SINGAPORE JUNIOR PHYSICS OLYMPIAD 2014
GENERAL ROUND

30 July, 2014

3:00 pm – 4:30 pm

Time Allowed: ONE hour THIRTY minutes

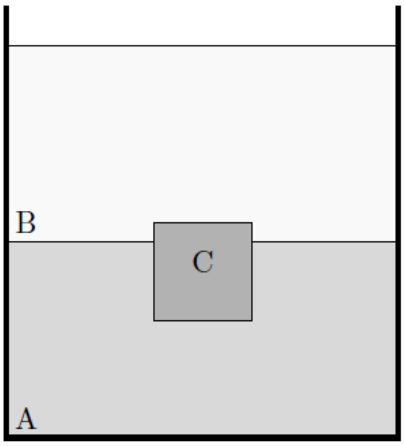
INSTRUCTIONS

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 marked 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. Graphic calculators are not allowed.
7. A table of information is given in page 2.

TABLE OF INFORMATION

Acceleration due to gravity at Earth surface, g	=	$9.80\ \mathrm{m/s^2}$
Universal gas constant, R	=	$8.31\ \mathrm{J/(mol \cdot K)}$
Vacuum permittivity, ϵ_0	=	$8.85 \times 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$
Vacuum permeability, μ_0	=	$4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$
Atomic mass unit, u	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
Speed of light in vacuum, c	=	$3.00 \times 10^{8}\ \mathrm{m/s}$
Charge of electron, e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
Planck's constant, h	=	$6.63 \times 10^{-34}\ \mathrm{J \cdot s}$
Mass of electron, m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Mass of proton, m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
Boltzmann constant, k	=	$1.38 \times 10^{-23}\ \mathrm{J/K}$
Avogadro's number, N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Standard atmosphere pressure, P_0	=	$1.01 \times 10^{5}\ \mathrm{Pa}$
Density of water, ρ_w	=	$1000\ \mathrm{kg/m^3}$
Specific heat (capacity) of water, c_w	=	$4.19 \times 10^{3}\ \mathrm{J/(kg \cdot {}^\circ C)}$
Latent heat of fusion of water, L_f	=	$3.33 \times 10^{5}\ \mathrm{J/kg}$
Latent heat of vaporization of water, L_v	=	$2.26 \times 10^{6}\ \mathrm{J/kg}$

1. The image shows two immiscible liquids A and B with a block of another material C. What can you say about the densities ρ_A, ρ_B, ρ_C of these material?

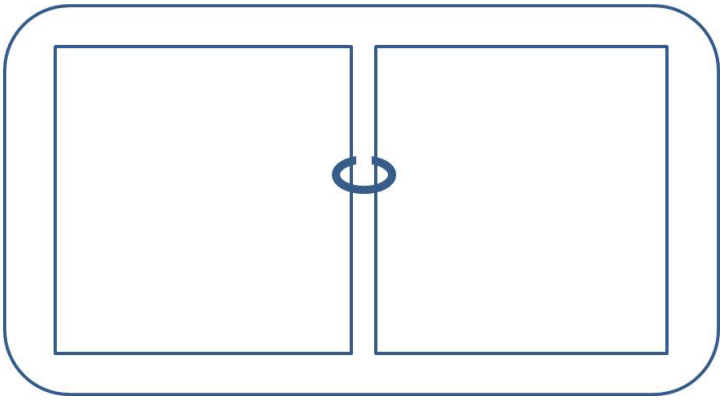


(A) $\rho_A < \rho_B < \rho_C$
(B) $\rho_C < \rho_B < \rho_A$
(C) $\rho_B < \rho_C < \rho_A$
(D) $\rho_C < \rho_A < \rho_B$
(E) $\rho_A < \rho_C < \rho_B$

2. By how much will the sea level rise if both the Antarctic (30 million km^3) and Greenland (2.6 million km^3) ice sheets are melted? Assume the ocean covers an area of 361 million km^2.
(Density of pure water - 1000 kg/m^3, density of ice 920 kg/m^3)

(A) 90 meters
(B) 83 meters
(C) 8.3 meters
(D) 9.8 meters
(E) 98 meters

3. As shown in the diagram, the setup comprises of a metal box with a metal pole at the center. The mass of the metal box and pole is M. A ring of mass m slides down the pole with an acceleration a. The frictional force between the ring and the pole is f. The force of the box on the floor, when the ring is sliding down, is hence

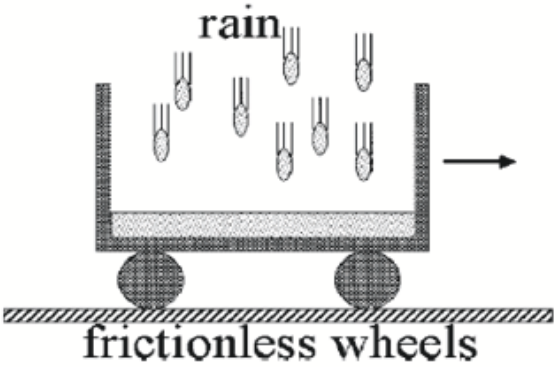


(A) Mg
(B) $(M+m)g$
(C) $Mg+f$
(D) $(M+m)g-f$
(E) $(M+m)a$

4. Suppose rain falls vertically into an open cart moving along a straight horizontal track with negligible friction as shown below.

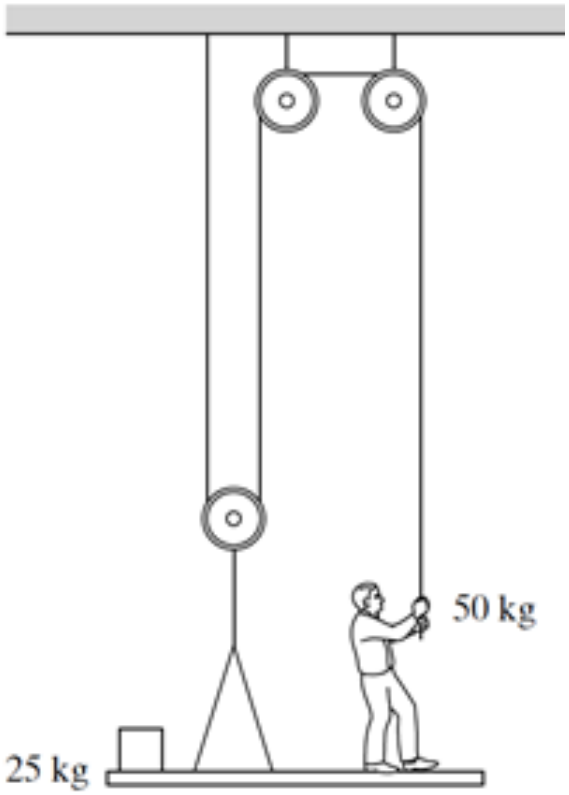
   As a result of the accumulating water inside the cart, the speed of the cart _____ and the kinetic energy of the cart (including the water) _____ .

   (A) increases, decreases
   (B) increases, stays the same
   (C) decreases, decreases
   (D) decreases, stays the same
   (E) does not change, stays the same



5. A 50 kg person stands on a 25 kg platform. He pulls on the rope that is attached to the platform via the frictionless pulley system shown here. If he pulls the platform up at a steady rate, with how much work does the person do in order to pull the platform (and himself) up by 2.0m? Ignore friction.

   (A) 1000 J
   (B) 750 J
   (C) 630 J
   (D) 500 J
   (E) 1500 J



6. Consider two resistors R_1 and R_2 connected in parallel. R_1 is a fixed resistor and R_2 is a variable resistor. Which of the following is true about the effective resistance R?

   (A) $R > R_1$
   (B) $R > R_2$
   (C) $0 \leq R \leq R_1$
   (D) $R_1 \leq R \leq R_2$
   (E) None of the above.

7. The oxygen (molar mass = 32 g/mol) and nitrogen (molar mass = 28 g/mol) molecules in this room has equal average

   (A) kinetic energies but the oxygen molecules move faster.
   (B) kinetic energies but the oxygen molecules move slower.
   (C) kinetic energies and speeds.
   (D) speeds but the oxygen molecules have a higher average kinetic energy.
   (E) speeds but the oxygen molecules have a lower average kinetic energy.

8. An isobaric process is one in which the pressure remains constant. In an isobaric expansion,

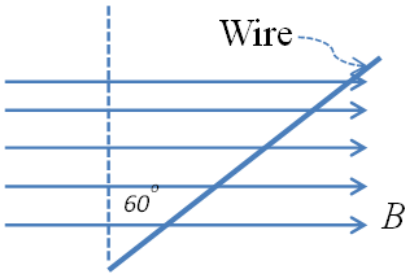
   (A) no work is done.
   (B) work is done on the gas.
   (C) work is done by the gas.
   (D) the temperature of the gas decreases.
   (E) no heat enters or leaves the system.

9. In which process will the internal energy of the system **not** change?

   (A) An adiabatic expansion of an ideal gas.
   (B) An isothermal compression of an ideal gas.
   (C) An isobaric expansion of an ideal gas.
   (D) An isovolumetic (isochoric) compression of an ideal gas.
   (E) The freeezing of some liquid at its melting point.

10. Calculate the force on a 20 cm length of wire carrying a current of 4.0 A at a direction as shown below. The magnetic field strength is 3.0 T.

(A) 2.4 N
(B) 1.2 N
(C) 240 N
(D) 120 N
(E) 2.1 N

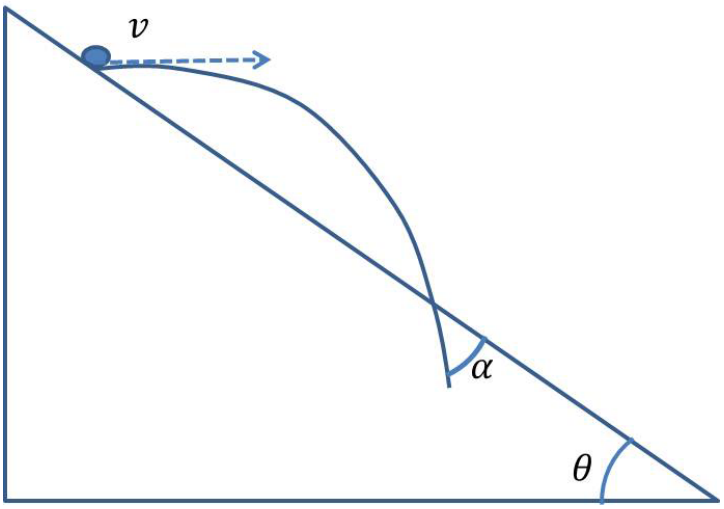


11. Rank the penetration range of the following radiations, from the least penetrating radiation to the most penetrating radiation.

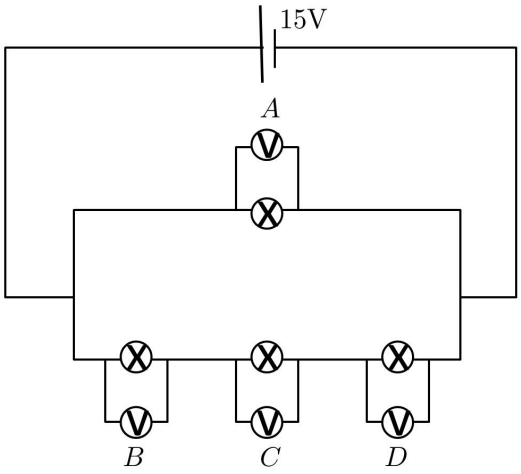
(A) Heavy charged particles, gamma rays, positrons
(B) Electrons, gamma rays, heavy charged particles
(C) Gamma rays, heavy charged particles, electrons
(D) Positrons, heavy charged particles, gamma rays
(E) Heavy charged particles, electrons, gamma rays

12. As shown in the figure below, a ball is thrown out horizontally from a slope. The slope makes an angle θ with the ground. At the first throw, the ball is ejected with a speed v_1 and at the second throw, it is ejected with a speed v_2. The angles that the ball made with the slope are measured to be α_1 and α_2 respectively. If v_1 is greater than v_2,

(A) $\alpha_1 = \alpha_2$
(B) $\alpha_1 > \alpha_2$
(C) $\alpha_1 < \alpha_2$
(D) $\alpha < \theta$
(E) It is not possible to infer much as the mass of the ball is not given.

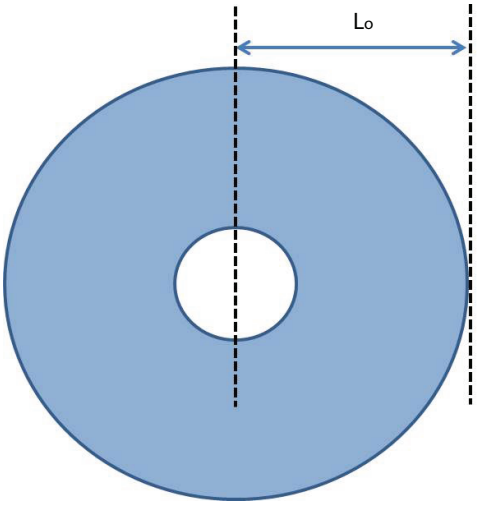


13. In the circuit given below, bulb C is found to have burnt out. Which of the following voltmeters will give a reading of 0 V?



(A) A only.
(B) B and D only.
(C) C only.
(D) B, C and D
(E) All will give a 0 V reading.

14. A uniform circular piece of metal has initial radius L_o. A circular piece is cut out of the center of the metal. The temperature of the metal is now raised so that the side lengths are increased by 4%. What has happened to the area of the circular hole cut out of the center of the metal?



(A) It is increased by 16 %.
(B) It is increased by 8 %.
(C) It is increased by 4 %.
(D) It is decreased by 4 %.
(E) It is decreased by 8 %.

15. Given a wave produced by a simple harmonic oscillator whose displacement in meters is given by the equation: $y = 0.3\sin(3\pi x + 24\pi t)$, what is the frequency of the wave ?

(A) 3 Hz
(B) 7.2 Hz
(C) 8.0 Hz
(D) 12 Hz
(E) 24 Hz

16. Non-polarized light first passes through one polarizing filter and then through a second. If the intensity of light emerging from the second filter is 12.5 % of the light that struck the first filter, at what angle must the axes of the two filters be with respect to one another?

(A) 7^o

(B) 30^o

(C) 42^o

(D) 60^o

(E) 69^o

17. The largest number of 100 W light bulbs (arranged in parallel) that can safely be run from a 200 V supply with a 5 A fuse is

(A) 2

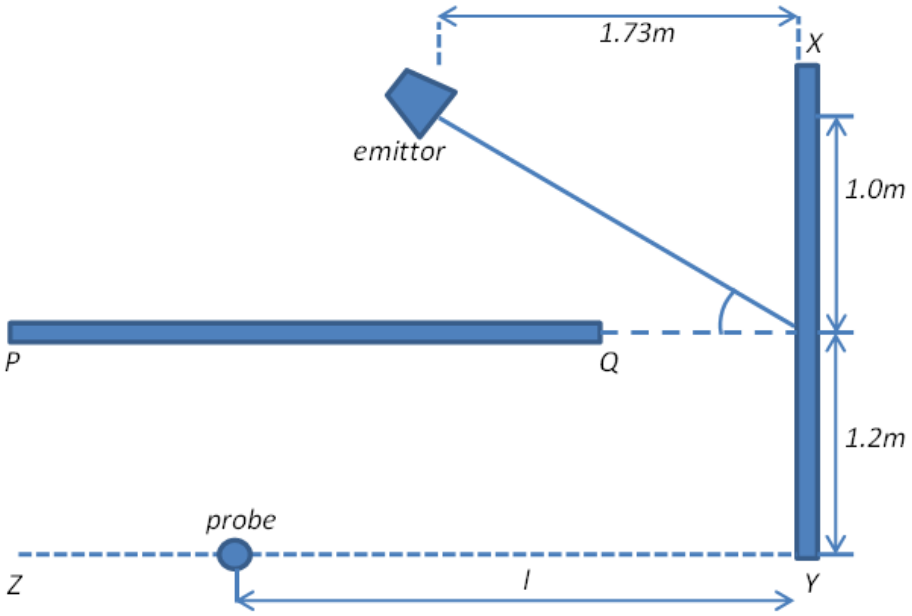
(B) 20

(C) 10

(D) 5

(E) 1

18. Microwaves from an emittor are incident on a metal plate (XY). A probe is used to search for the reflected wave. Please see figure below. What is the distance l such that the probe will receive microwaves of maximum intensity?



(A) 1.38 m

(B) 0.69 m

(C) 2.40 m

(D) 1.20 m

(E) 2.08 m

19. In the question before this, the emittor's frequency can be tuned. The probe is brought to a point $l = 1.73$ m and PQ is then removed. What should be the frequency of the emitted waves be so that microwave signals of maximum intensity can be picked up?

(A) 220 MHz

(B) 167 MHz

(C) 110 MHz

(D) 83 MHz

(E) 79 MHz

20. Before a train enters a tunnel, it is important that it sounds its horn. The train velocity is 80 km/h and the speed of sound is taken to be 340 m/s. The echo of the horn signal is reflected off the surface of the cliff through which the tunnel runs. The echo is heard 2.0 s after the driver sounds the horn. The distance of the train from the cliff at the time when the echo is heard is

(A) 318 m

(B) 260 m

(C) 362 m

(D) 159 m

(E) 636 m

21. In a Millikan oil drop experiment, an oil drop 1.2×10^{-15} kg is held stationary between a pair of electric plates held at 2.0 cm apart. The potential difference across the plates is 120 V.

What is the size of the charge on the oil droplet?

(A) 1.6×10^{-19} C

(B) 6.4×10^{-19} C

(C) 2.0×10^{-18} C

(D) 4.9×10^{-15} C

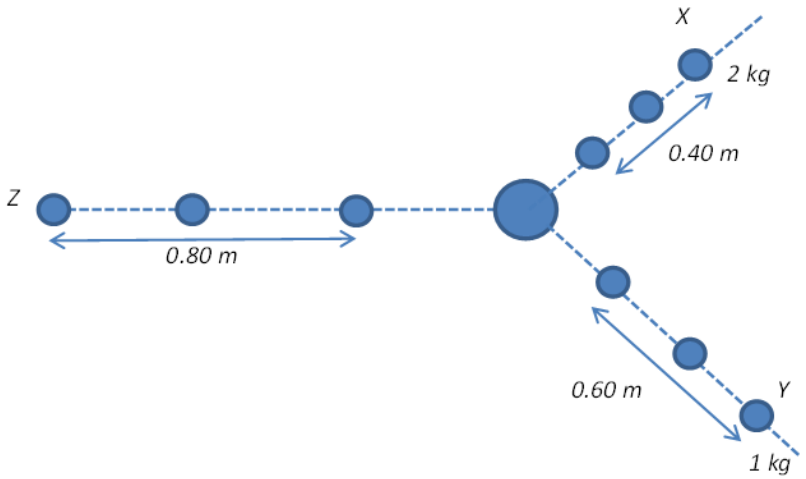
(E) 9.8×10^{-17} C

22. When we stand on the ground, the ground pushes upwards against us with a normal contact force. The nature of this force is

(A) electromagnetic
(B) nuclear strong
(C) gravitational
(D) nuclear weak
(E) electromotive force

23. A body at rest explodes breaking into three pieces which move off at different velocities, all in the same horizontal plane. The following figure shows the experimental results as drawn from a stroboscopic photograph of the event. The time interval between flashes was 0.10 s. The pieces X and Y travel at right angles to each other and are collected after the explosion and their masses are found to be 2.0 kg and 1.0 kg respectively. Piece Z was unfortunately lost after the explosion. What is the mass of piece Z?

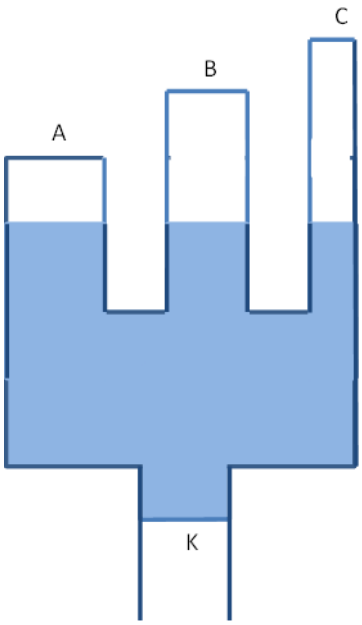
(A) 1.25 kg
(B) 1.50 kg
(C) 2.00 kg
(D) 0.85 kg
(E) 3.00 kg



24. A person stands at a distance 1.0 m from a mirror hung vertically on the wall. He can only see the upper half of his body. In order to see the entire length of his body, what should he do?

(A) Place himself 2.0 m away from the mirror
(B) Place himself 0.5 m away from the mirror
(C) Place himself 4.0 m away from the mirror
(D) Place himself 8.0 m away from the mirror
(E) It would be a futile attempt to just move himself forward or backward from the mirror.

25. In the sketch below, the mercury is at the same level in the sealed, connected tubes A, B and C. The cross sectional surface areas are such that $S_A > S_B > S_C$ and the air column above the mercury $L_A < L_B < L_C$. If we are to let a small amount of mercury flow out of a valve at K, which of the following will happen?



(A) The mercury level at A will be highest.

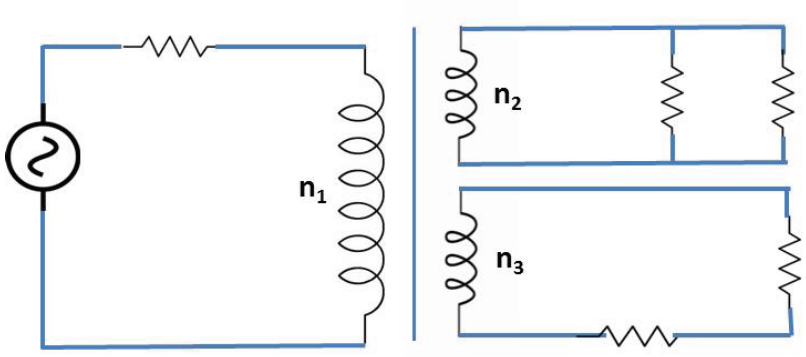
(B) The mercury level at B will be the highest.

(C) The mercury level at C will be the highest.

(D) The mercury levels will be the same.

(E) Not possible to predict the result given the circumstances.

26. In the diagram as shown, the resistor loads have the same power rating. They are attached in the circuit as shown. The respective number of windings in the ratio $n_1 : n_2 : n_3$ is thus



(A) 1 : 2 : 1

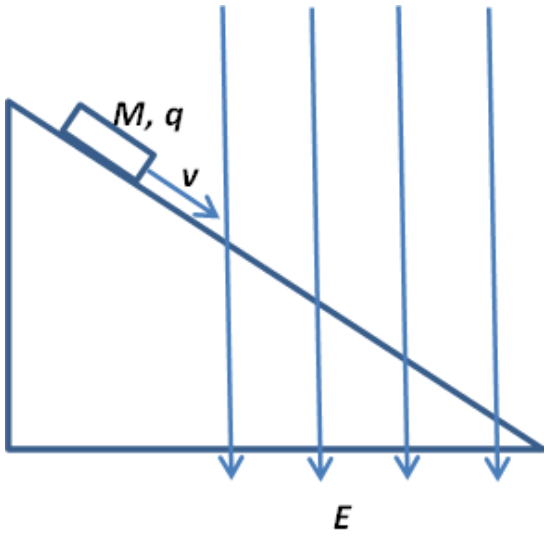
(B) 2 : 1 : 2

(C) 4 : 2 : 1

(D) 1 : 1 : 2

(E) 4 : 1 : 2

27. As shown in the diagram below, a mass M with charge $+q$ is sliding down the slope at constant velocity v. When the mass enters the region with the uniform electric field E,



(A) the mass will continue to slide down at constant velocity v.

(B) the velocity of the mass will increase as it slides down the slope.

(C) the velocity of the mass will decrease as it slides down the slope.

(D) the mass will come to a stop immediately.

(E) the mass will reverse direction and accelerate up the slope.

28. In the question above, we consider the case of applying an additional magnetic field pointing into the paper in the region where the electric field exists. We would expect that in the region where the fields exist,

(A) the mass will continue to slide down at constant velocity v.

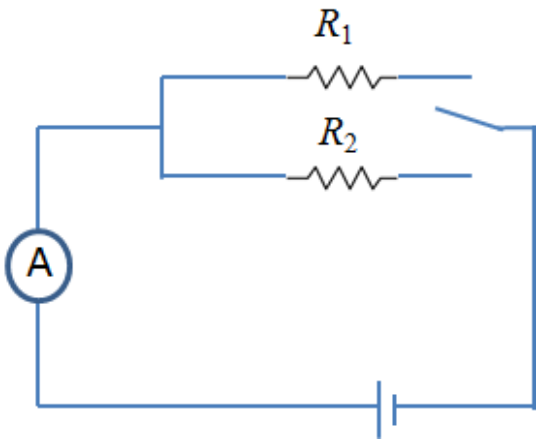
(B) the velocity of the mass will increase as it slides down the slope.

(C) the velocity of the mass will decrease as it slides down the slope.

(D) the mass will come to a stop immediately.

(E) the mass will reverse direction and accelerate up the slope.

29. In the circuit below, the resistances of R_1 and R_2 are known. By assuming the ammeter has negligible resistance, the circuit can be used to measure the e.m.f and the internal resistance r of the cell. However, the resistance of the ammeter can be significant. Under such circumstances, the measurements of e.m.f and r are such that



(A) the measured e.m.f is lower that the true value and the measured r is lower than its true value.

(B) the measured e.m.f is lower that the true value and the measured r is its true value.

(C) the measured e.m.f is the true value and the measured r is lower than its true value.

(D) the measured e.m.f is the true value and the measured r is higher than its true value.

(E) the measured values of the e.m.f and r are accurate.

30. A red ball is resting on a blue carpet. If white light is shone on them and they are viewed through a green filter, which of the following will the observer see?

(A) A black ball on a black carpet

(B) A red ball on a blue carpet

(C) A green ball on a green carpet

(D) A yellow ball on a cyan carpet

(E) A magenta ball on a cyan carpet

31. According to a thermodynamic model of the cooking process, the time t required to cook a joint of meat mass m is given by the formula

$$t = \frac{\alpha c \rho^k m^{2/3}}{\mu}$$

where ρ, c and μ are respectively the density, specific heat capacity and thermal conductivity of the meat and α is a dimensionless constant with a value of 0.029.

Using dimensional analysis, the value of k is

(A) 1
(B) 1/2
(C) 2/3
(D) 1/3
(E) -1/3

32. Water in a central heating system enters a 20 kW boiler at a temperature of 25°C and leaves at a temperature of 60°C. How much water flows through the boiler each second?

(A) 70 g/s
(B) 80 g/s
(C) 116 g/s
(D) 136 g/s
(E) 190 g/s

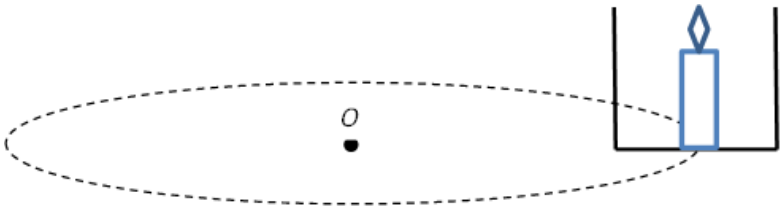
33. The count rate from a radioactive source is measured at one minute intervals. The results are recorded as follows:

Time/s	0	60	120
Counts per second	16583	5859	2020

What is the approximate value of the half-life?

(A) 20 s
(B) 30 s
(C) 40 s
(D) 50 s
(E) 60 s

34. A candle is lighted in a gas jar as shown below. If the jar swings in a circle about O at a constant speed, in which direction will the flame of the candle point?



(A) Forward, in the direction of motion.

(B) Backward, opposite to its velocity.

(C) Still vertically upwards.

(D) Inward, points towards O.

(E) Outwards, away from O.

35. As shown in the following figure, each resister has a resistance of R. What is the effective resistance between point a and b?

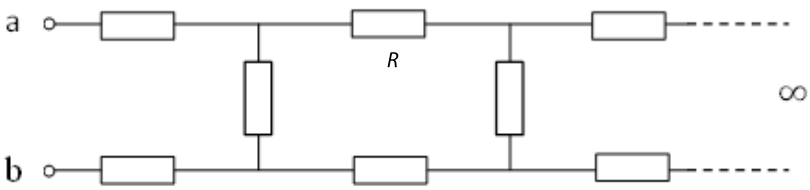
(A) $(1+\sqrt{3})R$

(B) $(1+\sqrt{5})R$

(C) $(1+\sqrt{5})R/2$

(D) $(1+\sqrt{3})R/2$

(E) R



36. A thunder cloud and the earth's surface may be regarded as a pair of charged parallel plates separated by a distance h. The capacitance of the system is C. When a lightning strike of mean current I and time duration t occurs, the electric field strength between the cloud and the earth is reduced by

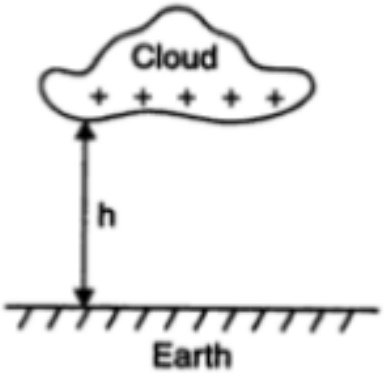
(A) $\dfrac{It}{C}$

(B) CIt

(C) $\dfrac{It}{Ch}$

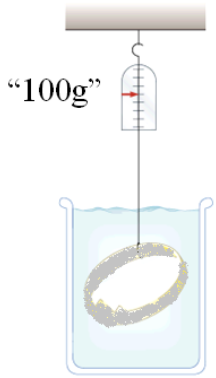
(D) $\dfrac{CIt}{h}$

(E) $\dfrac{Ith}{C}$



37. A spring balance reads 100 g when an iron ring is weighted in water. What will the balance read if the ring is now weighted in oil? The densities for water, oil and iron are 1000 kg/m^3, 720 kg/m^3 and 7874 kg/m^3 respectively.

(A) 96 g
(B) 98 g
(C) 100 g
(D) 102 g
(E) 104 g

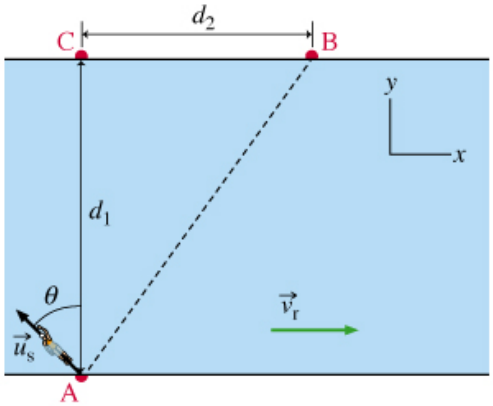


38. A system of 1614 particles, each of which is either an electron or a proton, has a net charge of -4.544 $\times$ 10^{-17} C. What is the total mass of this system?

(A) 1.11 $\times$ 10^{-24} kg
(B) 1.35 $\times$ 10^{-24} kg
(C) 1.47 $\times$ 10^{-27} kg
(D) 1.59 $\times$ 10^{-24} kg
(E) 2.70 $\times$ 10^{-24} kg

39. A swimmer wants to cross a river, from point A to point B, as shown in the figure. The distances d_1 and d_2 are 200 m and 150 m respectively. The speed of the river current, v_r is 5.00 km/h. Suppose that the swimmer's velocity relative to the water makes an angle of $\theta = 45.0°$ with the line AC as indicated in the figure. To directly reach point B, what speed u_s, relative to the water, should the swimmer have?

(A) 3.03 km/h
(B) 4.04 km/h
(C) 5.05 km/h
(D) 6.06 km/h
(E) 7.07 km/h



40. Two projectiles of same mass are fired from the ground and they land at the same horizontal level. Ratio of their minimum kinetic energies is 4:1 and the ratio of maximum heights attained by them is also 4:1. Find the ratio of their horizontal ranges.

(A) 16:1

(B) 4:1

(C) 8:1

(D) 2:1

(E) None of the above

41. A block of mass m is attached to a horizontal inextensible string and is moving upwards as shown in the figute below. Breaking strength of the string is $4mg$. The maximum positive and negative accelerations that the block can have are

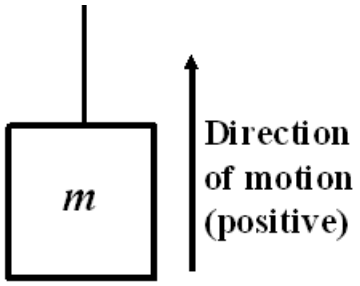
(A) 4g and 3g respectively.

(B) 4g and g respectively.

(C) 3g and 4g respectively.

(D) 3g and g respectively.

(E) 3g and 3g respectively.



42. A uniform chain of length L and mass m is lying on a smooth table. One third of its length is hanging vertically down over the edge of the table and the remaining two third is on the table. If g is the acceleration due to gravity, what is the work W required to pull the hanging part onto the table?

(A) mgL

(B) $mgL/3$

(C) $mgL/6$

(D) $mgL/9$

(E) $mgL/18$

43. Two satellites A and B have the same kinetic energy. Which of the statement is false?

(A) The satellite with greater mass has longer period.

(B) The satellite with greater mass has larger radius.

(C) The satellite with greater angular velocity has smaller radius.

(D) The satellite with greater velocity has higher total energy.

(E) None of the above

44. An electric sander has a continuous belt that rubs against a wood surface as shown schematically below. The sander is 100 per cent efficient and draws a current of 9 A from a 120 V power. The belt speed is 10 m/s. If the sander is pushing against the wood with a normal force of 100 N, the coefficient of friction is most nearly

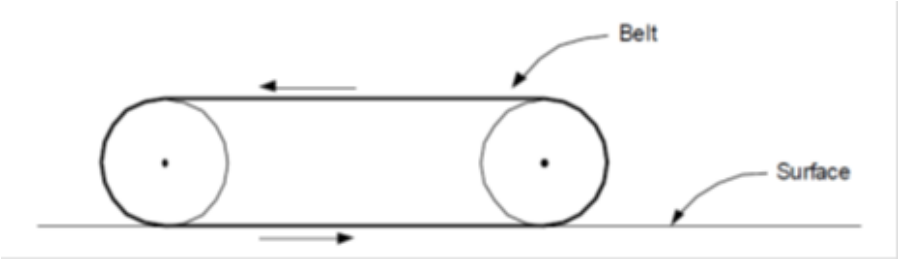
(A) 0.02

(B) 0.2

(C) 0.4

(D) 1.1

(E) 10



45. A rocket (A) is moving with constant speed 0.8c relative to the earth. A second rocket (B) overtakes the first rocket (A) with a constant speed of 40 m/s (seen by observer in first rocket A). Which of the following is true about the speed of the second rocket (B) relative to earth?

(A) smaller than $0.8c + 40$ m/s

(B) larger than $0.8c + 40$ m/s

(C) exactly $0.8c + 40$ m/s

(D) $-(0.8c + 40)$ m/s

(E) None of the above.

46. If on average, each fission reaction of ^{235}U releases 200 MeV of energy, how many nuclei of ^{235}U are split in a 200-MW reactor in one second?

(A) 6.3×10^{18}

(B) 6.0×10^{23}

(C) 1.0×10^{19}

(D) 1.6×10^{19}

(E) 2.7×10^{18}

47. The speed of sound is 340 m/s in air and 1500 m/s in water. A sound of 256 Hz is made under the water and travels to the air. In the air,

(A) the frequency remains the same but the wavelength is shorter.

(B) the frequency is higher but the wavelength remains the same.

(C) the frequency will be lower but the wavelength is longer.

(D) the frequency will be lower and the wavelength is shorter.

(E) both the frequency and wavelengths remain the same.

48. Suppose you wanted to start a fire using sunlight and a mirror. Which of the following statements is most accurate?

(A) It would be best to use a plane mirror.

(B) It would be best to use a convex mrror.

(C) it would be best to use a concave mirror, with the object to be ignited positioned at the centre of curvature of the mirror.

(D) It would be best to use a concave mirror, with the object to be ignited positioned halfway between the mirror and its centre of curvature.

(E) It is impossible to start a fire as mirrors form only virtual images.

49. In order for an atom to emit light, it must be

(A) in the gaseous state.

(B) stimulated by external radiation.

(C) in its ground state.

(D) in an excited state.

(E) fluorescent.

50. The particle nature of light is best illustrated by which of the following?

(A) The scattering of alpha particles from gold foil.

(B) The fact that hot objects emit electromagnetic radiation.

(C) The diffraction pattern observed when a beam of electrons is scattered by a crystal.

(D) The fact that a rainbow consists of a continuous spectrum of colours.

(E) The ejection of electrons from a metal surface illuminated by light.

END OF PAPER.