a distance of 0.80 m apart. How fast is each particle moving when the separation between them is one-third its initial value?

- A) 6.8 m/s
- B) 9.7 m/s
- C) 11 m/s
- D) 14 m/s
- E) 15 m/s

26.



A parallel-plate capacitor is connected to a battery as shown. What will happen if the separation of the plates is increased?

|    | <b>Capacitance</b> | <b>Voltage</b> | <b>Charge</b> |
|----|--------------------|----------------|---------------|
| A) | decreases          | decreases      | decreases     |
| B) | decreases          | unchanged      | decreases     |
| C) | decreases          | decreases      | increases     |
| D) | increases          | unchanged      | decreases     |
| E) | increases          | unchanged      | increases     |

27. An empty parallel plate capacitor is connected between the terminals of a 9.0 V battery and charged up. The capacitor is then disconnected from the battery, and the spacing between the capacitor plates is doubled. As a result of this change, the new voltage between the plates of the capacitor is

- A) zero, since it is disconnected from the battery.
- B) 9.0 V, since the charge density on each plate remains the same.
- C) 9.0 V, since it had been connected between the terminals of a 9.0 V battery.
- D) 18 V, since the capacitance is doubled.
- E) 18 V, since the capacitance is halved.

28. Two objects, 1 and 2, are identical and small enough that their sizes can be ignored relative to the distance between them, which is  $0.200\text{ m}$ . In a vacuum, each object carries a different charge,  $Q_1$  and  $Q_2$ , and they attract each other with a force of  $1.20\text{ N}$ . The objects are brought into contact, so the net charge is shared equally, and then they are returned to their initial positions. Now it is found that the objects repel one another with a force whose magnitude is equal to that of the initial attractive force. What is the initial charge on each object?

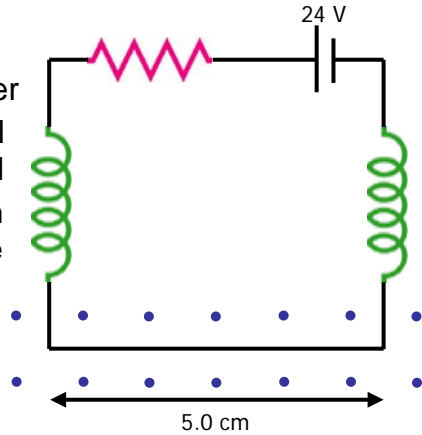
- A)  $|Q_1| \approx 5.58\ \mu\text{C}$ ,  $|Q_2| \approx 0.957\ \mu\text{C}$
- B)  $|Q_1| \approx 2.79\ \mu\text{C}$ ,  $|Q_2| \approx 0.479\ \mu\text{C}$
- C)  $|Q_1| \approx 1.86\ \mu\text{C}$ ,  $|Q_2| \approx 0.319\ \mu\text{C}$
- D)  $|Q_1| \approx 1.40\ \mu\text{C}$ ,  $|Q_2| \approx 0.239\ \mu\text{C}$
- E)  $|Q_1| \approx 1.12\ \mu\text{C}$ ,  $|Q_2| \approx 0.191\ \mu\text{C}$

29. A solenoid has a cross-sectional area of  $6.0 \times 10^{-4}\text{ m}^2$ , consists of 400 turns per metre, and carries a current of  $0.40\text{ A}$ . A 10-turn coil is wrapped tightly around the circumference of the solenoid. The ends of the coil are connected to a  $1.5\ \Omega$  resistor. Suddenly, a switch is opened, and the current in the solenoid dies to zero in a time of  $0.050\text{ s}$ . The average current induced in the coil is

- A) zero.
- B)  $4.0 \times 10^{-7}\text{ A}$ .
- C)  $1.6 \times 10^{-6}\text{ A}$ .
- D)  $1.6 \times 10^{-5}\text{ A}$ .
- E)  $0.40\text{ A}$ .

30. A straight wire of mass 10.0 g and length 5.0 cm is suspended from two identical springs that, in turn, form a closed circuit.

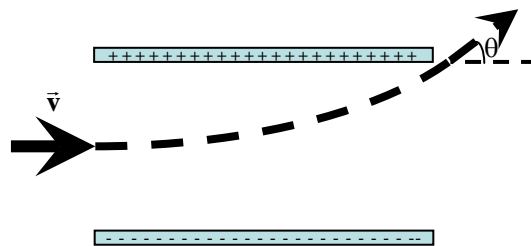
The springs stretch a distance of 0.50 cm under the weight of the wire. The circuit has a total resistance of  $12.0 \Omega$ . When a magnetic field directed out of the page (indicated by the dots in the figure) is turned on, the springs are observed to stretch an additional 0.30 cm. What is the strength of the magnetic field?



- A) 0.20 T
- B) 0.29 T
- C) 0.59 T
- D) 0.98 T
- E) 2.2 T

31. An electron is accelerated horizontally from rest in a television picture tube by a potential difference of 5500 V. It then passes between two horizontal plates 6.5 cm long and 1.3 cm apart that have a potential difference of 250 V.

At what angle  $\theta$  will the electron be travelling after it passes between the plates?



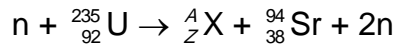
- A)  $2.6^\circ$
- B)  $5.7^\circ$
- C)  $6.5^\circ$
- D)  $11^\circ$
- E)  $13^\circ$

32. At a high point in the Earth's atmosphere,  $\text{He}^{2+}$  ions in a concentration of  $2.8 \times 10^{12} \text{ m}^{-3}$  are moving due north at a speed of  $2.0 \times 10^6 \text{ m/s}$ . Also, a  $7.0 \times 10^{11} \text{ m}^{-3}$  concentration of  $\text{O}_2^-$  ions is moving due south at a speed of  $7.2 \times 10^6 \text{ m/s}$ . Determine the magnitude and direction of the net current passing through unit area.
- A)  $0.99 \text{ A/m}^2$ , due north  
B)  $0.99 \text{ A/m}^2$ , due south  
C)  $1.7 \text{ A/m}^2$ , due north  
D)  $2.6 \text{ A/m}^2$ , due north  
E)  $2.6 \text{ A/m}^2$ , due south
33. In a certain experiment, the velocity of an electron is determined to an accuracy of  $\Delta v = 2 \times 10^5 \text{ m/s}$ . Assuming that the electron is non-relativistic, what is the most accurate knowledge we can hope to have about its position in this experiment?
- A)  $9.19 \times 10^{-11} \text{ m}$   
B)  $1.84 \times 10^{-10} \text{ m}$   
C)  $2.89 \times 10^{-10} \text{ m}$   
D)  $5.77 \times 10^{-10} \text{ m}$   
E)  $1.16 \times 10^{-9} \text{ m}$
34. A beam of monochromatic light falls on the surface of a metal and it emits electrons. If the frequency of the light is doubled but the intensity remains unchanged, which of the following statements is/are correct?
- (I) The energy of a photon in the beam is doubled.  
(II) The momentum of a photon in the beam is doubled.  
(III) The number of photons falling on the surface per second is halved.
- A) (I), (II) and (III)  
B) (I) and (II) only  
C) (II) and (III) only  
D) (I) only  
E) (III) only

35. The main reason why a chain reaction can occur in a nuclear reactor using uranium is that

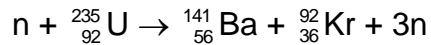
- A) a large quantity of energy is evolved in each fission.
- B) the products of nuclear fission are highly radioactive.
- C) plutonium is produced and it undergoes further fission.
- D) neutrons are produced when a nucleus undergoes fission.
- E) uranium is a highly radioactive element.

36. Find the unknown atomic number and mass number respectively, for the following reaction



- A) 141, 53
- B) 140, 54
- C) 53, 41
- D) 54, 140
- E) 54, 141

37. Approximately how much uranium (in kg) must undergo fission per day to provide 1000 MW of power? (Assume an efficiency of 30%). The nuclear reaction is



$$m(n) = 1.008665 \text{ u}$$

$$m(\text{U}) = 235.043915 \text{ u}$$

$$m(\text{Ba}) = 140.9139 \text{ u}$$

$$m(\text{Kr}) = 91.8973 \text{ u}$$

$$u = 1.66 \times 10^{-27} \text{ kg}$$

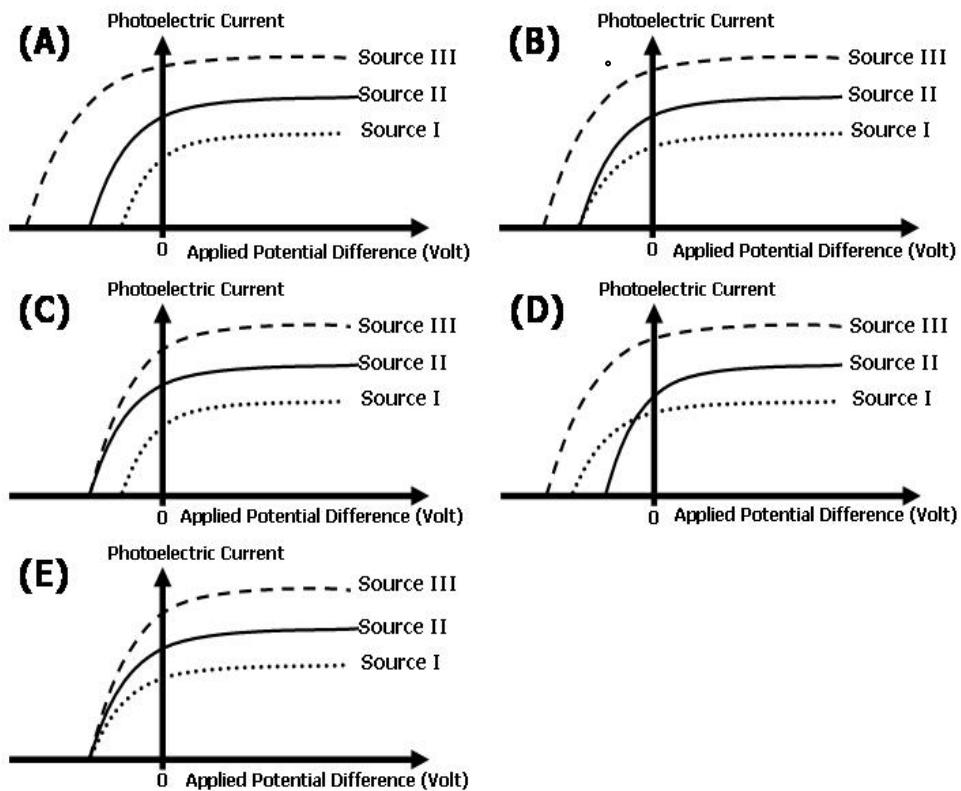
- A) 1.0      B) 3.5      C) 2.3      D) 4.6      E) 0.1

38. A student performed three separate experiments on photoelectric effect using three different light sources. The properties of the three light sources are summarized in the table below.

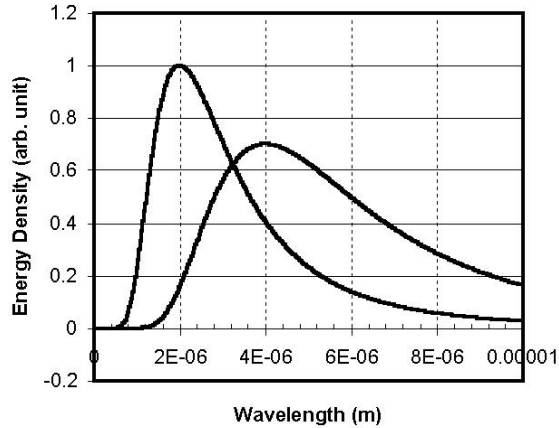
| Light Source | Light Intensity | Wavelength of emitted light |
|--------------|-----------------|-----------------------------|
| I            | $I$             | $\lambda$                   |
| II           | $2I$            | $\lambda$                   |
| III          | $4I$            | $2\lambda/3$                |

Which of the following figures would be the results of photocurrent versus applied potential obtained from these three separate experiments?

The same metal surface was used throughout the experiments.



39. The following plot shows the Blackbody Energy Density versus wavelength of two different cavities maintained at two different temperatures. What is the difference in the temperature between the two cavities? (Note that  $2\text{E-}06$  is the same as  $2 \times 10^{-6}$  and  $\lambda_m T = 2.90 \times 10^{-3} \text{ mK}$  )

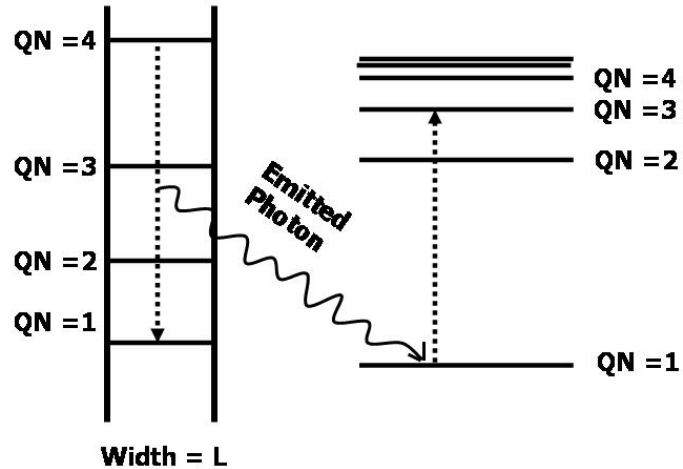


- A) 1448.90 K  
 B) 1086.68 K  
 C) 725 K  
 D) 362.22 K  
 E)  $2 \times 10^{-6}$  K
40. If we lived in a universe in which the value of Planck's constant is larger, which of the following statements would not be true?
- A) The de Broglie wavelength of an object would be longer  
 B) Photons with a fixed frequency would have more energy  
 C) The probability of tunneling across a barrier would be smaller  
 D) The maximum kinetic energy of the photoelectron would be larger  
 E) The product of the uncertainties in measuring the position and momentum of an object would be larger

41. An excited electron (quantum number =4) in a 1D potential box de-excites to the ground state and emit a photon. This photon subsequently becomes absorbed by an electron in a hydrogen atom. The electron in the hydrogen atom becomes excited to an excited state with quantum number =3. The process is illustrated in the following diagram. Determine the width of the potential box L.

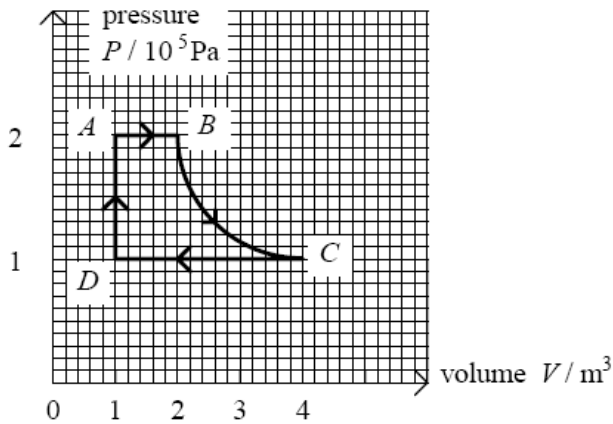
- A)  $2.7 \times 10^{-19}$  m  
 B)  $2.7 \times 10^7$  m  
 C)  $1.9 \times 10^{-9}$  m  
 D)  $6.8 \times 10^{-10}$  m  
 E)  $7.9 \times 10^{-10}$  m

**Energy Levels diagram for 1D potential box and Hydrogen Atoms (Note QN = Quantum Number)**



42. A piece of iron is suspended from a vertical spring. The iron (but not the spring) is immersed in a jar of water, and oscillates with period  $T_0$ . A vertical sinusoidal force of variable period  $T$  is now applied to the iron, using an electromagnet. Which one of the following statements is NOT correct?
- A) When the electromagnet is switched off, the period of the oscillations changes from  $T$  to  $T_0$ .
- B) The amplitude of the oscillations increases greatly when  $T$  is brought close to  $T_0$ .
- C) For any value of  $T$ , the water temperature rises, due to energy transferred from the electromagnet.
- D) If the electromagnet is switched off, the water gains energy as the amplitude of the oscillations decreases.
- E) For  $T$  not close to  $T_0$ , the forced oscillations decrease slowly in amplitude due to damping.

43. An ideal gas is taken through the series of changes shown.

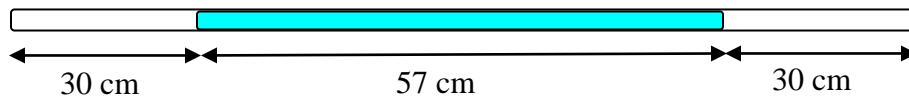


Which of the following statements is/are correct?

- (I) No net work is done by the gas in completing one cycle.
- (II) The work done by the gas during the change  $AB$  is equal to that done on the gas during the change  $CD$ .
- (III) The gas has the same temperature at  $B$  and at  $C$ .

- A) (I), (II) and (III) are correct.
- B) Only (I) and (II) are correct.
- C) Only (II) and (III) are correct.
- D) Only (I) is correct.
- E) Only (III) is correct.

44. A uniform tube, closed at both ends, contain a 57cm long column of mercury which divides two columns of air of each 30 cm long as shown in the diagram below. The air in the column is initially at atmospheric pressure. If the tube is then set upright on Earth, the eventual lengths of the top and bottom columns are \_\_\_\_\_ and \_\_\_\_\_ respectively.



- A) 30 cm, 30 cm
- B) 35 cm, 25 cm
- C) 10 cm, 40 cm
- D) 45 cm, 15 cm
- E) 40 cm, 20 cm

45. A room with an open window is initially at a temperature of  $5^{\circ}\text{C}$ . The heater is turned on until the air in the room reaches a uniform temperature of  $25^{\circ}\text{C}$ . Compare the internal energy of the air in the room before the heater is turned on ( $U_i$ ) to the internal energy of the gas left in the room after the heater is turned on ( $U_f$ ). You may assume that the pressure remains unchanged.

- A)  $U_f > U_i$
- B)  $U_f = U_i$
- C)  $U_f < U_i$
- D)  $U_f$  may be greater or less than  $U_i$ , depending on how fast the heating process is.
- E)  $U_f$  may be greater or less than  $U_i$ , depending on the temperature outside the room.

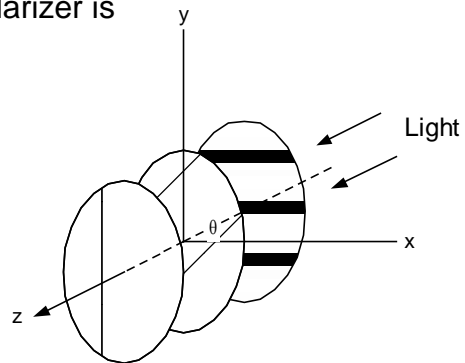
46. The percentage increase in the energy of a particle whose speed is changed from rest to  $0.8c$  (where  $c$  is the speed of light) is closest to

- A) 50%
- B) 67%
- C) 75%
- D) 80%
- E) 88%

47.

Unpolarized light of intensity  $I_0$  travelling in the  $+z$  direction passes successively through three perfect polarizers. The first of these passes light polarized along the  $x$ -axis, the middle one passes light polarized at an angle of  $\theta$  relative to the  $x$ -axis, and the last passes light polarized along the  $y$ -axis. The intensity of light emerging from the third polarizer is

- A) 0
- B)  $\frac{1}{2}I_0$
- C)  $\frac{1}{2}I_0 \sin^2 \theta$
- D)  $I_0 \cos^2 \theta$
- E)  $\frac{1}{8}I_0 \sin^2 2\theta$

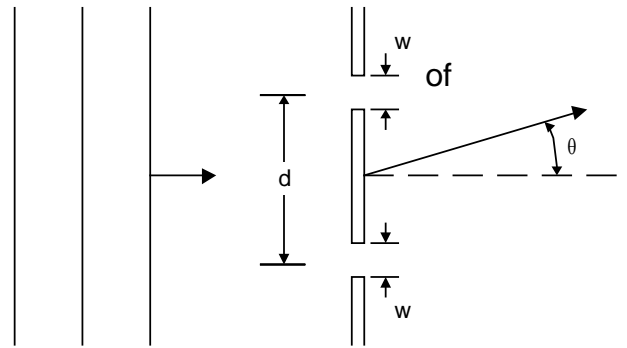


48. A car of rest length 5 meters passes through a garage of rest length 4 meters. Due to the relativistic Lorentz contraction, the car is only 3 meters long in the garage's rest frame. There are doors on both ends of the garage, which open automatically when the front of the car reaches them and close automatically when the rear passes them. The opening or closing of each door requires a negligible amount of time.

The velocity of the car in the garage's rest frame is

- A)  $0.4c$
- B)  $0.6c$
- C)  $0.8c$
- D) greater than  $c$
- E) not determinable from the data given.

49. A plane wave of monochromatic light with wavelength  $\lambda$  in vacuum is incident on two slits equal width  $w$ , as shown schematically. A pattern is observed on a screen a large distance away. The intensity of the light at  $\theta = 0$  is initially  $I_0$ .

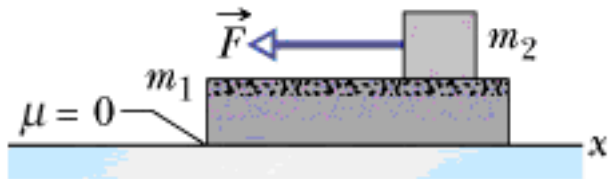


If one slit is blocked, the intensity at  $\theta = 0$  is

- A)  $\frac{I_0}{4}$
- B)  $\frac{I_0}{2}$
- C)  $\frac{I_0}{\sqrt{2}}$
- D)  $I_0$
- E)  $2I_0$

50. A slab of mass  $m_1 = 40.0$  kg rests on a frictionless floor, and a block of mass  $m_2 = 10.0$  kg rests on top of the slab. The coefficients of static friction and kinetic friction between the block and the slab are  $\mu_s = 0.600$  and  $\mu_k = 0.400$  respectively. The block is pulled by a horizontal force  $\mathbf{F}$ . What is the maximum value of  $\mathbf{F}$  such that  $m_1$  and  $m_2$  will move together, that is, there is no slipping between the two blocks?

- A) 39.2 N
- B) 73.5 N
- C) 58.8 N
- D) 157 N
- E) 195 N



END OF PAPER