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 **TWENTY** (**20**) 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, $u \approx 1.661 \times 10^{-27}\,\mathrm{kg}$

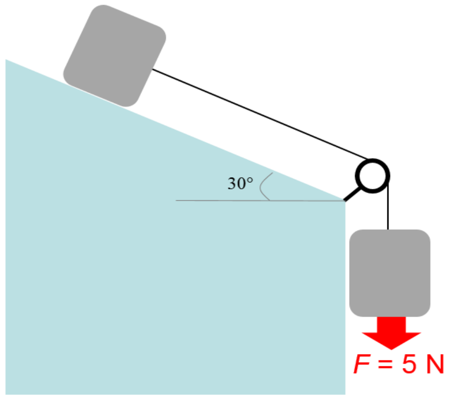
1. The initial velocity of a projectile is 10 ms^{-1} parallel to the ground. Its final velocity before hitting the ground is 15 ms^{-1} at an angle of 20° from the ground. What is the change in velocity?

A 3.6 ms^{-1}
B 5.1 ms^{-1}
C 6.6 $m\ s^{-1}$
D 14.9 $m\ s^{-1}$
E 18.2 ms^{-1}

2. A student throws a ball weighing 5N with a velocity of 10 m/s straight up. What is the net force on the ball when it has reached its highest position?

A 0 N
B 5 N, up
C 5 N, down
D 9.8 N, down
E 9.8 N, up

3. If two blocks are identical and each of them has a mass of 2 kg, and the inclined plane is at 30° from the horizontal, what is the acceleration of the block on the slope if 5 N of force is applied in the downward direction on the lower block as shown in the figure? Assume that pulley and all surfaces are frictionless, and the pulley and the string have negligible mass.

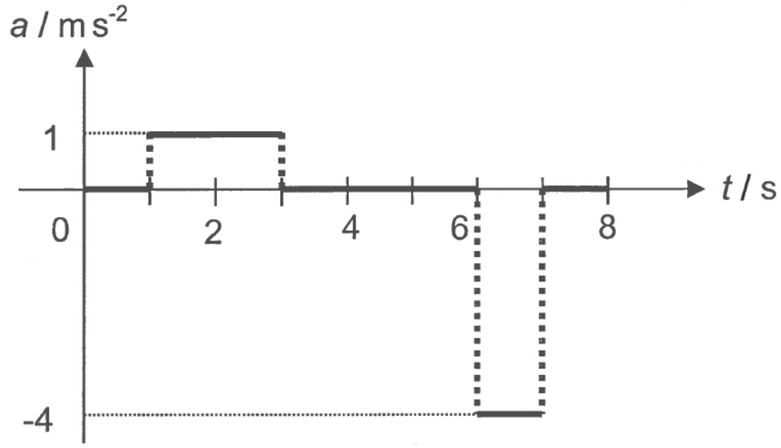


A 4.6 m/s^2
B 5.2 m/s^2
C 7.8 m/s^2
D 8.6 m/s^2
E 12.4 m/s^2

4. What gives the value of a body's acceleration?

A the area under its displacement-time graph
B the area under its velocity-time graph
C the gradient of its displacement-time graph
D the gradient of its velocity-time graph
E the area of its momentum-time graph

5. An object, initially at rest, moves along a straight line path. The graph below shows the variation of its acceleration, *a*, with time, *t*.



What is the total displacement of the object until $t = 8.0$ s?

A 2 m
B 3 m
C 6 m
D 11 m
E 14 m

6. A stationary ^{238}U nucleus decays by α emission generating a total kinetic energy *T*.

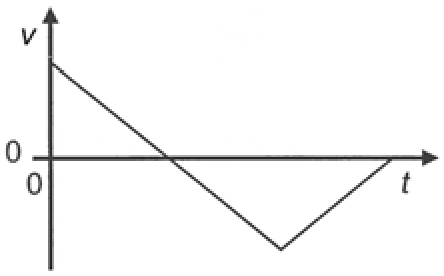
$$^{238}_{92}\mathrm{U} \rightarrow \, ^{234}_{90}\mathrm{Th} + \, ^{4}_{2}\alpha$$

What is the kinetic energy of the α-particle?

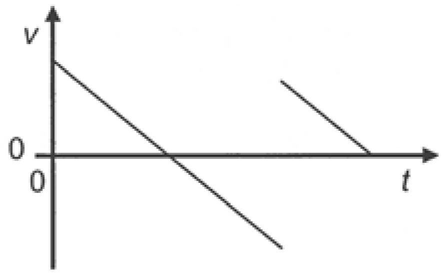
A slightly less than *T* / 2
B *T* / 2
C slightly less than *T*
D slightly greater than *T*
E *T* / 4

7. A tennis ball is thrown vertically upwards from the ground level. It rises before falling towards the ground and bounces up again.

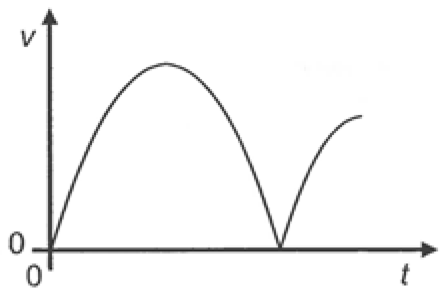
Which of the following graphs best represents the variation of velocity *v* with respect to time *t?*



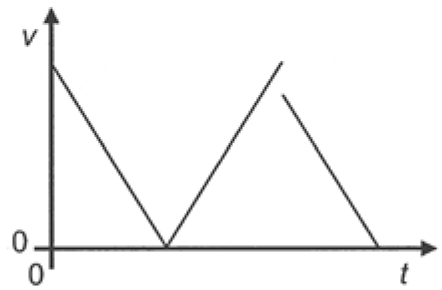
A



B



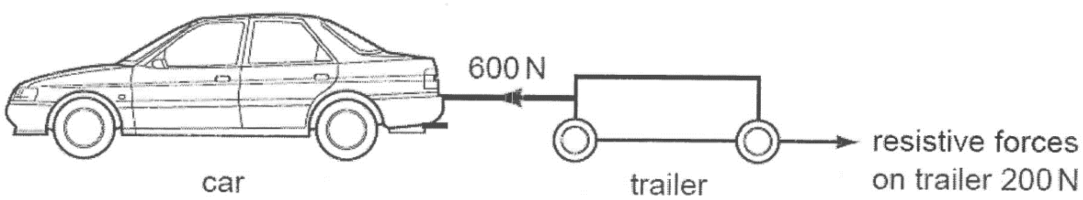
C



D

E None of the all above

8. A trailer of mass 400 kg is pulled by a car of mass 1200 kg. The diagram shows the horizontal forces acting on the trailer.



What is the net force acting on the car?

A 400 N
B 600 N
C 1200 N
D 1800 N
E 2200 N

9. A raindrop of mass *m* is falling vertically through the air with a steady speed *v*. It experiences a retarding force *kv* due to the air, where *k* is a constant. Given that the acceleration of free fall is *g*. Which of the following expressions gives the kinetic energy of the raindrop?

A $\frac{mg}{k}$

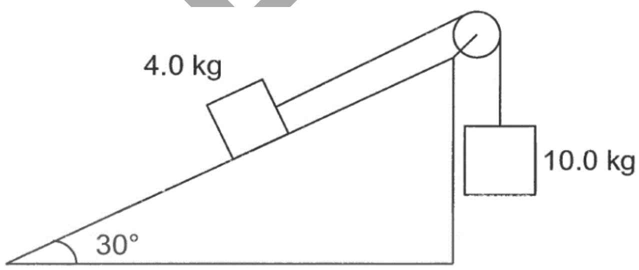
B $\frac{mg^2}{2k^2}$

C $\frac{m^3g^2}{2k^2}$

D $\frac{m^3g^2}{k^2}$

E $\frac{m^3g^2}{2k}$

10. In the figure the frictional force between the 4.0 kg mass and the inclined plane is 2.0 N.



If the distance moved by the 10.0 kg mass is 0.15 m, what is the speed gained by the 4.0 kg mass?

A 1.15 ms-1
B 1.28 ms^{-1}
C 1.64 ms^{-1}
D 1.72 ms^{-1}
E 2.14 ms^{-1}

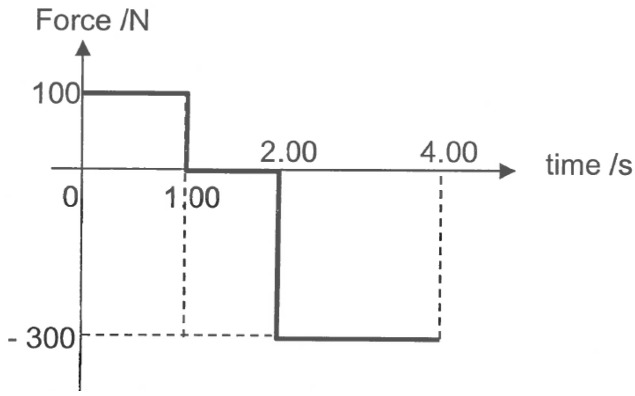
11. An electric motor is required to haul a cage of mass 400 kg up a mine shaft at constant speed through a vertical height of 1200 m in 2.0 minutes.

Given that the overall efficiency of the motor is 80%, what is the total power wasted?

(Efficiency = $\frac{\text{Actual Output}}{\text{Original Input}}$, where Actual Output = Original Input – Wastage)

A 7.8 kW
B 9.8 kW
C 39 kW
D 49 kW
E 58 kW

12. An object, initially moving with a velocity 92.0 ms^{-1}, experiences a force which varies with time as shown.



If the object has a mass of 8.50 kg, what is the final velocity of the object after 4.00 s?

A 174.12 ms^{-1}
B 163.23 ms^{-1}
C 33.18 ms^{-1}
D -33.18 ms^{-1}
E -151.44 ms^{-1}

13. A neutron is in head-on elastic collision with a stationary nitrogen nucleus. The mass of a nitrogen nucleus is 14 times of a neutron.

The neutron's velocity after collision is

A less in magnitude than its initial velocity.
B less in magnitude than the final velocity of the nitrogen atom.
C equal in magnitude to its initial velocity but in the opposite direction.
D greater in magnitude than its initial velocity.
E none of the above

14. In perfectly elastic collisions between two atoms, it is always true to say that

A the initial speed of one atom will be the same as the final speed of the other atom.
B the relative speed of approach between two atoms equals their relative speed of separation.
C the total momentum must be conserved, but a small amount of the total kinetic energy may be lost in the collision.
D whatever their initial state of motion, neither atom can be stationary after the collision.
E none of the above

15. A particle of mass *m* travelling with velocity *u* collides elastically and head-on with a stationary particle of mass *M*.

Which expression gives the velocity of the particle of mass *M* after the collision?

A u

B $\frac{mu}{M}$

C $\frac{2mu}{M+m}$

D $\frac{(M-m)u}{M+m}$

E $\frac{(M+m)u}{M-m}$

16. Given a directional vector AB, a particle of mass *m* is travelling with a velocity *v* in the direction of AB. At a later time, the velocity of the particle is observed to have the same magnitude but in the opposite direction of AB. What is the change of momentum that has taken place for the particle in the time interval?

A *mv* in the direction of AB
B *mv* in the direction of BA
C 2*mv* in the direction of AB
D 2*mv* in the direction of BA
E none of the above

17. Two people are on a ride where the inside cars rotate at constant angular velocity three times the constant angular velocity of the outer cars. If the two cars meet each other for the first time at $t = 0$, and rotating at 3ω and ω respectively, at what time will they meet each other for the 4th time?

A $t=\frac{\pi}{2\omega}$

B $t=\frac{\pi}{\omega}$

C $t=\frac{2\pi}{\omega}$

D $t=\frac{3\pi}{\omega}$

E $t=\frac{4\pi}{\omega}$

18. The hydrostatic pressure p at a depth h in a liquid of density ρ is given by the formula $p = h\rho g$.

Which equation, or principle of physics, is used in the derivation of this formula?

A density = mass ÷ volume
B potential energy = mgh
C atmospheric pressure decreases with height
D density increases with depth
E impulse = change in momentum

19. A crate is pushed 10 m along a horizontal surface by a force of 80 N. The frictional force opposing the motion is 60 N.

What are the correct values for the increasing in internal energy of the system and the additional kinetic energy of the crate?

	increase in internal energy/J	**additional kinetic energy/J**
A	200	600
B	200	800
C	600	200
D	600	800
E	600	400

20. If a cup of tea at 50 °C is allowed to cool to room temperature, heat released would be (assume room temperature to be equal to 25 °C and heat capacity of cup and tea to be = 5.0 kJ / K)

A 25 kJ
B 50 kJ
C 125 kJ
D 250 kJ
E 300 kJ

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

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

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 $\frac{125}{50}$
E $\frac{25}{50}$

23. A brass bar and a steel bar, each 0.800 m long, are at a temperature of $20^{\circ}\mathrm{C}$. 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 $0.005\,\mathrm{m}^2$ and $0.003\,\mathrm{m}^2$, 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	$2.0\times10^{-5}\,\mathrm{K}^{-1}$	$0.90\times10^{11}\,\mathrm{Pa}$
Steel	$1.2\times10^{-5}\,\mathrm{K}^{-1}$	$2.0\times10^{11}\,\mathrm{Pa}$

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

A 100
B 110
C 120
D 130
E 140

24. What is the critical angle for light traveling from crown glass (n = 1.52) into water (n = 1.33)?

A 57°
B 61°
C 42°
D 48°
E 53°

25. A heat-conducting rod, 1.10 m long, is made of an aluminum 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 aluminum end and the copper end are maintained at temperatures of $10^\circ\mathrm{C}$ and $250^\circ\mathrm{C}$, respectively. The thermal conductivities of aluminum and copper are $205\,\mathrm{W\,m^{-1}K^{-1}}$ and $385\,\mathrm{W\,m^{-1}K^{-1}}$, respectively. The temperature of the aluminum-copper junction in the rod, in $^\circ\mathrm{C}$, is closest to

A 81
B 73
C 66
D 59
E 54

26. An electromagnetic wave, passing from medium X to medium Y, undergoes a 30% decrease 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 30°
B 33°
C 45°
D 57°
E 60°

27. Three flat layers of transparent material are stacked upon one another. The top layer has index of refraction n_1, the middle has n_2 and the bottom one has n_3. If $n_1 < n_2 < n_3$, at what angle of incidence will a ray of light traverse the three layers in a single straight line?

A $\theta_i = \sin^{-1}(1/n_1)$
B $\theta_i = \sin^{-1}\left(1/(n_1+n_2+n_3)\right)$
C $\theta_i = \tan^{-1}(n_1+n_2+n_3)$
D There is no such an angle.
E There is such an angle, but it is not given.

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 10 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 5 m apart along the wall?

A 30°
B 45°
C 90°
D 156°
E 180°

30. Two narrow slits, 0.30 mm apart, are illuminated by a beam of light of wavelength 600 nm. An interference pattern is observed on a screen normal to the beam and 0.50 m from the slits. The distance in mm between adjacent dark lines on the screen is

A 0.25
B 0.30
C 0.50
D 1.0
E 2.0

31. Light of wavelength 620 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 $\pi/3$ 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 $F > \dfrac{Q_A Q_B}{4\pi\varepsilon_0 d^2}$

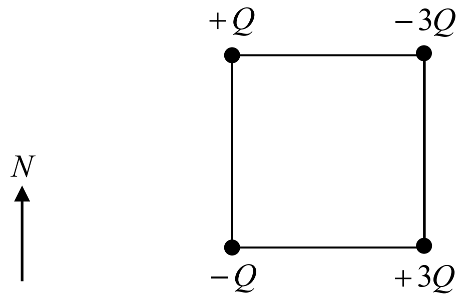
D $F = \dfrac{Q_A Q_B}{4\pi\varepsilon_0 (d - r_A - r_B)^2}$

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 0

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

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

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

E $\dfrac{2Q}{9\pi\varepsilon_0}$ to the South

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 $2.0\ \mu\text{F}$ 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 $89\ \mu\text{J}$

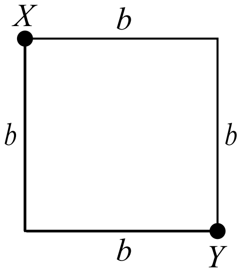
B $78\ \mu\text{J}$

C $64\ \mu\text{J}$

D $39\ \mu\text{J}$

E $25\ \mu\text{J}$

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

40. 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 $-2Q$. 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 $\frac{m\pi}{2QB}$

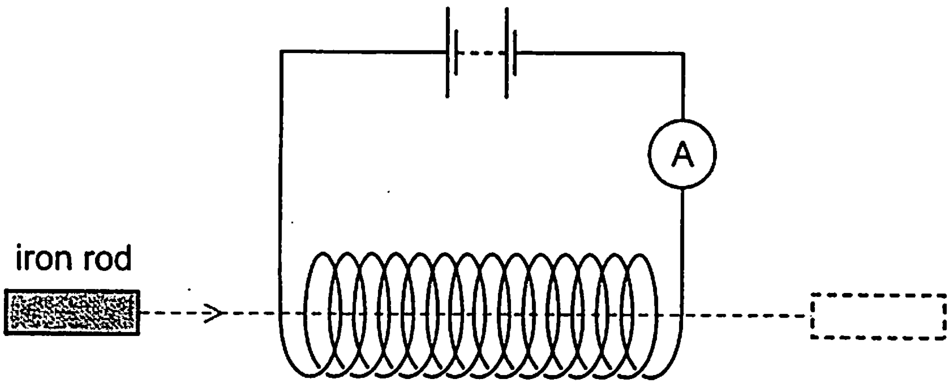
41. In defining the ampere it is said that the force per metre between two thin, infinitely long parallel straight wires in vacuum one metre apart, is $2\times10^{-7}\ \mathrm{N/m}$ when the current in each wire is 1 A. The force per metre, in N/m, when the wires each carry currents of 1 A and are 2 m apart is

A 5.0×10^{-8}
B 1.0×10^{-7}
C 2.0×10^{-7}
D 4.0×10^{-7}
E 8.0×10^{-7}

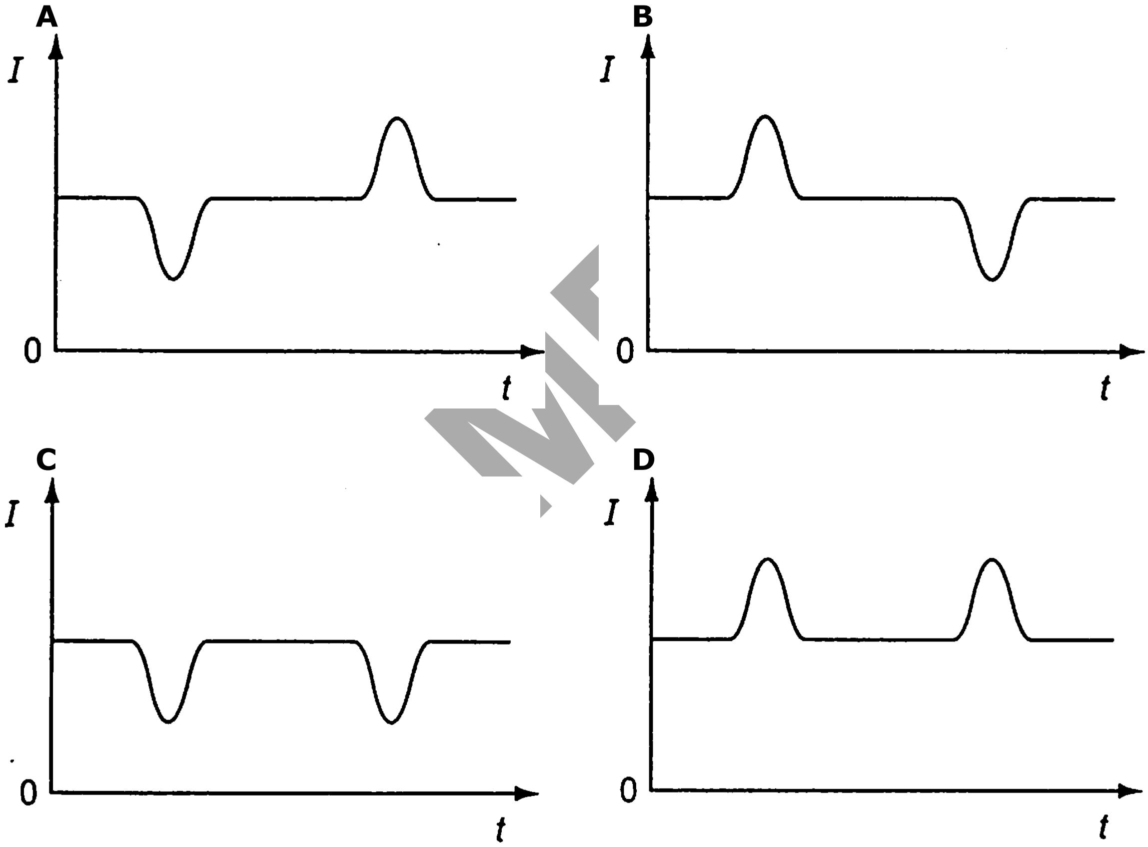
42. A circular loop of wire is placed in a uniform magnetic field of 1.2 T that is normal to the plane of the loop. The loop shrinks from a radius of 0.40 m to a radius of 0.20 m in 0.050 s, at a rate which generates a steady electromotive force (emf). The induced emf is

A 0 V
B 3.0 V
C 9.0 V
D 12.0 V
E 18.0 V

43. 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?

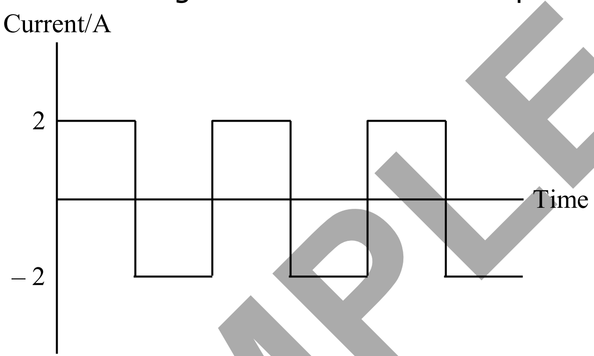


E None of the above.

44. A flat search coil containing 100 turns each of area $2.0 \times 10^{-2}\ \text{m}^2$ 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 $30°$?

A 0 C
B 0.0013 C
C 0.0050 C
D 0.010 C
E 0.020 C

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 4 A
B 2 A
C $3\sqrt{2}$ A
D $2\sqrt{2}$ A
E $\sqrt{2}$ 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 $0.71 I_0^2 R$
B $0.50 I_0^2 R$
C $0.35 I_0^2 R$
D $0.25 I_0^2 R$
E $I_0^2 R$

47. In a nuclear reaction, energy equivalent to 10^{-11} kg of matter is released. The energy released is approximately

A 4.5×10^{-6} J
B 9.0×10^{-6} J
C 3.0×10^{-3} J
D 4.5×10^{6} J
E 9.0×10^{5} J

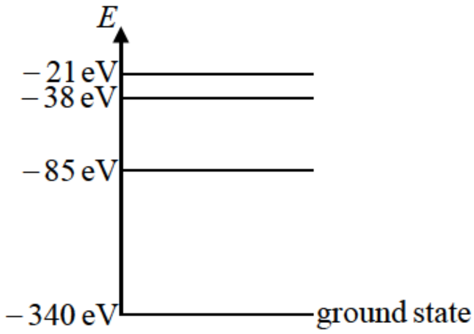
48. In a photoelectric experiment, one photoelectron is ejected from the metal for every 5 photons incident. Given that the photocurrent is $2.5\ \mu A$ and the frequency of the source is $6.0 \times 10^{14}\ Hz$, determine the power of the source in watt.

A 1.2×10^{-6}
B 2.0×10^{-18}
C 3.1×10^{-5}
D 6.2×10^{-4}
E 6.2×10^{-5}

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 $1.25 \times 10^{-20}\ N$ 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 302 eV
B 255 eV
C 64 eV
D 32 eV
E 17 eV

END OF PAPER