DREAMLINE STEAM OLYMPIAD

11–12
GRADE



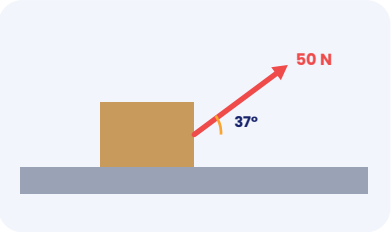
Grade 11–12 Science Olympiad Sample Questions

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Section A — Physics

Questions 1–10 · Mechanics, energy, waves, optics and electromagnetism

1 ADVANCED MECHANICS



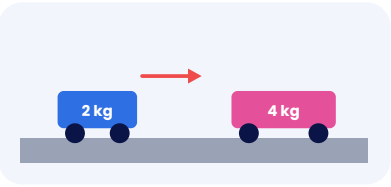
A student pulls a box across a horizontal floor using a force of 50N at an angle of 37° above the horizontal. The box moves at constant velocity. The coefficient of kinetic friction is 0.40.

Take $\sin 37° = 0.60$, $\cos 37° = 0.80$, and $g = 10\ \text{m s}^{-2}$. The mass of the box is 10kg.

What is the normal reaction force on the box?

(A) 70N (B) 100N (C) 40N (D) 130N

2 ENERGY, MOMENTUM AND COLLISIONS



A trolley of mass 2kg moves at $6\ \text{m s}^{-1}$ and collides with a stationary trolley of mass 4kg. They stick together after the collision.

What is the kinetic energy lost during the collision?

(A) 12J (B) 24J (C) 36J (D) 48J

3 CIRCULAR AND ROTATIONAL MOTION

A uniform solid disc rotates about its central axis. Its moment of inertia is $I = \frac{1}{2}MR^2$. A constant torque of 6N m acts on it, producing an angular acceleration of $3\ \text{rad s}^{-2}$.

What is the disc's moment of inertia?

(A) $0.5\ \text{kg m}^2$ (B) $1.0\ \text{kg m}^2$ (C) $2.0\ \text{kg m}^2$ (D) $18\ \text{kg m}^2$

4 GRAVITATION AND ORBITAL MOTION

A satellite moves in a circular orbit around Earth. Its orbital radius is increased from r to $4r$.

Assuming the gravitational field is produced by Earth alone, what happens to the satellite's orbital speed?

(A) It becomes four times greater.
(B) It becomes twice as great.
(C) It becomes one-quarter as great.
(D) It becomes half as great.

5 OSCILLATIONS AND SIMPLE HARMONIC MOTION

A mass attached to a spring performs simple harmonic motion with amplitude A and angular frequency ω.

What is the magnitude of its maximum acceleration?

(A) $\omega^2 A$
(B) ωA
(C) ωA
(D) $A\omega^2$

6 THERMAL PHYSICS AND KINETIC THEORY

An ideal gas is heated in a rigid, sealed container. Its absolute temperature increases from 300K to 450K.

What is the ratio of its final pressure to its initial pressure?

(A) 0.67
(B) 1.50
(C) 2.00
(D) 3.00

7 WAVES AND PHYSICAL OPTICS

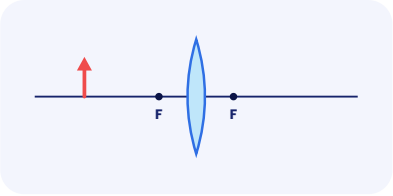
In a double-slit experiment, coherent light of wavelength 600nm produces an interference pattern on a screen. The slit separation is 0.30mm, and the screen is 2.0m away.

What is the approximate separation between adjacent bright fringes?



(A) 0.40mm
(B) 2.0mm
(C) 4.0mm
(D) 6.0mm

8 GEOMETRICAL OPTICS



An object is placed 30cm in front of a converging lens of focal length 10cm.

Using the thin-lens equation, where is the image formed?

(A) 5cm from the lens on the opposite side

(B) 10cm from the lens on the opposite side

(C) 20cm from the lens on the opposite side

(D) 15cm from the lens on the opposite side

9 ELECTRIC FIELDS, POTENTIAL AND CAPACITANCE

A parallel-plate capacitor has capacitance C when the space between its plates is air. A dielectric with relative permittivity 4 completely fills the gap, while the capacitor remains connected to a constant-voltage power supply.

What happens to the charge stored on the capacitor?

(A) It becomes four times its original value.

(B) It becomes twice its original value.

(C) It becomes one-quarter of its original value.

(D) It remains unchanged.

10 ELECTRIC CIRCUITS AND ELECTROMAGNETISM

A 12V battery with negligible internal resistance is connected to a 4Ω resistor in series with a parallel combination of two 6Ω resistors.

What is the total current supplied by the battery?

(A) 1.0A

(B) 2.0A

(C) 3.0A

(D) 6.0A

Section B — Chemistry

Questions 11–20 · Stoichiometry, bonding, energetics, equilibrium and analysis

11 · STOICHIOMETRY AND GENERAL CHEMISTRY

Magnesium reacts completely with excess hydrochloric acid according to the equation:

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

A sample of 2.4g of magnesium reacts completely. The molar mass of magnesium is 24g mol^{-1}.

What volume of hydrogen gas is produced at room temperature and pressure, assuming a molar gas volume of 24dm^3 mol^{-1}?

(A) 0.60dm^3 (B) 1.20dm^3 (C) 2.40dm^3 (D) 4.80dm^3

12 · THERMOCHEMISTRY AND CHEMICAL KINETICS

A reaction has an activation energy of 80kJ mol^{-1}. A catalyst provides an alternative reaction pathway with an activation energy of 50kJ mol^{-1}.

Which statement correctly describes the effect of the catalyst?

(A) It increases the enthalpy change of the reaction by 30kJ mol^{-1}.

(B) It makes the reaction exothermic.

(C) It increases the energy of the reactants.

(D) It lowers the activation energy without changing the overall enthalpy change.

13 · ATOMIC STRUCTURE, PERIODICITY AND CHEMICAL BONDING

An element has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^5$.

Which statement about this element is correct?

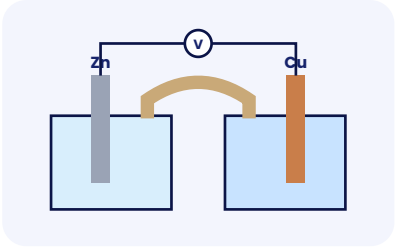
(A) It has seven valence electrons and commonly forms a 1- ion.

(B) It is a Group 2 metal that commonly forms a 2+ ion.

(C) It has a completely filled outer electron shell.

(D) It is a noble gas in Period 3.

14 ● REDOX AND ELECTROCHEMISTRY



A student constructs a galvanic cell using zinc and copper electrodes under standard conditions.

Given:

$E_{Cu^{2+}/Cu}^{\circ} = +0.34\,V$

$E_{Zn^{2+}/Zn}^{\circ} = -0.76\,V$

What is the standard cell potential?

(A) −1.10 V (B) +1.10 V (C) +0.42 V (D) −0.42 V

15 ● CHEMICAL EQUILIBRIUM, ACIDS AND BASES

A weak monoprotic acid, HA, has $K_a = 1.0 \times 10^{-5}$. A buffer contains equal concentrations of HA and its conjugate base, A^-.

What is the approximate pH of the buffer?

(A) 2 (B) 4 (C) 5 (D) 9

16 ● CHEMICAL EQUILIBRIUM AND LE CHATELIER'S PRINCIPLE

The Haber process is represented by the equilibrium:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The forward reaction is exothermic. The system is at equilibrium in a closed container.

Which change shifts the equilibrium towards ammonia?

(A) Increasing the temperature at constant pressure

(B) Decreasing the pressure at constant temperature

(C) Adding a catalyst

(D) Increasing the pressure at constant temperature

17 ORGANIC CHEMISTRY AND BIOMOLECULES

An organic compound has the molecular formula $C_3H_6O_2$. It reacts with sodium hydrogencarbonate solution, releasing carbon dioxide gas.

Which functional group is most likely present?

(A) Carboxylic acid
(B) Aldehyde
(C) Ester
(D) Ketone

18 ANALYTICAL CHEMISTRY

A 25.0cm^3 sample of hydrochloric acid is completely neutralised by 20.0cm^3 of 0.150mol dm^{-3} sodium hydroxide.

The reaction is:

$HCl + NaOH \rightarrow NaCl + H_2O$

What is the concentration of the hydrochloric acid?

(A) 0.075mol dm^{-3}
(B) 0.120mol dm^{-3}
(C) 0.150mol dm^{-3}
(D) 0.188mol dm^{-3}

19 INORGANIC AND COORDINATION CHEMISTRY

Copper(II) ions form a deep-blue complex when excess aqueous ammonia is added.

Which process best explains the formation of this complex?

(A) Copper ions lose all their outer-shell electrons.
(B) Ammonia molecules transfer protons to copper ions.
(C) Ammonia molecules donate lone pairs to the copper ion to form coordinate bonds.
(D) Copper ions form only ionic bonds with nitrogen atoms by electron transfer.

20 RATES OF REACTION AND EXPERIMENTAL DESIGN

A student investigates how temperature affects the rate of a reaction between two solutions. The student repeats the experiment at several temperatures but uses different concentrations of one reactant each time.

Why is this experimental design unreliable?

(A) Temperature cannot affect reaction rate.

(B) Concentration has no effect on reaction rate.

(C) The reaction must be at equilibrium at every temperature.

(D) The student has changed more than one independent variable, so the effect of temperature cannot be isolated.

Section C — Biology

Questions 21–30 · Cell biology, genetics, physiology, evolution and ecology

21 CELL AND MOLECULAR BIOLOGY

A researcher places identical plant cells in a concentrated sucrose solution. After several minutes, the cell membranes pull away from the cell walls.

Which process best explains this observation?

(A) Water leaves the cells by osmosis, causing the protoplasts to shrink.

(B) Sucrose enters the cells by active transport, increasing their volume.

(C) Water enters the cells by osmosis, increasing their turgor pressure.

(D) The cell walls dissolve because sucrose is hypertonic.

22 GENETICS AND GENE EXPRESSION

In a species of plant, purple flowers are controlled by a dominant allele, *P*, while white flowers are controlled by a recessive allele, *p*.

Two heterozygous purple-flowered plants are crossed:

Pp×*Pp*

Assuming complete dominance and normal segregation, what proportion of their offspring is expected to have white flowers?

(A) 0
(B) 21
(C) 41
(D) 43

23 HUMAN PHYSIOLOGY

A person climbs several flights of stairs. Their heart rate and breathing rate increase to supply active muscles with more oxygen.

Which statement best explains the increased oxygen delivery?

(A) The muscles stop performing aerobic respiration and rely entirely on photosynthesis.
(B) The kidneys increase oxygen production from glucose.
(C) The blood transports oxygen mainly dissolved in plasma.
(D) Increased ventilation and cardiac output help increase oxygen uptake and delivery to tissues.

24 EVOLUTION, ECOLOGY AND BIODIVERSITY

A population of insects contains individuals with different levels of resistance to a pesticide. After repeated pesticide applications, the proportion of resistant insects increases over several generations.

Which explanation is most scientifically accurate?

(A) Every insect develops resistance because it needs to survive.
(B) The pesticide deliberately causes the insects to develop useful mutations.
(C) Resistant insects stop passing their genes to offspring.
(D) Resistant insects are more likely to survive and reproduce, increasing the frequency of resistance alleles.

25 MICROBIOLOGY AND DISEASE

A student investigates an unknown infectious agent. The agent reproduces only inside living host cells and consists of genetic material surrounded by a protein coat.

Which conclusion is best supported by the evidence?

(A) The agent is a virus.

(B) The agent is a bacterium.

(C) The agent is a fungus.

(D) The agent is a protozoan.

26 BIOTECHNOLOGY AND GENETIC ENGINEERING

Scientists insert a human gene into bacterial cells to produce a human protein for medical use.

Which feature of the genetic code makes this approach possible in many cases?

(A) Every organism has exactly the same genes.

(B) The genetic code is nearly universal, allowing bacteria to interpret many human gene codons in the same way.

(C) Bacteria naturally possess every human chromosome.

(D) Bacterial cells translate DNA directly into proteins without RNA.

27 IMMUNOLOGY

After receiving a vaccine, a student develops a stronger and faster immune response when later exposed to the same pathogen.

Which mechanism best explains this improved response?

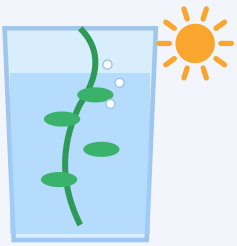
(A) Red blood cells remember the pathogen and produce antibodies.

(B) The vaccine permanently prevents all mutations in the pathogen.

(C) Memory B and T cells help generate a faster, more effective secondary immune response.

(D) The vaccine causes all white blood cells to become identical.

28 PHOTOSYNTHESIS AND CELLULAR RESPIRATION



A researcher measures the rate of photosynthesis in an aquatic plant at different light intensities. At low light intensity, increasing the light intensity increases the rate. At high light intensity, the rate levels off.

What is the best explanation for the plateau?

(A) Light becomes completely unnecessary for photosynthesis at high intensity.

(B) The plant stops absorbing carbon dioxide whenever light is strong.

(C) The plant has permanently lost its chlorophyll.

(D) Another factor, such as carbon dioxide concentration or temperature, has become limiting.

29 MOLECULAR BIOLOGY AND MUTATIONS

A mutation changes one DNA nucleotide in a protein-coding gene. The altered codon specifies the same amino acid as the original codon.

What is the most likely immediate consequence for the protein sequence?

(A) Every amino acid downstream must change.

(B) Translation must stop immediately.

(C) The protein must become twice as long.

(D) The amino acid sequence remains unchanged, although other effects on gene expression are possible.

30 EXPERIMENTAL BIOLOGY AND ENZYME ACTIVITY

A student investigates the effect of pH on an enzyme. Equal volumes of enzyme and substrate are used at each pH, but the student also changes the temperature between trials.

Which improvement would make the experiment more valid?

(A) Use a different enzyme for every pH value.

(B) Change the substrate concentration in every trial.

(C) Measure only the final colour of the solutions without controlling other variables.

(D) Keep temperature, enzyme concentration, substrate concentration and reaction time consistent while changing pH.