SINGAPORE JUNIOR PHYSICS OLYMPIAD 2019

GENERAL ROUND

23 May 2019, 1500 – 1700

Time Allowed: **2 Hours**

INSTRUCTIONS

1. **Read the instructions on this page** but **DO NOT TURN the page** until you are told to do so by the invigilator.

2. This paper contains **50** multiple choice questions and **16** printed pages (including this cover page). Each question or incomplete statement is followed by five suggested answers or completions. **Select only the best** in each case and then **shade** the corresponding bubble on the answer sheet.

3. Use **2B pencil** only to shade the bubbles on the answer sheet, and make sure any stray markings are properly erased.

4. At the end of the test, please **submit** the **answer sheet** and the **question paper (attach all rough paper** used during the competition to the question paper). **Only** the **answer sheet** will be **marked**. Answers written anywhere else will not be marked.

5. **Fill in your index number in the space labelled as "NRIC/FIN/ Passport No." on the answer sheet now.** Write your **name** and **school** on the **answer sheet** and **question paper** now.

6. **Scientific calculators** are **allowed**. **Graphing** calculators are **not** allowed.

7. Answer **ONLY** questions you are confident of. Marks will be deducted for wrong answers. **A question left unanswered (blank) will score a higher mark than a wrong answer.**

8. A general data sheet is given in the following page. You may **detach the data sheet when the competition starts** so that you can refer to it easily.

Name: _____

School: _____

GENERAL DATA SHEET

Acceleration due to gravity at the surface of Earth, $g = 9.80\ \text{ms}^{-2} = |g|$

Universal gravitational constant; $G = 6.67 \times 10^{-11}\ \text{kg}^{-1}\ \text{m}^3\ \text{s}^{-2}$

Universal gas constant, $R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$

Vacuum permittivity, $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$

Vacuum permeability, $\mu_0 = 4\pi \times 10^{-7}\ \text{T m A}^{-1}$

Atomic mass unit, $u = 1.66 \times 10^{-27}\ \text{kg}$

Speed of light in vacuum, $c = 3.00 \times 10^8\ \text{m s}^{-1}$

Speed of sound in air, $v_s = 340\ \text{ms}^{-1}$

Charge of electron, $e = 1.60 \times 10^{-19}\ \text{C}$

Planck's constant, $h = 6.63 \times 10^{-34}\ \text{J s}$

Mass of the Earth, $M_E = 5.97 \times 10^{24}\ \text{kg}$

Mass of electron, $m_e = 9.11 \times 10^{-31}\ \text{kg} = 0.000549u$

Mass of proton, $m_p = 1.67 \times 10^{-27}\ \text{kg} = 1.007u$

Mass of deuteron, $m_d = 3.34 \times 10^{-34}\ \text{kg} = 2.014u$

Rest mass of alpha particle, $m_\alpha = 4.003\ u$

Boltzmann constant, $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$

Avogadro's number, $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

Standard atmosphere pressure, $P_0 = 1.01 \times 10^5\ \text{Pa}$

Density of water, $\rho_w = 1000\ \text{kg m}^{-3}$

Specific heat (capacity) of water, $c_w = 4.19 \times 10^3\ \text{J kg}^{-1}\ \text{K}^{-1}$

Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^8\ \text{W m}^{-2}\ \text{K}^{-4}$

Radius of the sun, $R_S = 6.96 \times 10^5\ \text{km}$

Radius of the earth, $R_E = 6.37 \times 10^3\ \text{km}$

Distance between sun and earth, $d_{SE} = 1.5 \times 10^8\ \text{km}$

Acceleration due to gravity at the sun's surface, $g_S = 28.02\ \text{g}$

Temperature on the surface of the sun, $T_S = 5780\text{K}$

1. Which of the following is the SI unit for the weight of an object?

A kg m s^{-1} B kg m s^{-2} C kg m s
D kg m s^{2} E $\text{kg m}^{-1}\text{s}^{2}$

Questions 2 and 3

A particle starts from point O and travels due east at a constant speed of 10 ms^{-1} for 70 m to reach point A. It then immediately travels due north from A at constant speed of 5 ms^{-1} for 8 s to reach point B. At B, it immediately turns and travels due west at uniform speed of 8 ms^{-1} for 40 m to reach point C.

2. What is the magnitude of the displacement of the particle at C with respect to O?

A 30 m B 40 m C 50 m
D 70 m E 150 m

3. What is the magnitude of the average velocity of the particle during its journey from O to C?

A 2.5 ms^{-1} B 7.5 ms^{-1} C 7.7 ms^{-1}
D 9.0 ms^{-1} E 10.0 ms^{-1}

Questions 4 and 5

A particle is projected vertically upwards from the base of a tall building with a speed of 50.0 ms^{-1}. At the same time, another particle is dropped from the top of the building. The two particles meet after T sec and are found to have the same speed when they meet.

4. What is the value of T ?

A. 2.13 s B 2.55 s C 3.40 s
D 4.25 s E 5.10 s

5. What is the height of the building?

A 128 m B 155 m C 170 m
D 213 m E 255 m

Questions 6 and 7

A tractor of mass 2000 kg is pulling a trailer of mass 3000 kg up an incline of 1 in 10 along a line of greatest slope. I.e. if the angle of the incline is θ then $\sin\theta = 0.1$. The frictional resistance to the motion is 4000 N and one-quarter of it acts on the tractor. At first both vehicles move with an acceleration of 1.5 ms^{-2} but eventually they move with a constant velocity of 8 ms^{-1}.

6. What is the pulling force exerted by the engine of the tractor when both vehicles are accelerating?

A 3940 N B 11500 N C 12400 N
D 14400 N E 16400 N

7. What is the force exerted by the tow-bar on the tractor when both vehicles are moving at constant velocity?

A 1940 N B 3940 N C 5940 N
D 8900 N E 10400 N

8. A ball of mass m is projected vertically downwards with speed u from a certain height and rebounds from the ground back to the same height. Neglecting air resistance, which of the following statements is/are correct?

(1) The collision between the ball and the ground is not perfectly elastic.

(2) The loss in energy of the ball during the collision is greater than $\frac{1}{2}mu^2$

(3) If the ball is projected vertically upwards from the same height and with speed u, it would rebound to a greater height.

A (1) only B (3) only C (1) & (2) only
D (1) & (3) only E (1), (2) & (3) only

9. A car starts from rest and accelerates uniformly for 10 s. What is the ratio of the distance travelled in the 10 s to the distance travelled in the first second?

A 5 B 10 C 20
D 50 E 100

10. A train moving at 20.0 ms^{-1} slows down uniformly to 10.0 ms^{-1} in 5.0 s. What is the distance travelled by the train in the last second of its journey before it stops?

A 1.0 m B 3.0 m C 6.0 m
D 9.0 m E 10.0 m

11. A constant external torque Γ is applied to a flywheel which is initially at rest. The flywheel attains certain angular speed after 25 s. When the value of the constant external torque is doubled, the flywheel acquires the same angular speed from rest after 10 s. What is the average frictional torque exerted at the bearings of the flywheel?

A $\frac{\Gamma}{5}$ B $\frac{\Gamma}{4}$ C $\frac{\Gamma}{3}$
D $\frac{2\Gamma}{5}$ E $\frac{\Gamma}{2}$

12. A particle P of mass 6.0 kg makes a head-on collision with another particle Q of mass 2.0 kg. The two particles separate after the collision. What is the ratio of change in the speed of P to the change in the speed of Q?

A $\frac{1}{6}$ B $\frac{1}{3}$ C 1
D 3 E 6

13. Fig. 1 shows the displacement-time graphs for two particles A and B.

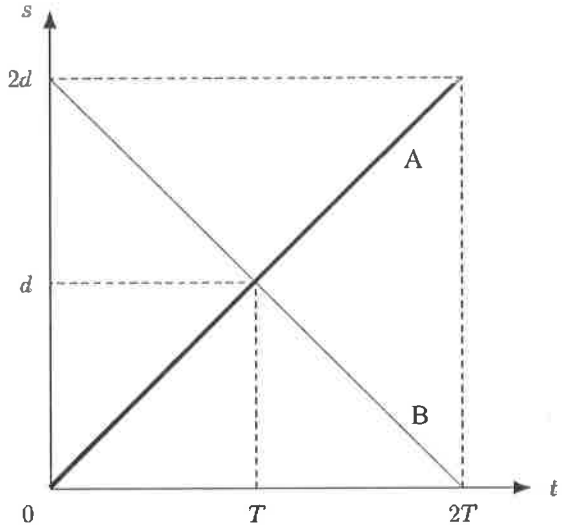


Fig. 1

Which of the following statements is **FALSE**?

A The two particles meet at time $t = T$.
B The two particles move through the same distance in the time interval $2T$.
C The distance between the two particles are equal at time $t = 0$ and at time $t = 2T$.
D Both particles move with the same velocity.
E Both particles move with the same constant acceleration.

14. The speed of a satellite orbiting near the surface of the earth is 7.9 km s^{-1}. The radius of the earth is about 4 times that of moon and the ratio of the average density of the earth to that of the moon is 5:4. What is the speed of a satellite orbiting near the surface of the moon?

A 1.8 km s^{-1} B 2.2 km s^{-1} C 2.5 km s^{-1}
D 3.6 km s^{-1} E 4.4 km s^{-1}

15. An object with mass m is at distance r from a point P. The linear speed of the object is v. It spins with angular velocity ω about its center of mass and its moment of inertia about its center of mass is I. What is the simplest expression for the maximum magnitude of the objects angular momentum about P?

A $mr^2\omega$
B $2mr^2\omega$
C Iv
D $I\omega$
E $I\omega + mrv$

16. A particle initially has momentum 44 kgms^{-1}. It is acted upon by a force **perpendicular** to its initial velocity for 10 s. The variation of the magnitude of the force with time is shown by the thick line in Fig. 2. At the end of the 10 s, the momentum of the particle is 71 kgms^{-1}. What is the value of y?

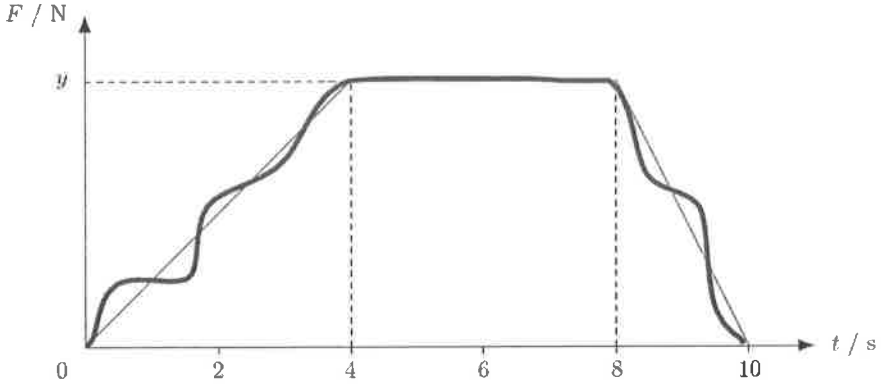


Fig. 2

A 4 B 6 C 8
D 12 E 16

17. When an object floats in water, it is found that 25.0% of its volume lies above the surface of water. When the same object floats in another liquid, it is found that only 14.8% of its volume lies above the liquid surface. Given that the density of water is 1000 kg m^{-3}, what is the density of the liquid?

A 592 kg m^{-3} B 750 kg m^{-3} C 852 kg m^{-3}
D 880 kg m^{-3} E 945 kg m^{-3}

18. A satellite is revolving round the earth in elliptical orbit. At perigee, the point of closest approach, it moves with 3 times the speed that it has at apogee, the point of greatest separation (See Fig. 3). At perigee it is 1000 km above the surface of the earth. The mass of the earth is 5.98×10^{24} kg and its radius is 6400 km. How high above the surface of the earth is it at apogee?

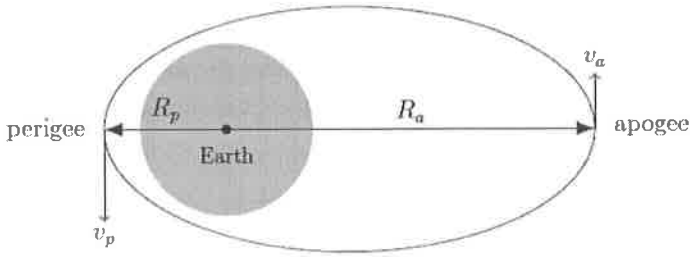


Fig. 3

A 3000 km B 10400 km C 15800 km
D 22400 km E 60400 km

19. A small object of mass 0.040 kg is attached to one end of an elastic string of unstretched length 0.50 m. The force constant of the elastic string is 40 N m^{-1}. The object is rotated steadily on a smooth table in a horizontal circle of radius 0.70m as shown in Fig. 4. What is the approximate speed of the object?

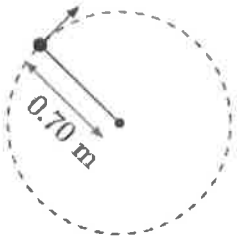


Fig.4

A 12 ms^{-1} B 15 ms^{-1} C 20 ms^{-1}
D 24 ms^{-1} E 30 ms^{-1}

20. A ladder is propped against a wall making an angle θ with the floor as shown in Fig. 5. The wall is frictionless but the coefficients of static friction and of kinetic friction between the floor and the ladder are μ_s and μ_k respectively. What is the expression for the smallest angle θ if the ladder is not to slip?

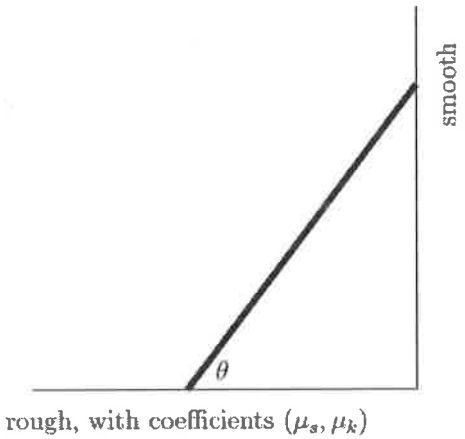


Fig. 5

A $\tan^{-1}\left(\frac{\mu_k}{2}\right)$

B $\tan^{-1}\left(\frac{1}{2\mu_s}\right)$

C $\tan^{-1}\left(\frac{1}{2\mu_k}\right)$

D $\tan^{-1}\left(\frac{\mu_s}{2}\right)$

E $\tan^{-1}\left(\frac{\mu_s}{\mu_k}\right)$

21. A cylinder is rotating freely about its axis with kinetic energy E_k. Its rotation is gradually reduced to a stop in a time interval T by applying a constant opposing torque. At time $\frac{T}{2}$ after applying the torque, what is the kinetic energy of the rotating cylinder?

A $\frac{E_k}{\sqrt{2}}$ B $E_k\left(1-\frac{1}{\sqrt{2}}\right)$ C $\frac{E_k}{2}$

D $\frac{E_k}{4}$ E $\frac{3E_k}{4}$

22. One end of an elastic string, having natural length a is fixed at a point. When a particle of mass m is attached to its free end, the string extends to a length ℓ as shown in Fig.6.

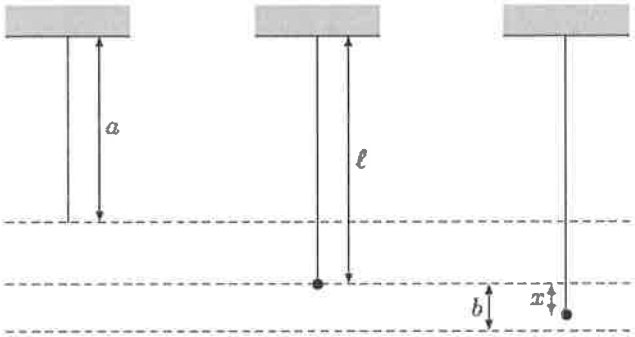


Fig. 6

The particle is pulled down through a small distance b where $b<(\ell-a)$ and then released. Taking $t=0$ to be the instant when the particle is released, which of the following equations describe the resulting oscillation of the particle?

A $x=(\ell-a)\sin\omega t$

B $x=(b+\ell-a)\sin\omega t$

C $x=(b+\ell-a)\cos\omega t$

D $x=b\sin\omega t$

E $x=b\cos\omega t$

23. Fig. 7 shows the variation of the acceleration, a of a particle with its displacement, x from a fixed point. Which one of the following graphs best illustrates the variation of its **speed**, v with x?

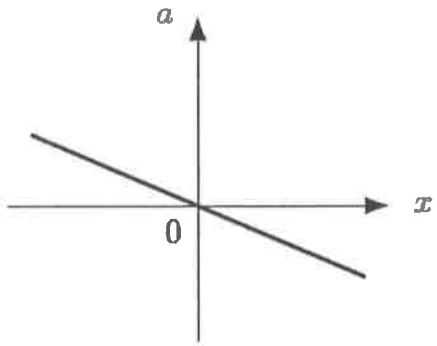
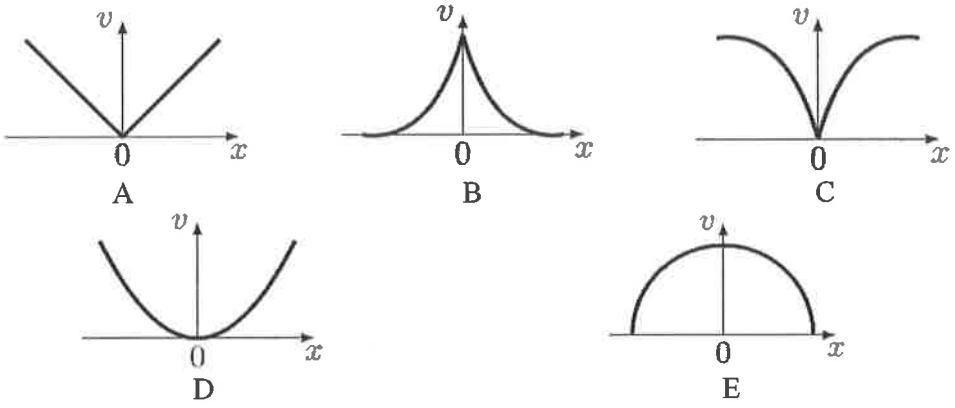


Fig. 7



24. Fig. 8 shows the variation of image distance v with object distance u for a thin lens. I.e. if the object is at u from the lens, its image will be located at v on the other side of the lens.

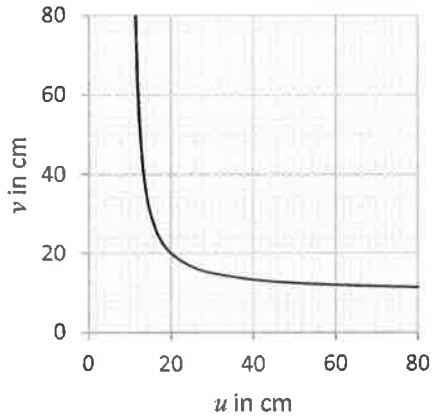


Fig. 8

From the graph, we may deduce that the lens is _____.

A converging and of focal length 10 cm
B converging and of focal length 20 cm
C converging and of focal length 40 cm
D diverging and of focal length 10 cm
E diverging and of focal length 20 cm

25. The focal length of an ideal converging lens **DOES NOT** depend on which of the following factors?

A The power of the lens
B The aperture of the lens
C The radius of curvature of the lens
D The material with which the lens is made of
E The refractive index of the medium in which the lens is placed

26. A particle P is oscillating in simple harmonic motion about a point O.

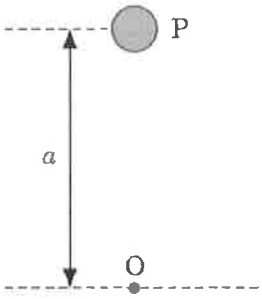


Fig. 9

Fig. 9 shows the position of the particle at a particular instant of time. The particle is at rest at this position. If T is the period of oscillation of the particle, what is the displacement of the particle from O at time $\frac{7T}{8}$ later?

A $\frac{a}{\sqrt{2}}$ below O B $\frac{a}{\sqrt{2}}$ above O C $\frac{a}{4}$ below O

D $\frac{a}{4}$ above O E $\frac{a}{2}$ below O

27. When a tuning fork A is sounded together with a standard tuning fork of frequency 256 Hz, the frequency of beats detected is 5 Hz. A small piece of plasticine is attached to the prong of tuning fork A and then both tuning forks are sounded together, the frequency of beats becomes 2 Hz. What is the frequency of tuning fork A ?

A 251 Hz B 254 Hz C 256 Hz
D 258 Hz E 261 Hz

28. A ray of red light has wavelength 493.5 nm when propagating in water. What will be its wavelength when the ray is propagating in a glass block?
[Absolute refractive indices of water and glass are 1.33 and 1.52 respectively]

A 324.7 nm B 431.8 nm C 564.0 nm
D 603.1 nm E 656.4 nm

29. A monochromatic light ray passes through a glass prism and is found to undergo minimum deviation. What is the relationship between the angle of incidence i and the angle of emergence e in this situation?

A $i > e$ B $i < e$ C $i = e$
D $i = 2e$ E $i = 90° - e$

30. A compound microscope possesses an objective lens that is changeable. To increase the magnifying power of the instrument, what changes need to be made to the objective lens?

A possesses a longer focal length and moved further away from the object.
B possesses a shorter focal length and moved further away from the object.
C possesses a shorter focal length and kept in the same position.
D possesses a longer focal length and moved closer to the object.
E possesses a shorter focal length and moved closer to the object.

31. Two loudspeakers at coordinates (-1.00 m, 0.00 m) and (1.00 m, 0.00 m) oscillate in phase at 340 Hz. The phase difference between the sound waves from the two speakers at coordinate (2.00 m, 4.00 m) is _____.

A zero B 0.50 radian C 1.57 radian
D 5.52 radian E 6.02 radian

32. A parallel beam of white light is incident normally on a diffraction grating. It is noted that the second-order and third-order spectra partially overlap. Which wavelength in the second-order spectrum appears at the same angle as the wavelength of 400 nm in the third-order spectrum?

A 180 nm B 270 nm C 400 nm
D 600 nm E 900 nm

33. A metal sphere has a diameter of 60.00 cm. It is charged until its surface charge density is 12.00 nC m^{-2}. What is the electric potential at the surface of the sphere?

A 122.0 V B 339.0 V C 406.8 V
D 488.1 V E 813.5 V

34. Two positive charges, each of magnitude $+Q$ are placed at a distance $2d$ apart in a dielectric medium with relative permittivity 3. The two positive charges are then placed in vacuum at a distance d apart. By how many times will the electrostatic force between the two positive charges increase?

A 1.5 times B 2.25 times C 6 times
D 12 times E 18 times

35. A negatively charged oil drop is held stationary between two horizontal charged metal plates as shown in Fig. 10.

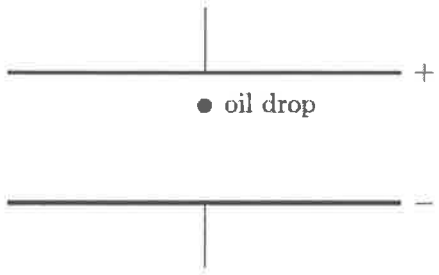


Fig. 10

The oil drop is now replaced with another oil drop with the same volume but having greater density and carries the same amount of negative charge as the previous drop. In order to keep the oil drop stationary, what change should be made?

A Move the two plates further apart
B Reverse the charges on the plate
C Decrease the positive charge on the positive plate
D Increase the potential difference between the two plates
E Allow the oil drop to come closer to the negative plate

36. The plates of a parallel plate capacitor each have area 3 m^2 and a separation of 1.5 mm. The capacitor is charged to a potential difference of 12 kV. If the energy stored in the charged capacitor is used to lift a mass of 4 kg, what is the maximum vertical height through which it can be raised?

A 1.62 cm B 3.25 cm C 4.88 cm
D 6.50 cm E 9.75 cm

37. A capacitor X has a capacitance of $3\mu F$ and a voltage rating of 10V. In order to obtain an effective capacitance of $1\mu F$ and a voltage rating of 60V, using only capacitors identical to X, what is the simplest arrangement to be made?

A Connect 2 capacitors in series with X
B Connect 2 capacitors in parallel with X
C Connect 1 capacitor in parallel with X and 5 more pairs of capacitors in series with the first pair
D Connect 5 capacitors in series with X
E Connect 6 capacitors in parallel with X

38. A $2.0\mu F$ capacitor is charged to a potential difference of V_0. It is then discharged through a resistor having resistance $2.5M\Omega$. After a time interval of T, the potential difference across the capacitor becomes $\frac{V_0}{e^3}$ where $e = 2.71828$, the base of natural logarithm. What is the value of T ?

A 2.5 s B 5.0 s C 7.5 s
D 12.5 s E 15.0 s

39. A p.d. of 1.0 V is applied to the ends of a uniform copper wire 91 cm long and with a diameter of 0.315 mm. How long does a free electron in the wire take to drift through a distance of 10 cm along the wire?

[Free electron density in copper $= 8.48\times10^{28}$ m^{-3}; Resistivity of copper $= 1.72\times10^{-8}$ Ωm]

A 330 ps B 3 ns C 160 ns
D 16 s E 22 s

40. When a potential difference of V is applied to a conducting rod of length ℓ and diameter d, the electric current flowing in the conductor is I. When the same potential difference is applied to a conducting pipe, made of the same material, but of length 3ℓ and outer diameter $2d$ and inner diameter d, what is the electric current flowing in this conductor?

A I B $4/3\,I$ C $8/3\,I$
D $3I$ E $4I$

41. A uniform wire has a resistance of 16Ω. It is bent into the shape of a square. What is the resistance between any two adjacent corners of the square?

A 2.0Ω B 3.0Ω C 4.0Ω
D 7.5Ω E 9.0Ω

42. Two cylindrical wires A and B are made of the same material and have the same mass. The length of wire A is twice that of wire B. Electric currents of 2A and 3A are passed through the wires A and B respectively. What is the ratio of the power dissipation in wire A to that in wire B?

A 2 : 9 B 8 : 9 C 4 : 3
D 16 : 9 E 9 : 4

43. An electron is moving in a straight line in a region where there exists a magnetic field and an electric field perpendicular to each other. What will be the motion of the electron if the electric field is switched off ?

A The electron will move with the same speed in a circular path.
B The electron will move with the same speed in a parabolic path.
C The electron will move with the same speed in a straight line.
D The electron will move with a reduced speed in a circular path.
E The electron will move with a reduced speed in a straight line.

44. Two cells of e.m.f.'s E_1 and E_2 and of negligible internal resistance are connected with two variable resistors P and Q as shown in Fig. 11. When the resistances of P and Q are adjusted to r_p and r_q respectively, the galvanometer shows null deflection. What is the value of the ratio $\frac{E_2}{E_1}$?

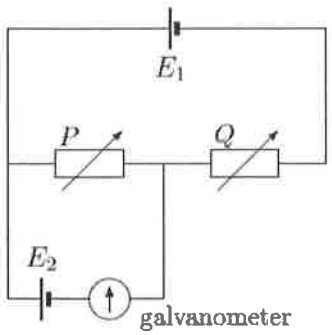


Fig. 11

A $\frac{r_p}{r_q}$ B $\frac{r_p}{r_p+r_q}$ C $\frac{r_q}{r_p+r_q}$
D $\frac{r_p+r_q}{r_p}$ E $\frac{r_p+r_q}{r_q}$

45. A high-resistance voltmeter is connected across the a cell of e.m.f. E and having internal resistance r. A variable resistor R is connected to the terminals of the cell as shown in Fig. 12.

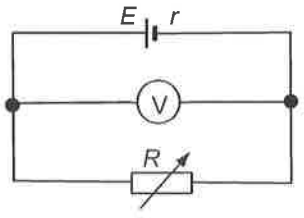


Fig. 12

When the resistance of R is 6.0 Ω, the reading of voltmeter is 4.0 V. When the resistance of R is increased to 9.0 Ω, the reading of the voltmeter becomes 4.5 V. What is the internal resistance of the cell?

A 0.5 Ω B 1.5 Ω C 2.0 Ω
D 3.0 Ω E 5.0 Ω

46. A hot liquid with mass 2 kg is contained in a flask the heat capacity of which is negligible. Just before the liquid begins to solidify at a temperature of 1007 °C, it is found that its temperature falls at a rate of 2.5 K min^{-1}. The temperature of the liquid then remains constant for 32 minutes by which time the liquid has all solidified. Using SI units, what is the numerical value of the ratio of the specific latent heat of fusion to specific heat capacity?

A 16 B 25 C 32
D 40 E 80

47. An ideal gas contained in a cylinder is compressed isothermally from volume V_1 and pressure p_1 to volume V_2 and pressure p_2. Which one of the statements below is true for the gas?

A Potential energy of the gas increases
B Kinetic energy of the gas increases
C Heat flows out from the gas
D No work is done on the gas
E The work done on the gas is $p_1V_1 - p_2V_2$

48. A constant-volume gas thermometer is used to determine the thermodynamic temperature T of a water bath. The pressure of the gas corresponds to the temperature T and to the triple point of water are respectively p and p_{tr}. The variation of $\frac{p}{p_{tr}}$ with p_{tr} is shown in Fig. 13 below.

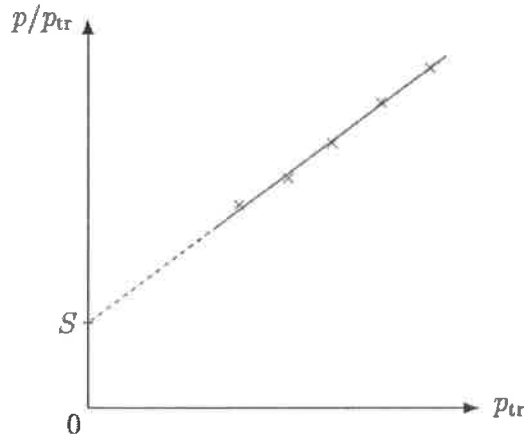


Fig. 13

What is the thermodynamic temperature of the water bath?

A S B $273.16(1+S)$ C $273.16+S$
D $273.16S$ E $\frac{S}{273.16}$

49. A slab of insulating material is made up of a layer of Styrofoam thickness 5 mm with thermal conductivity of 0.035 $Wm^{-1}K^{-1}$ sandwiched between two sheets of wood 5 mm thick each with thermal conductivity 0.17 $Wm^{-1}K^{-1}$. The rate of heat conduction per unit area through the whole slab is 24 $W\ m^{-2}$. What is the temperature difference between the two surfaces of the slab?

A 0.6 K B 2.4 K C 4.8 K
D 36 K E 96 K

50. Fig. 14 shows the variation of pressure p with $\frac{1}{V}$ where V represents volume for a fixed mass of a sample of monatomic ideal gas undergoing some change.

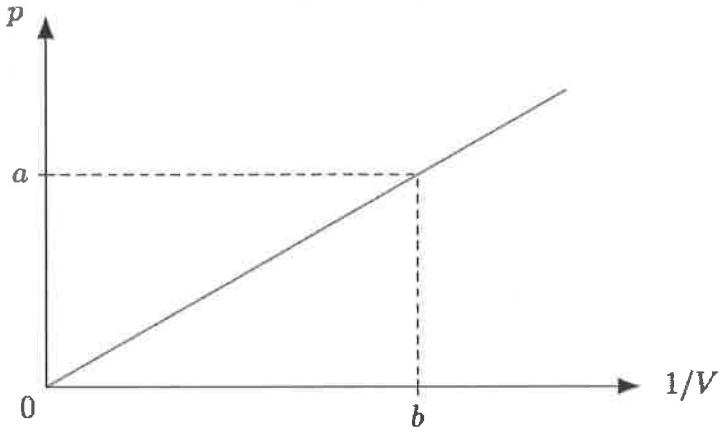


Fig. 14

If e represents the average kinetic energy per molecule of the gas, which of the following expressions gives the number of molecules in the sample of the gas?

A $\frac{3a}{2be}$ B $\frac{3b}{2ae}$ C $\frac{2a}{3be}$
D $\frac{b}{3ae}$ E $\frac{a}{3be}$

---------- End of Paper ----------