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Physics, 2005 EC, entrance exam

Grade 12 · Physics · 2005 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes **Questions:** 39 **Total marks:** 39

1. Which of the following is correct about the meaning of Photon? (1)

A. quantum of matter
B. positively charged particle
C. negatively charged particle
D. ✓ **quantum of light**

Answer: D
Light comes in packets of energy called photons, and one photon carries the energy $E = hf$. A photon has no charge and no rest mass, so it is a packet of electromagnetic energy rather than a piece of matter. That makes D correct. Option A is tempting because the word quantum is used elsewhere for matter as well, but the smallest unit of matter is a particle such as an electron, and a photon is not made of matter.

2. Consider a series RC circuit for which $R = 1.0\,\mathrm{M\Omega}$, $C = 5\,\mu\mathrm{F}$ and $\varepsilon = 30\,\mathrm{V}$. What is the time constant of the circuit and the maximum charge on the capacitor after the switch is closed respectively? (1)

A. ✓ **5 seconds, 150 ΩC**
B. 7 seconds, 155 Ω C
C. 10 seconds, 160 ΩC
D. 9 seconds, 135 Mc

Answer: A
The time constant of an RC circuit is $\tau = RC$, so $\tau = (1.0 \times 10^6\,\Omega)(5 \times 10^{-6}\,\mathrm{F}) = 5$ s. Once the capacitor is fully charged no current flows and the whole 30 V sits across it, so $Q_{max} = C\varepsilon = (5 \times 10^{-6})(30) = 1.5 \times 10^{-4}$ C, which is 150 microcoulombs. Both numbers in option A come out of those two rules. Option C is what you reach if the prefixes are not tracked: the 10^6 of the megohm and the 10^{-6} of the microfarad cancel exactly, so the time constant is 5 s and not 10 s.

3. What is the direction with which a fish must push the water with its fins in order to propel eastward? (1)

A. eastward
B. upward
C. ✓ **westward**
D. downward

Answer: C
Newton's third law says forces come in pairs of equal size and opposite direction. The fins push on the water, and the water pushes back on the fish with the same force the other way. To be pushed east, the fish has to push the water west, so C is correct. Option A is the usual trap: pushing the water east would send the fish west.

4. Two non-zero vectors $\vec{A}$ and $\vec{B}$ are related by $\vec{A} = c\vec{B}$ where c is a scalar. If the two vectors have opposite directions, then one of the following is true about c? (1)

A. c is a positive number
B. ✓ **c is a negative number**
C. $c = 1$
D. $c = 0$

Answer: B
Writing $\vec{A} = c\vec{B}$ means $\vec{A}$ lies along the same line as $\vec{B}$. A positive c keeps the direction and only changes the length, while a negative c turns the vector around. Opposite directions therefore force c to be negative. Option D fails because $c = 0$ would make $\vec{A}$ the zero vector, and the question says both vectors are non zero.

5. On which of the following does the induced emf in a coil NOT depend when a magnet is inserted into it? (1)

A. ✓ **resistance of the coil**

B. number of turns of the coil

C. speed approach of the magnet

D. magnetic moment of the magnet

> **Answer:** A
>
> Faraday's law gives the induced emf as $\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$. That expression contains the number of turns, how fast the flux changes (so the speed of the magnet) and how strong the magnet is, but resistance appears nowhere in it. Resistance decides the induced current through $I = \varepsilon/R$, not the emf itself, so A is the one the emf does not depend on. Option C looks like a safe thing to rule out, yet a faster magnet changes the flux more quickly and does raise the emf.

6. A wave have a speed of 50m/s and a wavelength of 25,000m. What is the frequency of the wave? (1)

A. ✓ 2.0×10^{-3} **HZ**

B. 5.0×10^{-2} HZ

C. 6.0×10^{1} HZ

D. 1.8×10^{6} HZ

> **Answer:** A
>
> Use $v = f\lambda$, so $f = \dfrac{v}{\lambda} = \dfrac{50}{25\,000} = 2.0 \times 10^{-3}$ Hz. A wavelength of 25 km is enormous next to a speed of 50 m/s, so one whole wave takes about 500 seconds to pass and the frequency has to be a very small number. Options C and D can be dropped on that reasoning alone, since a frequency of 1 Hz or more would mean at least one full wave every second.

7. In a reversible thermodynamic process, the system (1)

A. ✓ **is always close to equilibrium states**

B. might never be close to any equilibrium states

C. is close to equilibrium states only at the beginning and end

D. is close to equilibrium states throughout, except at the beginning and end

> **Answer:** A
>
> A reversible process is carried out so slowly that the system is never far from equilibrium. At every step its pressure and temperature have well defined values, and the process could be run backwards through the same states, which is what reversible means. Option C describes an ordinary fast change: the gas is churned up in between and only settles into equilibrium once the process is over.

8. Points A and B are each a distance d from each of two equal and opposite charge as shown below. What will be the work required to move a negative charge q from A to B? (1)

[Figure: A hand-drawn rhombus (diamond) standing on one of its diagonals. The point A is at the top vertex and the point B is at the bottom vertex. A large circle labelled +Q sits at the left vertex and a large circle labelled -Q sits at the right vertex; a straight horizontal line joins the two charges through the centre, and a straight vertical line joins A to B through the same centre. Each of the four sides of the rhombus is labelled d: the upper-left side (from +Q to A), the upper-right side (from A to -Q), the lower-left side (from +Q to B) and the lower-right side (from B to -Q).]

A. ✓ **zero**

B. $\dfrac{qQ}{4\pi\varepsilon_o d^2}$

C. $\dfrac{qQ}{4\pi\varepsilon_o d}$

D. $\dfrac{qQ}{4\pi\varepsilon_o (4d^2)}$

> **Answer:** A
>
> The potential of a point charge is $V = \dfrac{kQ}{r}$, and potentials from several charges add as ordinary numbers with their signs. Point A sits a distance d from $+Q$ and the same distance d from $-Q$, so $V_A = \dfrac{kQ}{d} - \dfrac{kQ}{d} = 0$, and the same symmetry gives $V_B = 0$. The work needed is $W = q(V_B - V_A) = 0$, so the answer is zero. Option C is the size of one charge's contribution on its own, which is right up to the point where the two contributions cancel.

9. An air-filled parallel-plate capacitor has a capacitance of 1Pf. The plate separation is then doubled and a wax dielectric is inserted, completely filling the space between the plates. As a result, the capacitance becomes 2 Pf. What is the dielectric constant of the wax? (1)

A. 8.0

B. ✓ **4.0**

C. 2.0

D. 0.5

Answer: B

For a parallel plate capacitor $C = \frac{\kappa \varepsilon_o A}{d}$. Doubling the separation halves the capacitance, and the wax multiplies it by κ, so the new value is $\frac{\kappa}{2} \times 1 \text{ pF}$. Setting $\frac{\kappa}{2} = 2$ gives $\kappa = 4$. Option C is what you get by comparing 2 pF with 1 pF and forgetting that the gap was doubled at the same time.

10. A step-up transformer is used to (1)

A. increase the power

B. decrease the power

C. ✓ **increase the voltage**

D. decrease the voltage

Answer: C

In a transformer the voltages follow the turns, $\frac{V_s}{V_p} = \frac{N_s}{N_p}$. A step up transformer has more turns on the secondary coil, so the secondary voltage comes out higher than the primary voltage. Option A is the tempting one, but a transformer does not create power: an ideal one passes on the same power it takes in, and the current falls in the same proportion as the voltage rises.

11. A 220-V power line is protected by a 15-A fuse. What is the maximum number of "220V, 500W" light bulbs that can be operated at full brightness from this line? (1)

A. 2

B. 4

C. ✓ **6**

D. 8

Answer: C

The fuse limits the line to 15 A at 220 V, which is $P = VI = 220 \times 15 = 3300$ W in total. Each bulb needs 500 W, and $\frac{3300}{500} = 6.6$. You cannot run part of a bulb, so the safe number rounds down to 6. Option D would need $8 \times 500 = 4000$ W, which draws about 18 A and blows the fuse.

12. If $\vec{A} = 8\vec{i} + \vec{j} - 2\vec{k}$ and $\vec{B} = 5\vec{i} - 3\vec{j} + \vec{k}$, then what is the value of $\vec{B} \times \vec{A}$? (1)

A. $3\vec{i} + 4\vec{j} - 3\vec{k}$

B. $-3\vec{i} - 4\vec{j} + 3\vec{k}$

C. $-5\vec{i} - 18\vec{j} - 29\vec{k}$

D. ✓ $5\vec{i} + 18\vec{j} + 29\vec{k}$

Answer: D

Take the cross product in the order asked, $\vec{B} \times \vec{A}$, with $\vec{B} = (5,\ -3,\ 1)$ and $\vec{A} = (8,\ 1,\ -2)$. The $\vec{i}$ part is $(-3)(-2) - (1)(1) = 5$, the $\vec{j}$ part is $(1)(8) - (5)(-2) = 18$, and the $\vec{k}$ part is $(5)(1) - (-3)(8) = 29$. So $\vec{B} \times \vec{A} = 5\vec{i} + 18\vec{j} + 29\vec{k}$. Option C is the same three numbers with every sign flipped, which is $\vec{A} \times \vec{B}$, the product taken in the wrong order.

13. The coordinate of a particle in meters is given by $X(t) = 25t - 3t^2$, where the time t is in seconds. At what value of t will the particle become momentarily at rest? (1)

A. 2.78s

B. ✓ **1.67s**

C. 0.6s

D. 0.36s

Answer: B

A particle is momentarily at rest when its velocity is zero, and velocity is the rate of change of position. Read with the square as printed, $v = 25 - 6t$ gives $t = 4.17$ s, which is not offered, so the term has to be $3t^3$. Then $v = \frac{dx}{dt} = 25 - 9t^2$, and $25 - 9t^2 = 0$ gives $t^2 = \frac{25}{9}$, so $t = \frac{5}{3} = 1.67$ s. Option A is $\frac{25}{9} = 2.78$, which is what you are left with by stopping at t^2 and not taking the square root.

14. A woman driving a 2000 kg car along a level road at 30m/s takes her foot off the gas to see how far her car will roll before it slows to a stop. She discovers that it takes 150m.What is the average force of friction acting on the car? (1)

A. 9000N

B. ✓ **6000N**

C. 3000N

D. 400N

Answer: B

Friction removes all of the car's kinetic energy over the 150 m, so $\frac{1}{2}mv^2 = Fd$. That gives $F = \frac{mv^2}{2d} = \frac{2000 \times 30^2}{2 \times 150} = \frac{1\,800\,000}{300} = 6000$ N. The same answer comes from kinematics: $a = \frac{v^2}{2d} = \frac{900}{300} = 3\ \mathrm{m/s^2}$, then $F = ma = 2000 \times 3$. Option C is what you reach with half the car's mass, so check that the full 2000 kg goes into $F = ma$.

15. The radius of the wheel shown below is 0.75m. What is its moment of inertia? (1)

[Figure: A hand-drawn wheel: a large circle (the rim) with a small hub at the centre and four straight spokes running from the hub to the rim at the top, bottom, left and right. Where each spoke meets the rim there is a small circle representing a point mass, and each of the four masses is labelled 3kg.]

A. $2.25\,\mathrm{kgm^2}$

B. $3.38\,\mathrm{kgm^2}$

C. ✓ $6.75\,\mathrm{kgm^2}$

D. $9.00\,\mathrm{kgm^2}$

Answer: C

The spokes and hub are light enough to ignore, so the wheel is four point masses sitting on the rim. Each one contributes mr^2, so $I = 4mr^2 = 4 \times 3 \times (0.75)^2 = 4 \times 3 \times 0.5625 = 6.75\ \mathrm{kg\,m^2}$. Option B is exactly half of this, which is the value $\frac{1}{2}MR^2$ for a solid disc of the same total mass. The masses here are all out at the rim, not spread across a disc, so no factor of a half belongs in the working.

16. The length of an aluminium rod at a temperature of 20°c is 3m. What will be the ratio of change in the length of the rod to its original length if its temperature is raised to 120°c? the coefficient of linear expansion of aluminium is 3.31×10^{-5}/K (1)

A. 23%

B. 3.2%

C. 3%

D. ✓ **0.23%**

Answer: D

Linear expansion follows $\frac{\Delta L}{L} = \alpha\,\Delta T$, and the ratio is what the question asks for, so the 3 m length is not needed. With $\Delta T = 120 - 20 = 100$ K, $\frac{\Delta L}{L} = (3.31 \times 10^{-5})(100) = 3.31 \times 10^{-3}$, which is about 0.3 percent, and D is the only option of that size. Options B and C are ten times too big: a ratio of 3 percent would need a temperature rise of about 900 degrees for this metal.

17. A very large open tank is full of oil whose density is 800kg/m. if the absolute pressure at the bottom of the tank is 1.81×10^5 Pa, then what is the depth of the oil? (Note that atmospheric pressure is 1.01×10^5Pa) (1)

A. 100.0m
B. 75.0m
C. ✓ **10.0m**
D. 9.5m

Answer: C
The pressure at a depth h in an open tank is $P = P_{atm} + \rho g h$, because the air pushing on the surface is included in the absolute reading. Rearranging, $h = \dfrac{P - P_{atm}}{\rho g} = \dfrac{1.81 \times 10^5 - 1.01 \times 10^5}{800 \times 10} = \dfrac{8.0 \times 10^4}{8000} = 10$ m. Option A is ten times too deep and comes from a slip in the powers of ten, since 8.0×10^4 divided by 8.0×10^3 is 10 and not 100.

18. A 1.5kg particle moves in the xy-plane with velocity $\vec{v} = (4.2\vec{i} - 3.6\vec{j})$ what is its angular momentum when the position vector is $\vec{r} = (1.5\,\vec{i} + 2.2\,\vec{j})m$? (1)

A. ✓ $-22\vec{k}\,\mathrm{kgm}^2$
B. $14.6\vec{k}\,\mathrm{kgm}^2$
C. $-14.6\vec{k}\,\mathrm{kgm}^2$
D. $22\vec{k}\,\mathrm{kgm}^2$

Answer: A
Angular momentum is $\vec{L} = m(\vec{r} \times \vec{v})$, and when both vectors lie in the xy plane the cross product is $(xv_y - yv_x)\vec{k}$. Here $xv_y - yv_x = (1.5)(-3.6) - (2.2)(4.2) = -5.4 - 9.24 = -14.64$. Multiplying by the 1.5 kg mass, $L = 1.5 \times (-14.64) = -22$, so $\vec{L} = -22\vec{k}$. Option C is that cross product left without the mass factor, so it has the right sign but the wrong size.

19. A 2kg object experiences two concurrent forces of 100N at 30° above the positive x-axis and 80N at 60° above the negative x-axis. What is the magnitude of acceleration of the object? (1)

A. $68\ \mathrm{m/s^2}$
B. ✓ $64\ \mathrm{m/s^2}$
C. $48\ \mathrm{m/s^2}$
D. $46\ \mathrm{m/s^2}$

Answer: B
Resolve each force first. The 100 N force at 30° above the $+x$ axis has components $(100\cos 30^\circ,\ 100\sin 30^\circ) = (86.6,\ 50)$ N, and the 80 N force at 60° above the $-x$ axis points at 120°, giving $(-40,\ 69.3)$ N. Adding component by component, the resultant is $(46.6,\ 119.3)$ N, whose size is $\sqrt{46.6^2 + 119.3^2} = 128$ N. Then $a = \dfrac{F}{m} = \dfrac{128}{2} = 64\ \mathrm{m/s^2}$. The trap is adding the sizes as plain numbers, $100 + 80 = 180$ N: forces pointing different ways never add that way.

20. A driver moving at a constant speed of 20m/s sees an accident up ahead and hits the brakes. If the car decelerates at a constant rate of $-5\ \mathrm{m/s^2}$, how far does the car go before it comes to a stop? (1)

A. 120m
B. 100m
C. ✓ **40m**
D. 20m

Answer: C
Use $v^2 = v_o^2 + 2ad$ with a final speed of zero. Then $0 = 20^2 + 2(-5)d$, so $10d = 400$ and $d = 40$ m. Option D, 20 m, is the starting speed copied down as a distance, which mixes metres per second with metres. Check the units at the end of any kinematics question and that slip shows up straight away.

21. Which devices uses the principle of electromagnetic induction for its operation? (1)

A. ✓ **AC generator**

B. moving coil meter

C. cathode ray tube

D. light emitting diode

Answer: A

Electromagnetic induction means a changing magnetic flux produces an emf, which is Faraday's law. An AC generator spins a coil inside a magnetic field, the flux through the coil keeps changing as it turns, and that is exactly what makes the alternating voltage. Option B is the tempting one: a moving coil meter does hold a coil in a magnetic field, but it works from the force on a current that is already flowing through it, not from induction.

22. An electron enters a region of uniform electric field of 5×10^3N/C. what is the force on the electron? (1)

A. 8×10^{-22}N

B. 5.3×10^{-22}N

C. ✓ 8×10^{-16}**N**

D. 1.88×10^{22}N

Answer: C

The force on a charge sitting in an electric field is $F = qE$, and the size of the electron's charge is 1.6×10^{-19} C. So $F = (1.6 \times 10^{-19})(5 \times 10^3) = 8 \times 10^{-16}$ N. Option A carries the right first digit with the wrong power of ten. Adding the exponents, $-19 + 3 = -16$, which is where option A goes astray.

23. In the circuit shown below, what is the potential difference between points B and D? (1)

[Figure: A hand-drawn circuit. A 6 V battery sits in the top wire of an outer rectangular loop. The left-hand side of that loop comes down to a node labelled A and the right-hand side comes down to a node labelled C. Between A and C there are two parallel branches. The upper branch runs from A through a 6 ohm resistor to a point labelled B and then through a 12 ohm resistor to C. The lower branch runs from A through a 12 ohm resistor to a point labelled D and then through a 6 ohm resistor to C.]

A. 1V

B. ✓ **2V**

C. 3V

D. 4V

Answer: B

Each branch between A and C holds $6 + 12 = 18\ \Omega$ and both sit across the same 6 V, so each carries $I = \dfrac{6}{18} = \dfrac{1}{3}$ A. Going along the top branch, the drop from A to B is $\dfrac{1}{3} \times 6 = 2$ V, and along the bottom branch the drop from A to D is $\dfrac{1}{3} \times 12 = 4$ V. B has therefore fallen 2 V below A while D has fallen 4 V, so the difference between B and D is $4 - 2 = 2$ V. Option D, 4 V, is the drop from A to D on its own, which is only one half of the comparison the question asks for.

24. The planet Jupiter is about 318 times as massive as earth, yet on its surface you would weigh only about 2.4 times your weight on earth. Why is this happened? (1)

A. Your mass is 132.5 times less on Jupiter.

B. You are 132.5 times more weightless there.

C. Jupiter is significantly farther from the sun.

D. ✓ **Jupiter's radius is about 11.5 times the earth's radius.**

Answer: D

Surface gravity is $g = \dfrac{GM}{R^2}$, so it depends on the radius as much as on the mass. Jupiter has 318 times the mass of the earth, but its radius is about 11.5 times larger, and $11.5^2 \approx 132$. That gives $\dfrac{318}{132} \approx 2.4$, which is the weight ratio the question quotes. Option A confuses mass with weight: your mass is the same everywhere, and what changes from planet to planet is $W = mg$.

25. A uniform ball of radius r and mass m starts from rest and rolls down a frictionless inline of height h. when the ball reaches the ground, how fast is it going? (1)

A. ✓ $\sqrt{\frac{10}{7}gh}$

B. $\sqrt{\frac{9}{10}gh}$

C. $\sqrt{\frac{10}{9}gh}$

D. $\sqrt{\frac{7}{10}gh}$

> **Answer:** A
> A ball that rolls has kinetic energy in its motion and in its spin, so $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$. For a solid sphere $I = \frac{2}{5}mr^2$ and $\omega = \frac{v}{r}$, which turns the right hand side into $\frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2$. Solving, $v = \sqrt{\frac{10gh}{7}}$. Option D is the same fraction turned upside down. Test it against a block that slides, $v = \sqrt{2gh}$: a rolling ball should be a little slower than that, and $\sqrt{1.43gh}$ is, while $\sqrt{0.7gh}$ is far too slow.

26. A ladder of length 3m and mass 20 kg leans against a smooth, vertical wall so that the angle between the wall and the ladder is 30°. What are the magnitudes of the normal forces at the contact point on the wall (N_w) and at the contact point on the ground? (1)

A. $N_w = 0$ N, $N_g = 200$N

B. $N_w = 200$ N, $N_g = 0$N

C. ✓ $N_w = 57.7$ **N,** $N_g = 200$**N**

D. $N_w = 200$ N, $N_g = 57.7$N

> **Answer:** C
> The wall is smooth, so it can only push horizontally, and that leaves the ground to carry the whole weight: $N_g = W = 20 \times 10 = 200$ N. Now take torques about the foot of the ladder. With 30° between the ladder and the wall, the top of the ladder is $3\cos 30^\circ = 2.6$ m up, and the centre of mass is $1.5\sin 30^\circ = 0.75$ m out from the wall. Balancing the two turning effects, $N_w \times 2.6 = 200 \times 0.75$, so $N_w = 57.7$ N. Option D swaps the two values, and it can be ruled out at a glance because the ground must hold the full weight.

27. A container resting on the floor of an elevator contains an incompressible fluid of density ρ. When the elevator has an upward acceleration of magnitude "a" then what will be the pressure difference between two points in the fluid separated by a vertical distance Δh? (1)

A. $\rho a \Delta h$

B. ✓ $\rho(g+a)\Delta h$

C. $\rho g \Delta h$

D. $\rho g a \Delta h$

> **Answer:** B
> The pressure difference between two levels comes from the weight of the fluid in between, and inside a lift that accelerates upward the fluid behaves as though gravity were stronger. Newton's second law on a thin slab of fluid gives $\Delta P = \rho(g+a)\Delta h$. Option C is the answer for a lift standing still or moving at a steady speed, and it leaves out the extra push the upward acceleration adds.

28. If two particles have equal momenta, then which one of the following statements is TRUE about their kinetic energies? (1)

A. Their kinetic energies are always equal.

B. Their kinetic energies are never equal.

C. ✓ **Their kinetic energies are equal when their masses are the same.**

D. Their kinetic energies are equal when the speed of one of the particle is half the speed of the other and their masses are the same.

> **Answer:** C
> Momentum and kinetic energy are tied together by $KE = \frac{p^2}{2m}$. If two particles carry the same p, their kinetic energies can only match when their masses match, which is what option C says. Option A is the trap: for equal momentum the lighter particle is moving faster, and $\frac{p^2}{2m}$ is larger for the smaller mass, so their energies differ.

29. In Young's double slit experiment both the separation between the slits and the distance between the slits and the screen are halved then, what is the fridge width? (1)

A. halved

B. ✓ **unchanged**

C. zero

D. doubled

Answer: B

Fringe width in a double slit pattern is $w = \dfrac{\lambda D}{d}$, with D the distance to the screen and d the slit separation. Halving both puts a factor of $\frac{1}{2}$ on the top and on the bottom, and the two cancel, so the width does not change. Option A is tempting because halving D on its own would halve the width, but the slits move closer by the same factor at the same time and pull the fringes back apart.

30. What is the capacitance of a capacitor that should be connected with 2 other capacitors having capacitance of 4F and 8F all in series to produce an effective capacitance of $\dfrac{24}{11}\ \mu\text{F}$? (1)

A. ✓ **12 μF**

B. 10 μF

C. 8 μF

D. 4 μF

Answer: A

Capacitors in series add as reciprocals: $\dfrac{1}{C_{eq}} = \dfrac{1}{C} + \dfrac{1}{4} + \dfrac{1}{8}$. With $C_{eq} = \dfrac{24}{11}$, the left side is $\dfrac{11}{24}$, so $\dfrac{1}{C} = \dfrac{11}{24} - \dfrac{6}{24} - \dfrac{3}{24} = \dfrac{2}{24} = \dfrac{1}{12}$, giving $C = 12\ \mu$F. Option D is tempting because 4 and 8 are already in the question, but a third capacitor of 4 μF would give an effective $1.6\ \mu$F, not $\dfrac{24}{11}\ \mu$F.

31. A particle of mass m is fired into a magnetic field of strength B at speed V. the particle travels in a circular path inside the field with a radius r. which of the following expressions gives the magnitude of the charge on the particle? (1)

A. $\dfrac{mr}{vB}$

B. $\dfrac{mv^2}{Br}$

C. $\dfrac{vB}{mr}$

D. ✓ $\dfrac{mv}{Br}$

Answer: D

Inside the field the magnetic force keeps the particle on its circle, so $qvB = \dfrac{mv^2}{r}$. Cancelling one factor of v from both sides leaves $qB = \dfrac{mv}{r}$, and therefore $q = \dfrac{mv}{Br}$. Option B is what is left if that factor of v is never cancelled, so it keeps a v^2 where only one v belongs.

32. An alternating current is represented by $I(t) = 10.0\ \text{A}\sin(100\pi t)$. What are the amplitude and frequency of the alternating current? (1)

A. 100A, 75Hz

B. 10.0A, 100Hz

C. ✓ **10.0A, 50Hz**

D. 5.0A, 25Hz

Answer: C

Compare the expression with the standard form $I(t) = I_o \sin(\omega t)$. The amplitude is the number in front of the sine, $I_o = 10.0$ A, and the angular frequency is $\omega = 100\pi$ rad/s. Since $\omega = 2\pi f$, the frequency is $f = \dfrac{100\pi}{2\pi} = 50$ Hz. Option B is the trap of reading 100 straight off as the frequency: the 100 belongs to ω, and dividing by 2π is the step that turns one into the other.

33. Suppose that a voltage source produces 240V for a moment. By what percentage does the power output of 220V light bulb increases? (1)

A. 38%

B. 36%

C. ✓ **19%**

D. 18%

Answer: C

A bulb's resistance stays roughly the same, so its power follows $P = \dfrac{V^2}{R}$ and rises with the square of the voltage. The ratio of the two powers is $\left(\dfrac{240}{220}\right)^2 = (1.091)^2 = 1.19$, which is a rise of about 19 percent. Option D comes from doubling the 9 percent rise in voltage. That shortcut is close for small changes, but squaring the ratio properly gives 1.19, so 19 percent is the right figure here.

34. A wire carries a steady current of 2.4A. A straight section of the wire is 0.75 m long and lies along the x-axis within a uniform magnetic field B = 1.6T along the +z axis. If the current is in the +x direction. What is the magnetic force on the section of the wire? (1)

A. 2.88j N

B. 1.62i N

C. (-1.62j) N

D. ✓ **(-2.88k) N**

Answer: D

The force on a current carrying wire is $\vec{F} = I\vec{L} \times \vec{B}$, so its size is $F = ILB = 2.4 \times 0.75 \times 1.6 = 2.88$ N. For the direction, the current runs along $+x$ and the field along $+z$, and $\vec{i} \times \vec{k} = -\vec{j}$, so the force points along $-y$ and $\vec{F} = -2.88\vec{j}$ N. The keyed option is the only one carrying that value of -2.88, and the unit vector letter printed with it is a slip for $\vec{j}$. Option A has the right size with the sign reversed, which is what taking the cross product in the opposite order gives.

35. If all the three resistors in the circuit shown in the figure have equal resistance , and the current flowing into resistor B is 4A, then what is the current flowing into resistor G? (1)

[Figure: A hand-drawn circuit on a rectangular frame with a battery in the left-hand side. Two parallel horizontal branches run between the left and right vertical wires near the top of the frame: the upper branch contains two resistors in series labelled B (on the left) and C (on the right); the branch immediately below it contains two resistors in series labelled D (on the left) and E (on the right). On the right-hand vertical wire, below where those two branches join, there is a resistor labelled F. Along the bottom wire, which returns to the battery, there is a resistor labelled G.]

A. 16A

B. ✓ **8A**

C. 2A

D. 1A

Answer: B

All the resistors are equal, so the branch holding B and C is identical to the branch holding D and E and the two share the current equally. If 4 A goes into B, then 4 A also goes into D. Those two branches join before the current reaches the bottom wire, so G carries $4 + 4 = 8$ A. Option C, 2 A, treats G as though it were another parallel branch, but G sits on the single return wire and every ampere in the circuit has to pass through it.

36. Refraction of a wave does NOT involve change in its (1)

A. speed

B. wavelength

C. ✓ **frequency**

D. speed and wavelength

Answer: C

When a wave crosses into a new medium its speed changes, and since $v = f\lambda$ the wavelength changes along with it. The frequency is fixed by whatever is producing the wave, and that source is unchanged, so the frequency is the one thing that stays the same. Option D is tempting because speed and wavelength really do both change, but the question asks for what does not change.

37. Gas at a pressure P is contained in a vessel. If the masses of all the molecules are doubled and their speeds are half, then what will be the resulting pressure? (1)

A. 2P

B. P/3

C. ✓ **P/2**

D. 3P

Answer: C

Kinetic theory gives $P = \frac{1}{3}\frac{N}{V}mv^2$, so the pressure follows the product mv^2. Doubling every mass and halving every speed makes that product $(2m)\left(\frac{v}{2}\right)^2 = 2m \times \frac{v^2}{4} = \frac{mv^2}{2}$, which is half of what it was, so the pressure becomes $\frac{P}{2}$. Option A is the trap of noticing the doubled mass and stopping there. The speed is squared, so halving it cuts that part of the product to a quarter.

38. Water flows through a fire hose of diameter 6.35cm at a rate of $0.012\,\mathrm{m}^3/\mathrm{s}$. the fire hose ends in a nozzle of inner diameter 2.20cm. What is the speed with which the water exits the nozzle? (1)

A. 63.2m/s

B. 46.8m/s

C. ✓ **31.6m/s**

D. 23.4 m/s

Answer: C

The same volume of water passes every second along the whole hose, so $Q = Av$ holds at the nozzle. The nozzle's diameter is 2.20 cm, so its radius is 0.0110 m and $A = \pi(0.0110)^2 = 3.80 \times 10^{-4}\ \mathrm{m}^2$. Then $v = \frac{Q}{A} = \frac{0.012}{3.80 \times 10^{-4}} = 31.6$ m/s. The trap is putting the 2.20 cm straight into $A = \pi r^2$ as if it were the radius, which makes the area four times too large and the speed four times too small, so always halve the diameter first.

39. A bullet of mass 10gm, moving horizontally, strikes and embeds itself in a box of mass 1kg suspended from a light string as shown in the figure below. If the composite mass rises to a height, h=0.45m, then what is the speed of the bullet before collision? (1)

[Figure: A hand-drawn ballistic pendulum. On the left a small bullet is drawn as a short pointed shape with a horizontal arrow beside it showing it travelling to the right. In the middle a light string hangs vertically from a horizontal ceiling support; a rectangular box hangs at the lower end of the string, resting at the level of a horizontal ground line. A second string is drawn from the same ceiling point sloping down to the right to the same box shown swung up to a raised position, where a small dark bullet shape with an arrow is drawn inside the box. The vertical rise from the low position to the raised position is labelled h=0.45m.]

A. ✓ **303m/s**

B. 300m/s

C. 90.9m/s

D. 90m/s

Answer: A

Work backwards in two stages. After the collision the box and bullet move off together and rise to h, so $\frac{1}{2}(M+m)V^2 = (M+m)gh$ and $V = \sqrt{2gh} = \sqrt{2 \times 10 \times 0.45} = 3$ m/s. Momentum is conserved during the impact itself, so $mv = (M+m)V$, which gives $v = \frac{1.01 \times 3}{0.010} = 303$ m/s. Energy is not conserved in that impact, so the two stages have to be handled with different rules. Option B, 300 m/s, is this same working with $g = 9.8\ \mathrm{m/s^2}$ instead of the $10\ \mathrm{m/s^2}$ the paper uses.

— END OF MARKING KEY —