UNIVERSITY ENTRANCE EXAMINATION 2018

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 **NINETEEN** (**19**) 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, $e \approx 1.602 \times 10^{-19}\,\mathrm{C}$

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

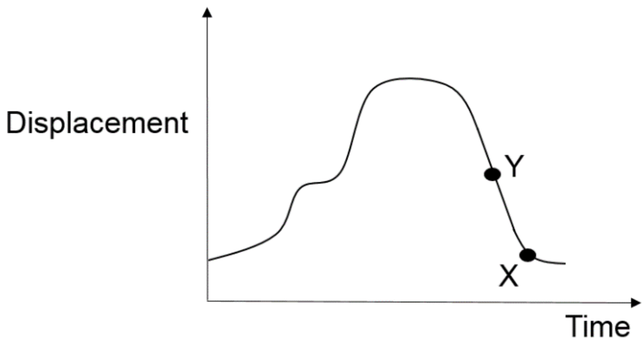
1. A displacement vector with a magnitude of 20 m could have perpendicular components with magnitudes of

- **A** $\sqrt{20}$ m and $\sqrt{20}$ m
- **B** 10 m and 10 m
- **C** 12 m and 16 m
- **D** 12 m and 80 m
- **E** 16 m and 8 m

2. What is the center of gravity of an object?

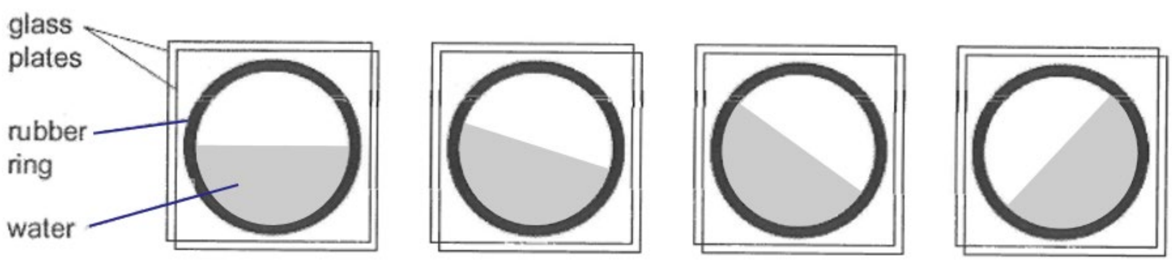
- **A** the geometrical center of the object
- **B** the point about which the total torque is zero
- **C** the point at which the weight of the object may be considered to act
- **D** the point through which gravity acts
- **E** the intersection of the vertical symmetrical line and the horizontal symmetrical line

3. The following graph shows how the horizontal displacement of a car moving on a flat ground changes with time for part of its journey.



An improvised accelerometer, used to measure the acceleration of the car, is made by sandwiching a rubber ring between the two glass plates and introducing some coloured water insider the ring. The accelerometer is subsequently fastened at the door of the car. Diagram **D** corresponds to point X on the graph.

Which diagram shows the angle of water surface in the accelerometer at point Y?



A **B** **C** **D**

E None of the above

4. An object starts from rest and falls freely for 40 m near the surface of a planet. If the time of fall is 4 s, what is the magnitude of the acceleration due to gravity on the planet?

A 0 m/s^2
B 5.0 m/s^2
C 10 m/s^2
D 20 m/s^2
E 40 m/s^2

5. A motorist travelling at 10 ms^{-1} can bring his car to rest in a braking distance of 10 m. In what distance could he bring the car to rest from a speed of 30 ms^{-1} using the same braking force?

A 17 m
B 30 m
C 52 m
D 90 m
E 98 m

6. Newton's third law concerns the forces of interaction between two bodies.

Which of the following statements relating to the third law is **not** correct?

A The two forces must be of the same type.
B The two forces must act on different bodies.
C The two forces are always opposite in direction.
D The two forces are equal and opposite so the bodies are in equilibrium.
E None of the above.

7. In a Formula One race, Sebastian Vettel driving the Ferrari race car has to make a pit-stop to re-fuel the petrol tank. After the re-fueling, he starts from rest with a constant acceleration of 11.0 ms^{-2} and takes 3.5 s to enter the main speedway from the pit area. At the instance Sebastian enters the main speedway, another race car on the speedway, driven by Hamilton, traveling at a constant velocity of 69.4 ms^{-1} passes Sebastian's car.

What is the total time required for Sebastian's car to catch up with Hamilton from the time he completes the re-fueling? Assume that Sebastian maintains a constant acceleration throughout this time.

A 5.62 s
B 9.12 s
C 12.6 s
D 16.1 s
E 18.2 s

8. Two satellites in space collide inelastically. What happens to the kinetic energy and momentum?

	kinetic energy	momentum
A	conserved	conserved
B	conserved	reduced
C	reduced	conserved
D	reduced	reduced
E	reduced	increased

9. A cyclist is riding at a steady speed on a level road.

According to Newton's third law of motion, what is equal and opposite to the backward push of the back wheel on the road?

A the force exerted by the cyclist on the pedals
B the forward push of the road on the back wheel
C the tension in the cycle chain
D the total air resistance and friction force
E the force provided by the break pads on the wheels.

10. What is meant by the weight of an object?

A the gravitational field acting on the object
B the gravitational force acting on the object
C the mass of the object multiplied by gravity
D the object's mass multiplied by its acceleration
E the object's mass multiplied by its velocity

11. A fighter-bomber flies towards a target at a speed of 750 kmh^{-1}. At a height of 500 m above the ground, it releases a 150-kg bomb while diving at an angle of 20° below the horizontal.

How far ahead of the target horizontally must the bomb be released?

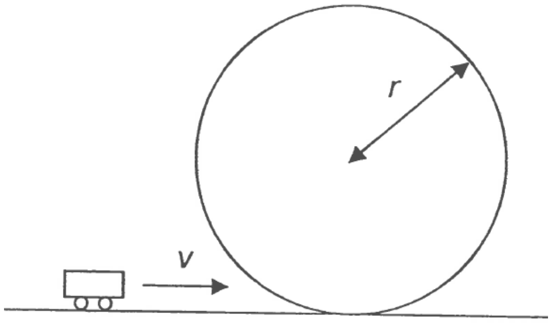
A 173 m **B** 1013 m **C** 3013 m **D** 3813 m **E** 4813 m

12. A projectile will attain its largest height if it is fired at an angle of

A 0°
B 30°
C 45°
D 60°
E 90°

from the horizontal.

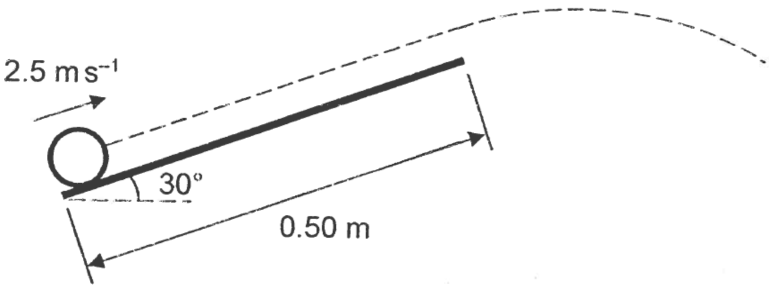
13. A roller coaster of mass *m* moves in a vertical circle of radius *r*. The roller coaster will be up-ide-down when it is at the highest point of the circle.



At what minimum speed *v* must the roller coaster be travelling at the bottom of the circle so that the ride will be safe?

A $\sqrt{rg}$
B $\sqrt{2rg}$
C $\sqrt{3rg}$
D $\sqrt{4rg}$
E $\sqrt{5rg}$

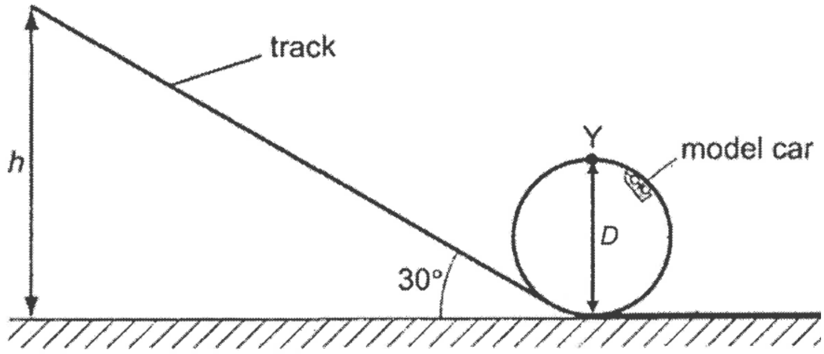
14. A ball of mass 200 g is projected up a smooth inclined plane of length 0.50 m, at an angle 30° above the horizontal, with an initial speed of 2.5 ms^{-1}. The ball subsequently leaves the other end of the plane and proceeds with a projectile motion.



Assuming that the air resistance is negligible, what is the minimum of the kinetic energy for the whole flight?

A 0 J
B 0.10 J
C 0.13 J
D 0.47 J
E 0.62 J

15. A model car is released from rest at a height *h* on a frictionless track.



The car goes around the loop of diameter *D* without dropping from the track.

What is the minimum possible value of the initial height *h* required for the car to remain on the track while going around the loop?

A $\frac{5D}{4}$

B $\frac{3D}{2}$

C $2D$

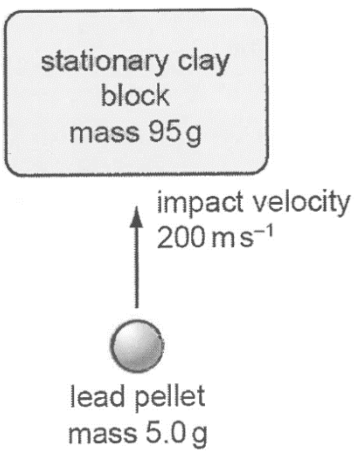
D $\frac{5D}{2}$

E $\frac{5D}{3}$

16. A lead pellet is shot vertically upwards into a clay block that is stationary at the moment of impact but is able to rise freely after the impact.

The pellet hits the block with an initial velocity of 200 ms^{-1}. It embeds itself in the block and does not emerge.

How high above its initial position will the block rise?



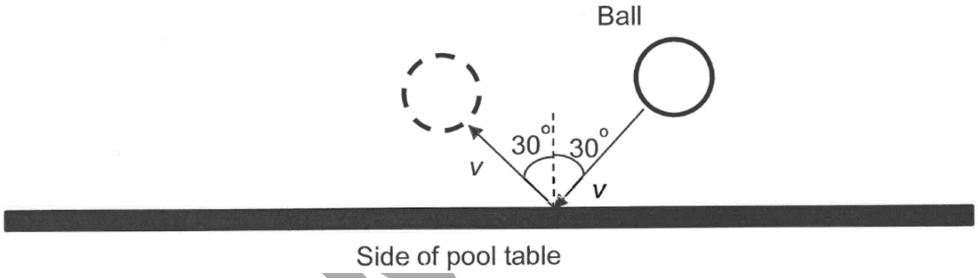
A 5.1 m
B 5.6 m
C 10 m
D 14 m
E 22 m

17. A car mass of 1.2×10^3 kg travels along a horizontal road at a speed of 10 ms^{-1}. It then accelerate at 0.20 ms^{-2}. At the time it begins to accelerate, the total resistive force acting on the car is 160 N.

What total output is developed by the car as it begins the acceleration?

A 0.80 kW
B 1.6 kW
C 2.4 kW
D 4.0 kW
E 5.6 kW

18. A snooker ball of mass *m* travels at a speed *v* towards the side of a snooker table. The ball strikes the side of the table at an angle of 30° as shown. The time of contact between the ball and the side is Δt. What is the expression for the average force acting on the ball?



Plan View

A $\dfrac{mv}{\Delta t}$

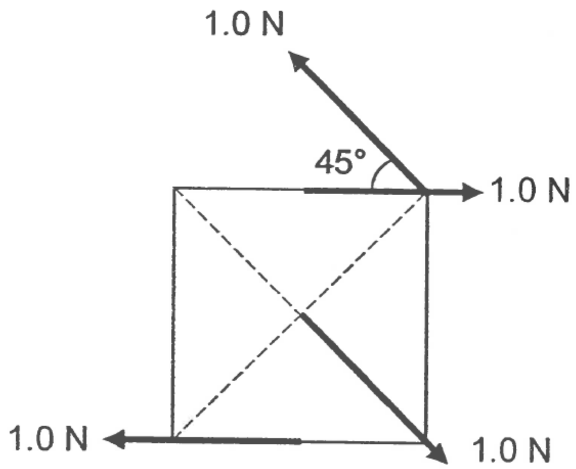
B $\dfrac{mv \times \cos 30^o}{\Delta t}$

C $\dfrac{2mv \times \cos 30^o}{\Delta t}$

D $\dfrac{2mv \times \csc 30^o}{\Delta t}$

E $\dfrac{2mv \times \sin 30^o}{\Delta t}$

19. The figure below shows forces acting on a piece of square cardboard of negligible mass on a horizontal plane. The cardboard has a length of 5.0 cm on each side.



Which of the following statements is possibly true?

A The cardboard is not in equilibrium.
B The cardboard is in rotational equilibrium.
C The cardboard is not in translational equilibrium.
D The cardboard will rotate in an anticlockwise direction.
E The cardboard will undergo linear acceleration.

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 4200 J
D 42000 J
E None of above

21. When the pressure of an ideal gas is increased at constant volume, the average kinetic energy of the gas molecules

A may either increase or decrease, depending on whether or not the process is carried out adiabatically.
B may or may not change, but insufficient information is given to make such a determination.
C does not change.
D increases.
E decreases.

22. One junction X of a thermocouple is placed in melting ice at 273 K and the other junction Y in steam at 373 K. The e.m.f. measured is 2.0 mV. Junction Y is then transferred to a bath at a temperature of 398 K. Assuming that the variation of e.m.f. with temperature difference is linear, the e.m.f., in mV, recorded will now be

A $\frac{746}{273}$
B $\frac{796}{273}$
C $\frac{796}{373}$
D $\frac{25}{50}$
E $\frac{125}{50}$

23. A brass bar and a steel bar, each 0.800 m long, are at a temperature of $20°\text{C}$. Each bar is placed at that temperature between rigid walls 0.800 m apart. The cross-sectional areas for the brass and steel bars are $0.005\,\text{m}^2$ and $0.003\,\text{m}^2$, respectively. The coefficient of linear expansion and Young modulus of the two materials are given in the table below.

	Coefficient of Linear Expansion	Young modulus
Brass	$2.0\times10^{-5}\,\text{K}^{-1}$	$0.90\times10^{11}\,\text{Pa}$
Steel	$1.2\times10^{-5}\,\text{K}^{-1}$	$2.0\times10^{11}\,\text{Pa}$

The temperature is raised until the combined force exerted by the two bars is 1.8 MN. The temperature at which this occurs, in $°\text{C}$, is closest to

A 140
B 130
C 120
D 110
E 100

24. A heat-conducting rod, 1.10 m long, is made of an aluminium section, 0.20 m long, and a copper section, 0.90 m long. Both sections have a cross-sectional area of $0.0004\,\mathrm{m}^2$. The aluminium end and the copper end are maintained at temperatures of $10^\circ\mathrm{C}$ and $250^\circ\mathrm{C}$, respectively. The thermal conductivities of aluminium and copper are $205\,\mathrm{W\,m^{-1}K^{-1}}$ and $385\,\mathrm{W\,m^{-1}K^{-1}}$, respectively. The temperature of the aluminium-copper junction in the rod, in $^\circ\mathrm{C}$, is closest to

A 54
B 59
C 66
D 73
E 81

25. The speed of light in a material is 0.50c. What is the critical angle of a light ray at the interface between the material and a vacuum?

A 21°
B 24°
C 27°
D 30°
E 34°

26. An electromagnetic wave, passing from medium X to medium Y, undergoes a 30% increase in wave speed. If the angle of incidence at the interface of X and Y is 45°, what is the angle of refraction in medium Y?

A 33°
B 35°
C 45°
D 59°
E 67°

27. Three flat layers of transparent material are stacked upon one another. The top layer has index of refraction n_1, the middle n_2 and the bottom one n_3. If $n_1 > n_2 > n_3$, and a ray of light in air strikes the top layer, at which surface given can total internal reflection occur first?

A the top surface
B the surface between materials with indices n_1 and n_2
C the surface between materials with indices n_2 and n_3
D the bottom surface
E Total internal reflection cannot occur at any of these surfaces.

28. A convex lens has a focal length *f*. An object is placed between infinity and 2*f* from the lens along a line perpendicular to the center of the lens. The image is located at what distance from the lens?

A farther than *2f*
B *2f*
C *f*
D between *f* and *2f*
E between the lens and *f*

29. Parallel water waves of wave length 20 m strike a straight sea wall. The wavefronts make an angle 30° with the wall. What is the difference in phases between the waves at two points 10 m apart along the wall?

A 30°
B 45°
C 90°
D 180°
E None of the above.

30. Two narrow slits, 0.30 mm apart, are illuminated by a beam of light of wavelength 700 nm. An interference pattern is observed on a screen normal to the beam and 3.0 m from the slits. The distance in mm between adjacent dark lines on the screen is

A 1.0
B 3.0
C 5.0
D 7.0
E 9.0

31. Light of wavelength 420 nm is incident on a diffraction grating of 3.8×10^5 lines per metre. Which one of the following is the highest diffraction order which can be observed?

A 2
B 3
C 4
D 5
E 6

32. The least distance between two points of a progressive transverse wave which have a phase difference of $2\pi/3$ rad is 0.050 m. If the frequency of the wave is 500 Hz, what is the speed of the wave?

A 24 m/s
B 25 m/s
C 75 m/s
D 150 m/s
E 300 m/s

33. Two conducting spheres *A* and *B*, of radii r_A and r_B, carry charges $+Q_A$ and $+Q_B$ respectively. The centres of the spheres are a distance *d* apart with *d* slightly greater than $r_A + r_B$. Which of the following statements about the electrostatic forces *F* between the spheres is true?

A $F < \dfrac{Q_A Q_B}{4\pi\varepsilon_0 d^2}$

B $F = \dfrac{Q_A Q_B}{4\pi\varepsilon_0 d^2}$

C $F > \dfrac{Q_A Q_B}{4\pi\varepsilon_0 d^2}$

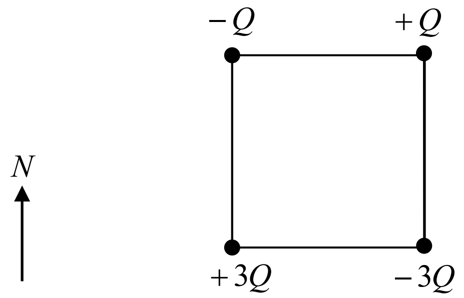
D $F = \dfrac{Q_A Q_B}{4\pi\varepsilon_0 (d + r_A + r_B)^2}$

E $F < \dfrac{Q_A Q_B}{4\pi\varepsilon_0 (d + r_A + r_B)^2}$

34. The electrostatic potential at a distance of 150 mm from an isolated point charge, in vacuum, is 6.0×10^4 V. The electric field, in V/m, at the same point is

A 1.6×10^6
B 2.7×10^6
C 4.0×10^2
D 4.0×10^5
E 9.0×10^4

35. Four point charges are arranged at the corners of a square of length 3 m as shown.



The electric field at the centre of the square is

A $\dfrac{2Q}{9\pi\varepsilon_0}$ to the East

B $\dfrac{2Q}{9\pi\varepsilon_0}$ to the West

C $\dfrac{\sqrt{2}Q}{9\pi\varepsilon_0}$ to the East

D $\dfrac{\sqrt{2}Q}{9\pi\varepsilon_0}$ to the West

E 0

36. An electron is emitted from an electron gun with a speed of $3.0\times10^6\ \text{m/s}$. It moves towards a metal grid which is positioned at 10.0 cm away from the gun. The grid is maintained at a potential of $-20\ \text{V}$ with respect to the electron gun. What is the speed of the electron as it reaches the grid?

A $1.4\times10^6\ \text{m/s}$

B $2.3\times10^6\ \text{m/s}$

C $3.0\times10^6\ \text{m/s}$

D $3.5\times10^6\ \text{m/s}$

E $4.0\times10^6\ \text{m/s}$

37. A $4.0\ \mu\text{F}$ capacitor has a potential difference of 5.0 V applied across its plates. If the potential difference across its plates is increased to 8.0 V, how much additional energy does the capacitor store?

A $36\ \mu\text{J}$

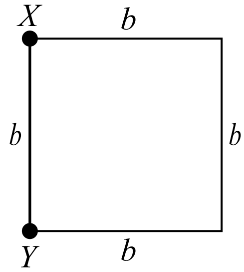
B $50\ \mu\text{J}$

C $78\ \mu\text{J}$

D $130\ \mu\text{J}$

E $160\ \mu J$

38. Wire of resistivity ρ and cross-sectional area A is formed into a square of side b, as shown below.



The resistance between two vertices of the square, X and Y, is

A $\frac{3}{4}\frac{\rho b}{A}$

B $4\frac{\rho b}{A}$

C $\frac{\rho b}{A}$

D $4\frac{A}{\rho b}$

E $\frac{4}{3}\frac{A}{\rho b}$

39. The battery is disconnected from a series RC circuit after the capacitor is fully charged and is replaced by an open switch. When the switch is closed,

A the capacitor does not allow current to pass.
B the current stops in the resistor.
C the potential difference across the resistor is always greater than the potential difference across the capacitor.
D the potential difference across the resistor is always less than the potential difference across the capacitor.
E the potential difference across the resistor is always equal to the potential difference across the capacitor.

40. In defining the ampere it is said that the force per metre between two thin, infinitely long parallel straight wires in vacuum one metre apart, is 2×10^{-7} N/m when the current in each wire is 1 A. The force per metre, in N/m, when the wires each carry currents of 3 A and are 2 m apart is

A 1.8×10^{-6}
B 2.0×10^{-7}
C 2.3×10^{-7}
D 4.5×10^{-7}

E 9×10^{-7}

41. A neutral sub-atomic particle is at rest in a uniform magnetic field of magnitude *B*. It splits into two particles each of mass *m*, one of which has a positive charge $+Q$. The particles then move with velocities perpendicular to the magnetic field. After what time will the particles collide?

A $\frac{5m\pi}{2QB}$

B $\frac{2m\pi}{QB}$

C $\frac{3m\pi}{2QB}$

D $\frac{m\pi}{QB}$

E $\frac{m\pi}{2QB}$

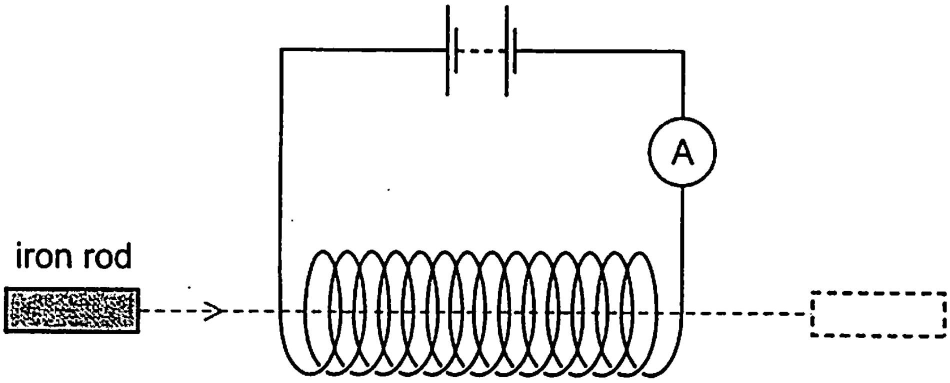
42. A flat search coil containing 100 turns each of area $2.0\times10^{-2}\ \mathrm{m}^2$ is connected to a galvanometer. The total resistance of the circuit is $50\,\Omega$. The coil is placed such that its plane is normal to a magnetic field of magnitude 0.25 T. What is the quantity of charge induced when the coil is turned over through an angle of 90°?

A 0 C
B $2.0\times10^{-4}\mathrm{C}$
C 0.010 C
D 0.020 C
E 0.040 C

43. A circular loop of wire is placed in a uniform magnetic field of 1.2 T that is normal to the plane of the loop. The loop shrinks from a radius of 0.20 m to a radius of 0.10 m in 0.050 s, at a rate which generates a steady electro-motive force (emf). The induced emf is

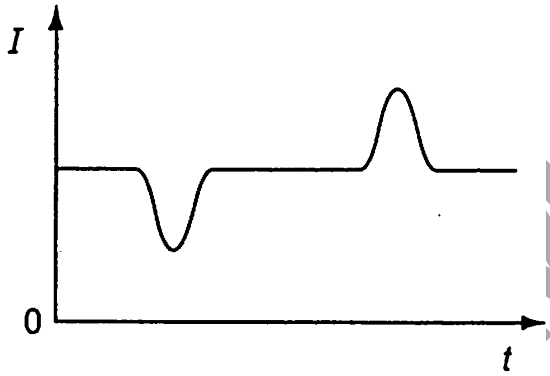
A 0 V
B 0.75 V
C 1.1 V
D 2.3 V
E 3.0 V

44. A solenoid with a large number of turns of wire is connected in series with an ammeter and a battery.

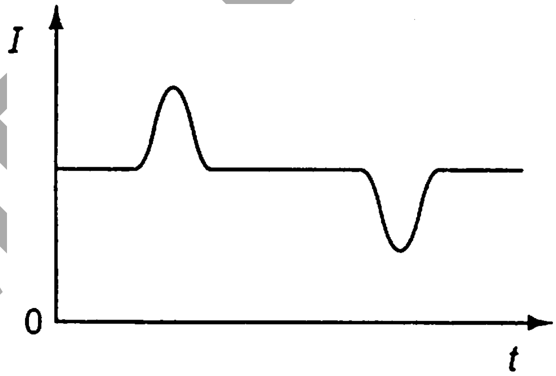


An iron rod is passed through the solenoid at constant speed. Which graph shows the variation with time t of the reading I of the ammeter?

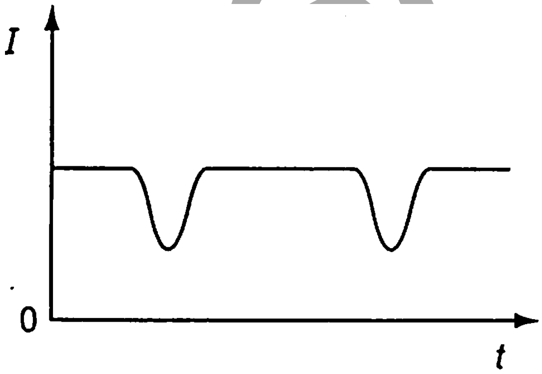
A



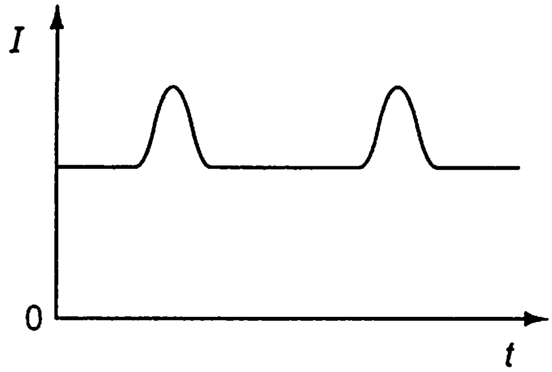
B



C

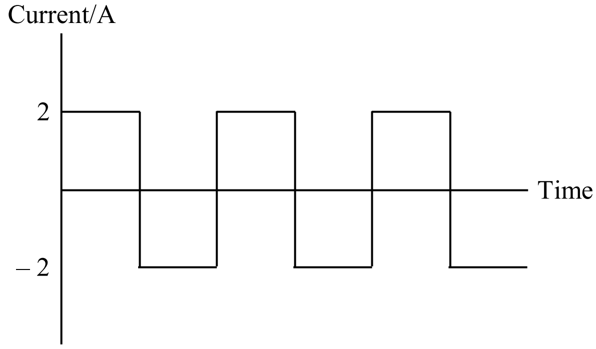


D



E None of the above.

45. The graph shows a rectangular waveform with a peak current of 2 A.



To give the same root-mean-square current as the waveform shown, a sinusoidal current of the same frequency will have a peak value of

A $\sqrt{2}$ A
B $2\sqrt{2}$ A
C $3\sqrt{2}$ A
D 2 A
E 4 A

46. A sinusoidal current of peak value I_0 passes through a resistor *R* with a diode connected in series with it. The average rate of heat dissipated in *R* is

A $I_0^2 R$
B $0.25 I_0^2 R$
C $0.35 I_0^2 R$
D $0.50 I_0^2 R$
E $0.71 I_0^2 R$

47. In a nuclear reaction, energy equivalent to 10^{-10} kg of matter is released. The energy released is approximately

A 4.5×10^{-5} J
B 9.0×10^{-5} J
C 3.0×10^{-5} J
D 4.5×10^{6} J
E 9.0×10^{6} J

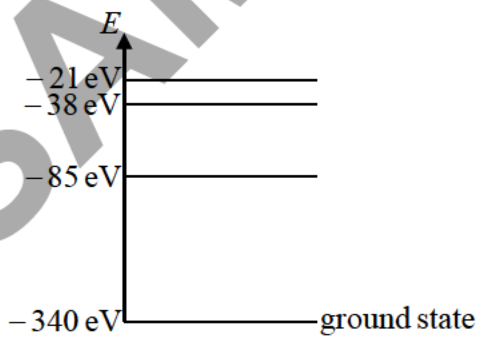
48. In a photoelectric experiment, one photoelectron is ejected from the metal for every 10 photons incident. Given that the photocurrent is $2.5\ \mu A$ and the frequency of the source is $6.0 \times 10^{14}\,Hz$, determine the power of the source in watt.

A 6.2×10^{-4}
B 6.2×10^{-5}
C 6.2×10^{-6}
D 6.3×10^{-11}
E 4.0×10^{-18}

49. Alice shone a beam of monochromatic light of wavelength 580 nm that is totally absorbed at normal incidence by an object. The light exerts a force of $2.50 \times 10^{-20}\,N$ on the object. What is the number of photons hitting the object per second?

A 5.5×10^{6}
B 1.1×10^{7}
C 2.2×10^{7}
D 4.4×10^{7}
E 2.8×10^{8}

50. The diagram below (not drawn to scale) gives the first few electron energy levels within a single-electron atom.



Which of the following gives the energy of a photon that could NOT be emitted by this atom during an electron transition?

A 17 eV
B 22 eV
C 64 eV
D 255 eV
E 302 eV

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