UNIVERSITY ENTRANCE EXAMINATION 2019

NUS National University of Singapore

PHYSICS

Duration : 2 hours

Please read the following instructions carefully.

1. This paper is made up of 50 Multiple-Choice questions and comprises **TWENTY**-**ONE** (**21**) printed pages.

2. **Do not write on the question paper**.

3. Answer all questions and indicate your answers on the answer sheet provided. Marks will not be deducted for wrong answers.

4. Do not take any paper, including the question paper or unused answer sheets, out of the examination hall.

USEFUL INFORMATION:

Acceleration due to gravity, $g \approx 9.80\ \mathrm{m\,s^{-2}}$

Avogadro's number, $N_A \approx 6.022 \times 10^{23}$ particles/mol

Universal gas constant, $R \approx 8.314\ \mathrm{J\,K^{-1}\,mol^{-1}}$

Gravitational constant, $G \approx 6.673 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$

Coulomb constant, $k \approx 8.99 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$

Magnitude of charge of electron, $e \approx 1.602 \times 10^{-19}$ C

Mass of electron, $m_e \approx 9.109 \times 10^{-31}\ \mathrm{kg}$

Mass of proton, $m_p \approx 1.673 \times 10^{-27}\ \mathrm{kg}$

Mass of neutron, $m_n \approx 1.675 \times 10^{-27}\ \mathrm{kg}$

Speed of light, $c \approx 2.998 \times 10^{8}\ \mathrm{m\,s^{-1}}$

Planck's constant, $h \approx 6.626 \times 10^{-34}\ \mathrm{J\,s}$

Atomic mass unit, $u \approx 1.661 \times 10^{-27}\ \mathrm{kg}$

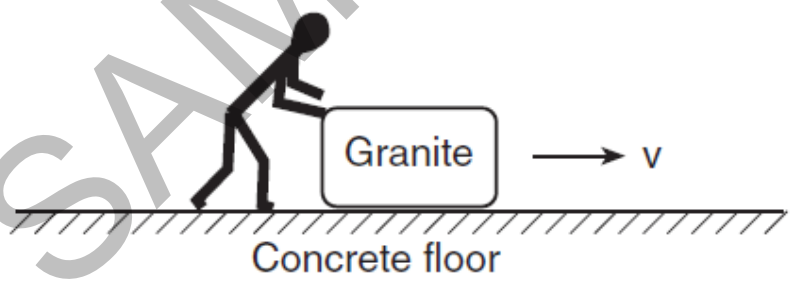
1. The equation for the change of position of a race car starting at x = 0 m is given by $x = A + Bt + Ct^2 + Dt^3$, where t is time. The dimensions of D are

A $L^{-1}T^{-3}$
B LT
C $L^{-3}T$
D LT^{-3}
E LT^{-2}

2. What is the total displacement of a student who walks 3 blocks east, 2 blocks north, 1 block west, and then 2 blocks south?

A 0
B 2 blocks east
C 2 blocks west
D 8 blocks
E 12 blocks

3. The diagram below shows a granite block being slid at constant speed across a horizontal concrete floor by a force parallel to the floor.



Which pair of quantities could be used to determine the coefficient of friction for the granite on the concrete?

A mass and speed of the block
B mass and normal force on the block
C frictional force and speed of the block
D frictional force and normal force on the block
E None of the above

4. An object with an initial speed of 4.0 meters per second accelerates uniformly at 2.0 meters per second^2 in the direction of its motion for a distance of 5.0 meters. What is the final speed of the object?

A 6.0 m/s
B 10 m/s
C 14 m/s
D 36 m/s
E 40 m/s

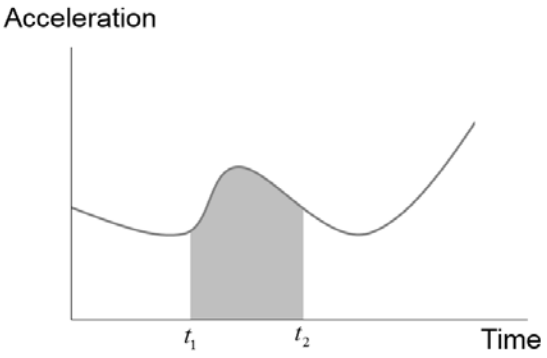
5. A projectile is fired from a gun near the surface of Earth. The initial velocity of the projectile has a vertical component of 98 meters per second and a horizontal component of 49 meters per second. How long will it take the projectile to reach the highest point in its path?

A 5.0 s
B 10 s
C 20 s
D 100 s
E 120 s

6. A 1.0-kilogram rubber ball traveling east at 4.0 meters per second hits a wall and bounces back toward the west at 2.0 meters per second. Compared to the kinetic energy of the ball before it hits the wall, the kinetic energy of the ball after it bounces off the wall is

A one-fourth as great
B one-half as great
C the same
D four times as great
E None of the above

7. The variation of the acceleration with time of a body moving on a straight line is shown in the graph below.



The shaded area represents

A the velocity at t_1
B the velocity at t_2
C the change in displacement from t_1 to t_2
D the change in velocity from t_1 to t_2
E the average velocity between t_1 and t_2

8. When a 1000 kg car and a 10000 kg truck collide head-on, why is the passenger on the car more likely to experience a bigger force by the seat belt?

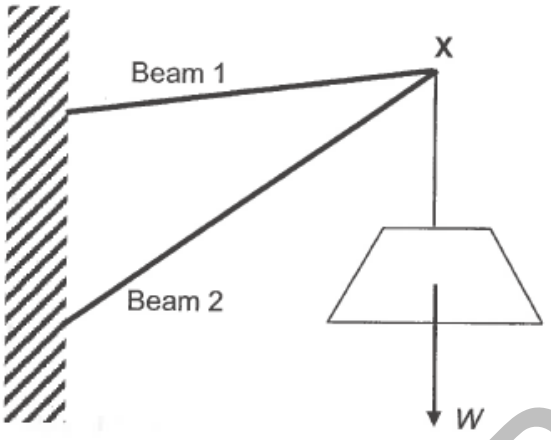
A The car experiences a bigger force than the truck.
B The car experiences a smaller force than the truck.
C The car undergoes a larger change of velocity than the truck.
D The deceleration of the truck has a larger magnitude than the deceleration of the car.
E None of the **A**, **B**, **C** and **D**

9. An aeroplane flying in a straight line at a constant height of 500 m with a speed of 200 m/s releases an object. The object takes a time *t* to reach the ground and travels a horizontal distance *d* in doing so.

Ignoring the air resistance, which one of the following gives the value of *t* and *d*?

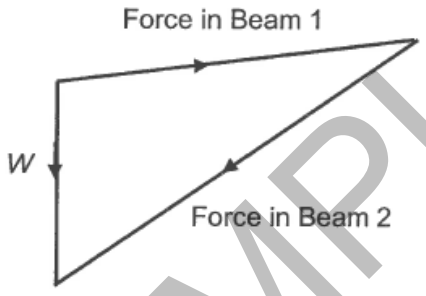
	t (s)	*d* (km)
A	10.10	2.02
B	10.10	5.05
C	25.50	5.05
D	25.50	10.10
E	25.50	20.30

10. Two rigid beams, 1 and 2, are fixed to a vertical wall. A stationary load of weight *W* is hung from point **X** where the two beams are joined as shown.

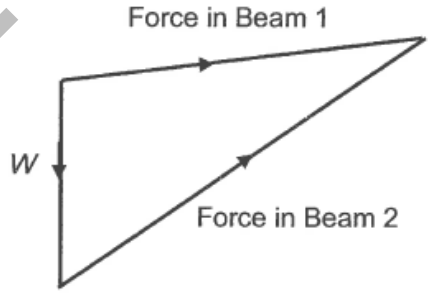


Which diagram shows the forces acting at X?

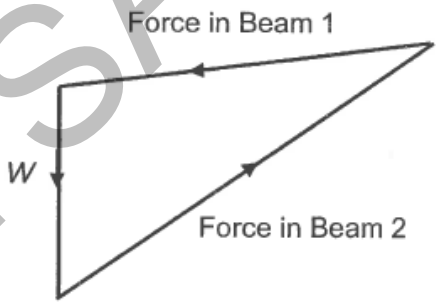
A



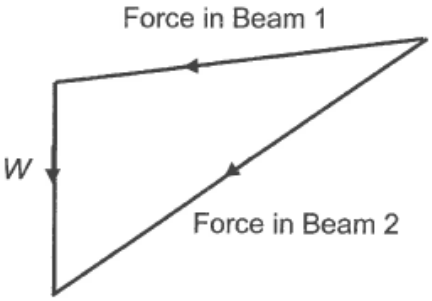
B



C

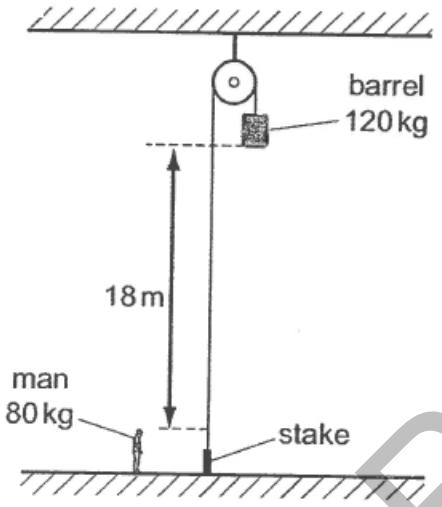


D



E None of **A**, **B**, **C** and **D**

11. The diagram shows a barrel suspended from a frictionless pulley on a building. The rope supporting the barrel goes over the pulley and is secured to a stake at the bottom of the building.



A man stands close to the stake. The bottom of the barrel is 18 m above the man's head. The mass of the barrel is 120 kg and the mass of the man is 80 kg. The man keeps hold of the rope after loosening it from the stake and is lifted upwards as the barrel falls.

What is the man's upward speed when his head is level with the bottom of the barrel?

A 5.22 ms^{-1}
B 5.94 ms^{-1}
C 9.42 ms^{-1}
D 10.26 ms^{-1}
E 12.64 ms^{-1}

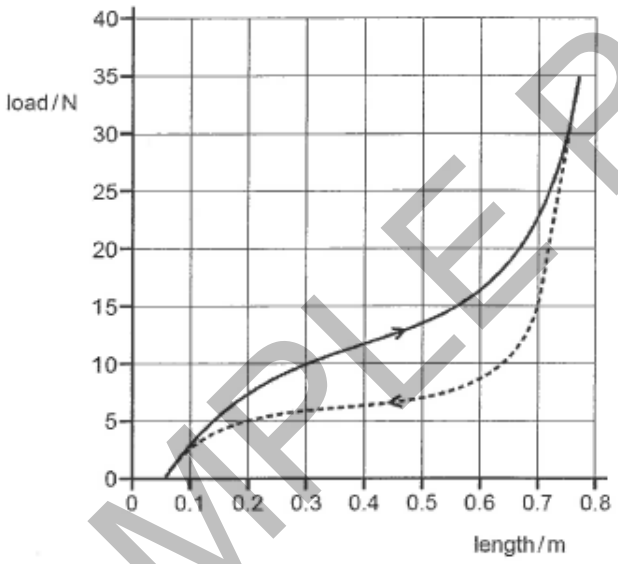
12. The acceleration of free fall on the Moon is one-sixth of that on the Earth, and it takes time t for a stone to fall from rest for a distance of 2 m on the Earth. What is the time taken for the stone to fall from rest for a distance of 2 m on the Moon? Assume that the air resistance is negligible on the Earth and on the Moon.

A $6t$
B $\frac{t}{6}$
C $\sqrt{6}\,t$
D $\sqrt{6t}$
E $\frac{t}{\sqrt{6}}$

13. A 4.0-kilogram rock and a 1.0-kilogram stone fall freely from rest from a height of 100 meters. After they fall for 2.0 seconds, the ratio of the rock's speed to the stone's speed is

A 1:1
B 1:2
C 2:1
D 4:1
E 6:1

14. The solid line on the following graph shows how the length of a rubber band varies when an increasing load is applied.



The dotted line shows how the length subsequently varies as the load is gradually decreased.

Which statement is correct?

A Energy is released from the rubber band when it is stretched longer.

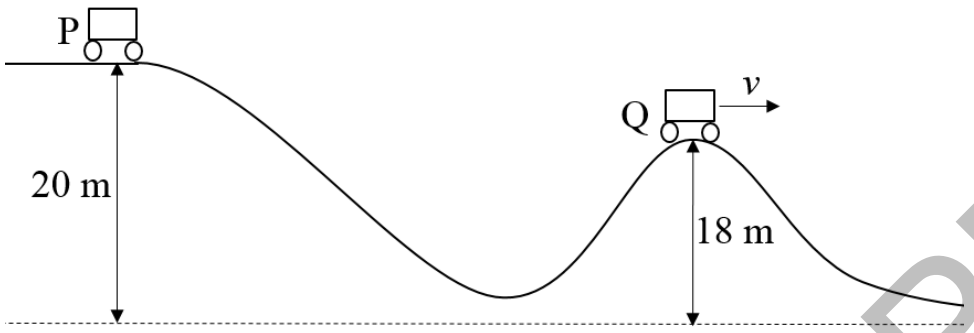
B Energy is received by the rubber band when it goes back to the natural length.

C The total work done on the rubber band during one cycle of stretch and release is 0.

D The total work done on the rubber band during one cycle of stretch and release is positive.

E The total work done on the rubber band during one cycle of stretch and release is negative.

15. In a frictionless roller coaster ride a car of mass 15 kg starts from rest at the top of the first hill at point P of height 20 m.



What will be the magnitude of the force from the car exerted on the hill when it reaches the top of the second hill at point Q where the height is 18 m with a radius of curvature of 9 m?

A 32.33 N
B 41.67 N
C 65.67 N
D 81.67 N
E 92.33 N

16. A man intends to position a box on a long and rough horizontal table by giving it a push and letting go. He misjudges his push and the box goes only one-third of the way to the intended position. If the initial speed of the box after the push is v_o and the resistive force acting on the box is a constant, what should the initial speed of the box be for it to slide to the intended position?

A $\sqrt{2}\, v_o$

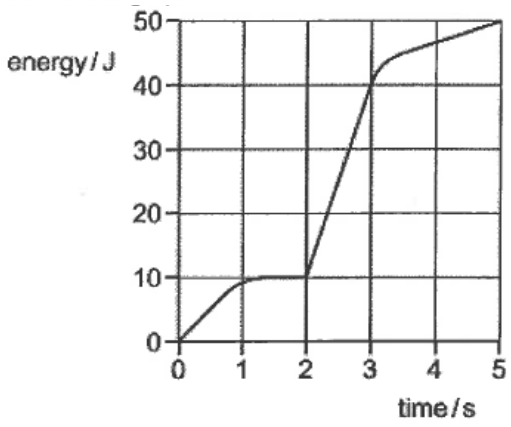
B $\sqrt{3}\, v_o$

C $\sqrt{6}\, v_o$

D $3v_o$

E $4v_o$

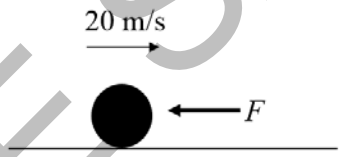
17. An electrical generator is started at time zero. The total electrical energy generated during the first 5 seconds is shown in the graph.

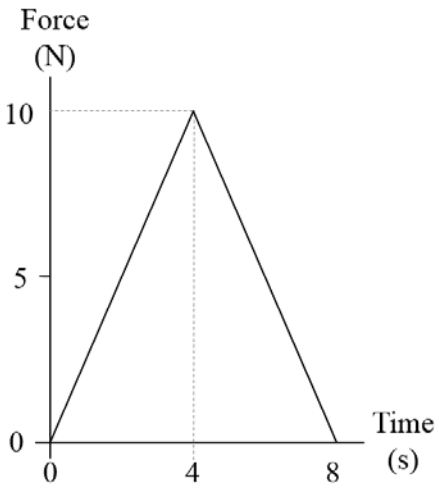


What is the maximum electrical power generated at any instant during the first 5 seconds?

A 10 W
B 13 W
C 30 W
D 50 W
E None of the above

18. A ball of mass 2.0 kg, initially moving at a velocity v of 20 m/s, is acted on by a variable force F as shown below.





What is the velocity of the ball after 8.0 s?

A -20 m/s
B 0 m/s
C 20 m/s
D 40 m/s
E 60 m/s

19. An iron ball at 40 degree Centigrade is dropped in a mug containing water at 40 degree Centigrade. The heat will

A flow from iron ball to water.
B flow from water to iron ball.
C not flow from iron ball to water or from water to iron ball.
D increase the temperature of both.
E None of the above

20. Assuming heat capacity of a 10 g of water to be 42 J / K, heat required to raise its temperature from 25 °C to 35 °C would be

A 42 J
B 420 J
C 640 J
D 4200 J
E None of the above

21. An ideal gas at 0 °C is contained within a rigid vessel. The temperature of the gas is increased by 1 °C. What is P_f/P_i, the ratio of the final to initial pressure?

A 273/274
B 274/273
C 1/2
D 1/10
E 1/273

22. Which one of the following properties of a gas is not consistent with kinetic theory?

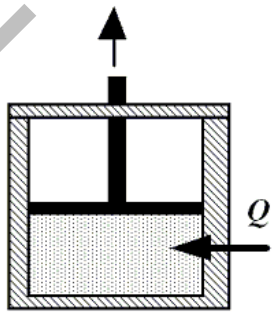
A Gas molecules are widely separated.
B Gases fill whatever space is available to them.
C Gas molecules move rapidly in a random fashion.
D The average speed of the gas molecules is smaller at high temperatures.
E Gas molecules make elastic collisions with the walls of the containing vessel.

23. A bubble with a volume of 1.0 cm^3 forms at the bottom of a lake that is 20.0 m deep. The temperature at the bottom of the lake is 10.0 °C. The bubble rises to the surface where the temperature is 25.0 °C. Assume that the bubble is small enough that its temperature always matches that of its surroundings. What is the volume of the bubble just before it breaks the surface of the water?

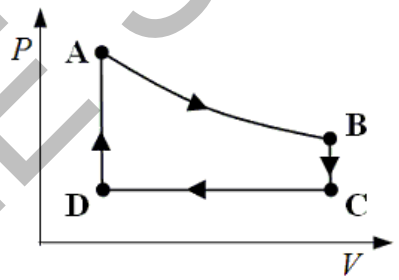
A 2.1 cm^3
B 2.8 cm^3
C 3.1 cm^3
D 6.0 cm^3
E 7.7 cm^3

24. Enclosed beneath the moveable piston in the drawing is 4.8 moles of a monatomic ideal gas. The gas performs work on the piston as 2300 J of heat are added from the surroundings. During the process, the temperature of the gas decreases by 45 K. How much work does the gas perform?

A 1.4 x 10^3 J
B 3.2 x 10^3 J
C 4.4 x 10^3 J
D 5.0 x 10^3 J
E 6.0 x 10^3 J



25. An ideal monatomic gas expands isothermally from state A to state B. The gas then cools at constant volume to state C. The gas is then compressed isobarically to D before it is heated until it returns to state A.



$V_A = V_D = 2$ liters $V_B = V_C = 4$ liters
P_A 10 atm $T_A = 327$ °C
$P_C = 2$ atm

What is the pressure of the gas at point B?

A 5 atm
B 10 atm
C 20 atm
D 25 atm
E 30 atm

26. Two canoes are 10 m apart on a lake. Each bobs up and down with a period of 8.0 seconds. When one canoe is at its highest point, the other canoe is at its lowest point. Both canoes are always within a single cycle of the waves. Determine the speed of the waves.

A 0.65 m/s
B 0.75 m/s
C 1.3 m/s
D 2.5 m/s
E 5.0 m/s

27. A transverse periodic wave described by the expression

$$y = \sin\left[2\pi\left(\frac{x}{2} + \frac{t}{10}\right)\right]$$

(where *y* and *x* are in meters and *t* is in seconds) is established on a string. Which one of the following statements concerning this wave is false?

A The amplitude is 1.0 m.
B The wave travels with speed 5.0 m/s.
C The wavelength of the wave is 2.0 m.
D The frequency of the wave is 0.10 Hz.
E The wave is travelling in the negative *x* direction.

28. Two loudspeakers are located 3.0 m apart on the stage of an auditorium. A listener at point P is seated 19.0 m from one speaker and 15.0 m from the other. A signal generator drives the speakers in phase with the same amplitude and frequency. The wave amplitude at P due to each speaker alone is A. The frequency is then varied between 30 Hz and 400 Hz. The speed of sound is 343 m/s.

At what frequency or frequencies will the listener at P hear a maximum intensity?

A 170 Hz only
B 113 Hz and 226 Hz
C 86 Hz, 170 Hz, 257 Hz and 343 Hz
D 57 Hz, 114 Hz, 171 Hz, 228 Hz, 285 Hz, 342 Hz and 399 Hz
E 43 Hz, 85 Hz, 128 Hz, 170 Hz, 213 Hz, 257 Hz, 298 Hz, 344 Hz and 387 Hz

29. For a diffraction horn loudspeaker, sound emerges through a rectangular opening. The opening of a diffraction horn has a width of 0.12 m. If the speaker emits a continuous tone with a wavelength of 0.09 m, at what angle does the first minimum occur?

A 47°
B 39°
C 23°
D 12°
E 66°

30. When plucked, a 0.62-m guitar string produces a sound wave with a fundamental frequency of 196 Hz. The speed of sound in air is 343 m/s. Determine the ratio of the wavelength of the sound wave to the wavelength of the waves that travel on the string.

A 0.071
B 0.28
C 0.49
D 1.4
E 2.0

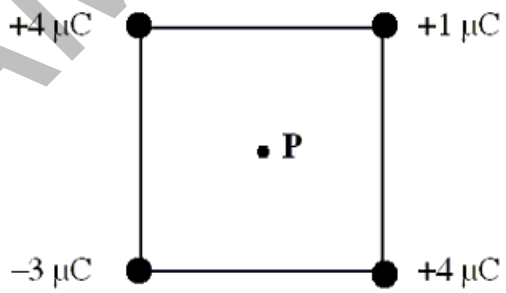
31. When a tuba is played, the player makes a buzzing sound and blows into one end of a tube that has an effective length of 3.50 m. The other end of the tube is open. If the speed of sound in air is 343 m/s, what is the lowest frequency the tuba can produce?

A 8.00 Hz
B 12.0 Hz
C 16.0 Hz
D 24.0 Hz
E 49.0 Hz

32. At which point (or points) is the electric field zero N/C for the two point charges shown on the *x* axis?

A The electric field is never zero in the vicinity of these charges.
B The electric field is zero somewhere on the *x* axis to the left of the +4*q* charge.
C The electric field is zero somewhere on the *x* axis to the right of the –2*q* charge.
D The electric field is zero somewhere on the *x* axis between the two charges, but this point is nearer to the –2*q* charge.
E The electric field is zero at two points along the *x* axis; one such point is to the right of the –2*q* charge and the other is to the left of the +4*q* charge.

33. Four point charges are placed at the corners of a square as shown in the figure. Each side of the square has length 2.0 m. Determine the magnitude of the electric field at the point P, the center of the square.



A 2.0×10^{-6} N/C
B 3.0×10^{-6} N/C
C 9.0×10^{3} N/C
D 1.8×10^{4} N/C
E 2.7×10^{4} N/C

34. Two point charges are held at the corners of a rectangle as shown in the figure. The lengths of sides of the rectangle are 0.050 m and 0.150 m. Assume that the electric potential is defined to be zero at infinity.

What is the electric potential energy of a +3.0 μC charge placed at corner A?

A zero joules
B 3.6 J
C 2.3 J
D 0.10 J
E 0.18 J

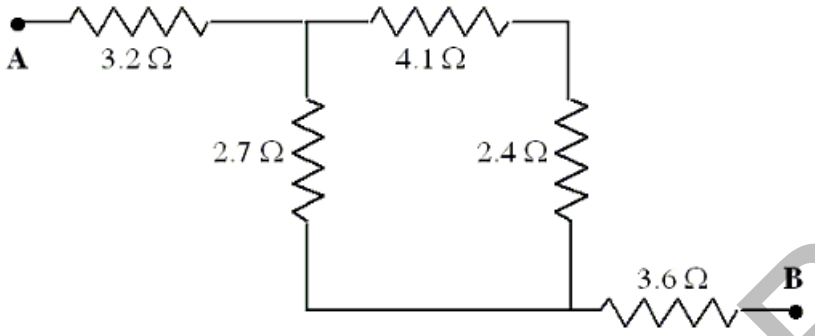
35. A parallel plate capacitor has a potential difference between its plates of 1.6 V and a plate separation distance of 2.5 mm. What is the magnitude of the electric field if a material that has a dielectric constant of 3.4 is inserted between the plates?

A 110 V/m
B 170 V/m
C 190 V/m
D 240 V/m
E 290 V/m

36. A battery is manufactured to have an emf of 24.0 V, but the terminal voltage is only 22.0 V when the battery is connected across a 10.0-Ω resistor. What is the internal resistance of the battery?

A 0.46 Ω
B 0.68 Ω
C 0.91 Ω
D 1.2 Ω
E 3.9 Ω

37. Five resistors are connected as shown in the diagram. The potential difference between points A and B is 15 V.



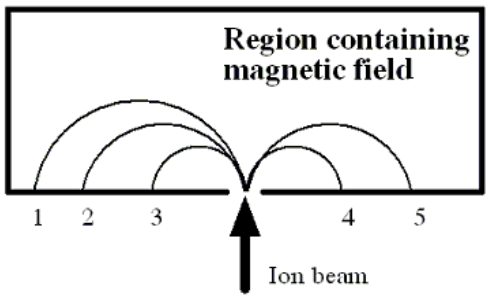
What amount of energy is dissipated in the 2.7-Ω resistor in 9.0 seconds?

A 15 J
B 24 J
C 29 J
D 36 J
E 52 J

38. Three parallel plate capacitors, each having a capacitance of 1.0 μF are connected in parallel. The potential difference across the combination is 100 V. What is the charge on any one of the capacitors?

A 30 μC
B 100 μC
C 300 μC
D 1000 μC
E 3000 μC

39. A beam consisting of five types of ions labeled A, B, C, D, and E enters a region that contains a uniform magnetic field as shown in the figure below. The field is perpendicular to the plane of the paper, but its precise direction is not given. All ions in the beam travel with the same speed. The table below gives the masses and charges of the ions. Note: 1 mass unit = 1.67×10^{-27} kg and $e = 1.6 \times 10^{-19}$ C

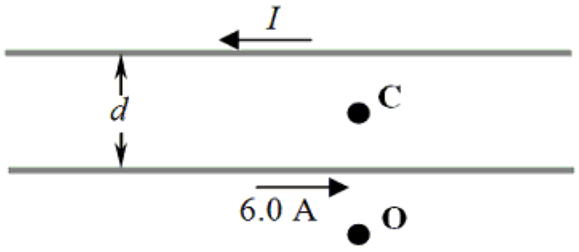


Ion	*Mass*	*Charge*
A	2 units	$+e$
B	4 units	$+e$
C	6 units	$+e$
D	2 units	$-e$
E	4 units	$-e$

Which ion falls at position 2?

A Ion A
B Ion B
C Ion C
D Ion D
E Ion E

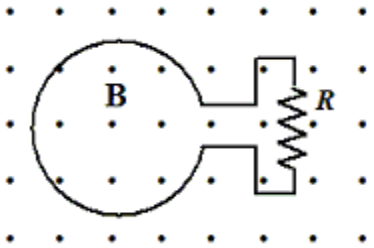
40. Two long, straight, parallel wires separated by a distance d carry currents in opposite directions as shown in the figure. The bottom wire carries a current of 6.0 A. Point C is at the midpoint between the wires and point O is a distance $0.50d$ below the 6-A wire as suggested in the figure. The total magnetic field at point O is zero tesla.



Determine the magnitude of the magnetic field at C if $d = 0.10$ m.

A 2.4×10^{-5} T
B 4.8×10^{-5} T
C 9.6×10^{-5} T
D 1.1×10^{-4} T
E 1.4×10^{-4} T

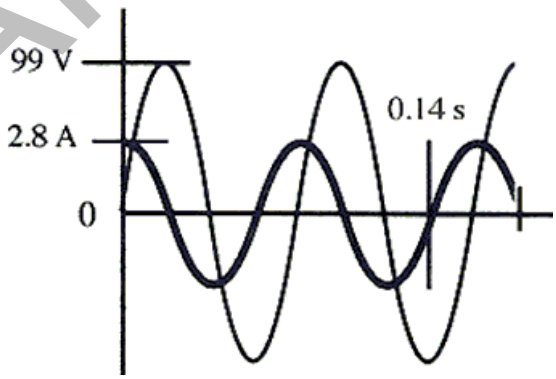
41. The figure shows a uniform, 3.0-T magnetic field that is normal to the plane of a conducting, circular loop with a resistance of 1.5 Ω and a radius of 0.024 m. The magnetic field is directed out of the paper as shown. Note: The area of the non-circular portion of the wire is considered negligible compared to that of the circular loop.



What is the average current around the loop if the magnitude of the magnetic field is doubled in 0.4 s?

A 2.8×10^{-3} A, clockwise
B 4.5×10^{-3} A, clockwise
C 4.5×10^{-3} A, counter-clockwise
D 9.0×10^{-3} A, clockwise
E 9.0×10^{-3} A, counter-clockwise

42. The graph shows the voltage across and the current through a single circuit element connected to an ac generator.



Identify the circuit element.

A The element is a 25-Ω resistor.
B The element is a 35-Ω resistor.
C The element is a 0.45-H inductor.
D The element is a 360-μF capacitor.
E The element is a 510-μF capacitor.

43. An object is placed 20.0 cm in front of a convex spherical mirror with radius of curvature 60.0 cm. Which one of the following phrases best describes the image?

A virtual and located at infinity
B real and located 12 cm from the mirror
C real and located 17 cm from the mirror
D virtual and located 12 cm from the mirror
E virtual and located 17 cm from the mirror

44. A fiber optic line is composed of a core with an index of refraction of 1.51 and cladding with an index of 1.40. Which one of the following relations best describes angles of incidence θ that will result in total internal reflection within the fiber optic line?

A $\theta < 68°$
B $\theta > 68°$
C $\theta < 22°$
D $\theta > 22°$
E $0 \leq \theta \leq 90°$

45. In two separate double slit experiments, an interference pattern is observed on a screen. In the first experiment, violet light (λ = 708 nm) is used and a second-order bright fringe occurs at the same location as a third-order dark fringe in the second experiment. Determine the wavelength of the light used in the second experiment.

A 1320 nm
B 862 nm
C 503 nm
D 431 nm
E 495 nm

46. A laser emits photons of energy 5.0 eV with a power of 10^{-2} W. How many photons are emitted each second?

A 4.0×10^{14}
B 2.7×10^{15}
C 5.0×10^{18}
D 3.1×10^{21}
E 2.5×10^{21}

47. Photons of energy 5.0 eV strike a metal surface that has a work function of 3.5 eV. Determine which one of the following best describes the kinetic energy of the emitted electrons.

A 1.5 eV or less
B 1.5 eV or more, but less than 2.5 eV
C 1.5 eV or more, but less than 3.5 eV
D 3.5 eV or more
E 3.5 eV or less, but more than 1.5 eV

48. What happens to the de Broglie wavelength of an electron if its momentum is reduced to one-half of its initial value?

A The wavelength increases by a factor of 2.
B The wavelength decreases by a factor of 2.
C The wavelength increases by a factor of 4.
D The wavelength decreases by a factor of 2.
E The wavelength increases by a factor of 3.

49. Determine the maximum wavelength of incident radiation that can be used to remove the remaining electron from a singly ionized helium atom He^+ ($Z = 2$). Assume the electron is in its ground state.

A 6.2 nm
B 12.4 nm
C 22.8 nm
D 45.6 nm
E 54.4 nm

50. The half-life of a particular isotope of iodine is 8.0 days. How much of a 10.0-g sample of this isotope will remain after 30 days?

A 0.37 g
B 0.45 g
C 0.60 g
D 0.74 g
E 1.25 g

END OF PAPER