

Instructions for teachers for Engineering and Physical Sciences

There are ten sessions of multiple-choice questions here, on the following topics:

1. S.I. units, dimensional analysis, measurement theory (**pages 2-5**)
2. Electrostatics and magnetism (**pages 6-9**)
3. Electromagnetic induction and energy (**pages 10-13**)
4. Thermal energy and ideal gases (**pages 14-17**)
5. Static pressure and fluid dynamics (**pages 18-21**)
6. Scalars, vectors, couples and equilibrium (**pages 22-25**)
7. Material science, work and friction (**pages 26-30**)
8. Projectile motion, Newton's laws and momentum (**pages 31-34**)
9. Waves (**pages 35-38**)
10. Circular motion and SHM (**pages 39-43**)

To run a session, you need to print **two documents per pair of students**:

- *student questions*,
- *student feedback*.

Students having to share the questions and feedback sheets is an important part of the set-up, as it should help to encourage discussion.

The questions have been written or selected/modified from resources such as examination papers, to be deliberately challenging and tricky at times, since if the questions are too easy, it often leads to little discussion. Reassure students, where applicable, that questions like this won't be used in their summative assessments. Please emphasise to students that this activity is not about knowing the answers, but an opportunity to discuss and explore ideas.

Avoid the temptation to correct students whilst they are discussing. Instead, it is a good idea to allow time following the activity to discuss the most challenging questions as a group.

Always feel free to reach out at:

m.heron@surrey.ac.uk, our project lead, or another member of the research team: <https://www.surrey.ac.uk/research-projects/educational-dialogue-improving-foundation-year-student-outcomes#team>.

Whilst efforts have been made to correct errors and resolve ambiguities, some likely persist – let your discussions explore and uncover them!

1. S.I. units, dimensional analysis, measurement theory

Question 1.

The world subscribes to a common set of units and conventions. This system is known as the Syst me International (S.I.) – or colloquially, the ‘metric’ system. It is formed from seven S.I. ‘base units’ (such as meters, seconds and kilograms) from which all other units can be derived, known as S.I. ‘derived units’ (such as Newtons, Joules and Pascals).

Which one of the following is **not** a S.I. base unit?

- A The kelvin
- B The mole
- C The coulomb
- D The candela

Question 2.

Using any equation related to the physical quantity you are interested in, you can determine the S.I. base units of the quantity. For example, from $F = m \times a$, we know that Newtons = $\text{kg} \times \text{m s}^{-2}$. Newtons is the derived unit, and its base units are kg m s^{-2} .

What are the S.I. base units of electrical resistance?

- A $\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$
- B $\text{kg m}^2 \text{s}^{-3} \text{A}^{-1}$
- C $\text{kg m}^2 \text{s}^{-2} \text{A}^{-1}$
- D $\text{kg m}^2 \text{s}^{-1} \text{A}^{-2}$

Question 3.

Sometimes we use prefixes to describe very large or very small numbers. For example, the kilogram is kilo (1000) grams, and nanoseconds are nano (10^{-9}) seconds.

Which prefix would be the equivalent to a *mega giga micro femto* Joule?

- A Mega
- B Giga
- C Micro
- D Femto

Question 4.

Units are our way of describing how big or small 'something' is. The 'something' is what we describe as the 'physical quantity'. For example, the length of a string is a physical quantity, we can measure it. How we report that measurement, using a scale of meters or millimetres, is our unit.

Which one of the following is **not** a physical quantity?

- A Temperature
- B The average kinetic energy of particles
- C The intermolecular forces between particles
- D Kelvins

Question 5.

Dimensionless quantities are calculated quantities which do not relate to a physical quantity. In an experimental sense, it means they do not exist! However, it doesn't mean they are not useful. Ratios and transcendental functions (functions that require an infinite series to describe them) are good examples of dimensionless quantities.

Which one of the following would be a dimensionless quantity?

- A The permittivity of free space (ϵ_0)
- B π (pi)
- C The Planck constant (h)
- D The speed of light (in a vacuum) (c)

Question 6.

We can use dimensional analysis to determine whether or not an equation is physically sensible. If the dimensions of one side of the equation equal those on the other, then the equation is valid.

First, decide on an equation for Pressure and then choose which one of the following equations might represent a physical quantity of pressure.

- A Mass / Length x Time²
- B Mass / Length² x Time²
- C Mass x Length / Time²
- D Mass x Length² / Time²

Question 7.

Accuracy refers to how close a measurement is to its true value. Precision refers to how close repeated measurements are to one another.

In which one of the following is precision likely more important than accuracy?

- A Precision should never be prioritised over accuracy
- B A GPS system determining the location of a vehicle
- C A weather forecasting model predicting the next day's temperature
- D A laboratory measuring the concentration of a chemical in a solution for experimental research.

Question 8.

Accuracy refers to how close a measurement is to its true value. How then, do we decide what the 'real value is' to confirm the accuracy of our measurement?

- A Confirm your measurements with other students doing the same experiments. If they are similar (within error bars of each other), we can confirm good accuracy.
- B Repeat your measurement several times and take the average of the measurements (and estimate the error).
- C A scientific consensus must be reached through measurements of the same physical constant through different theoretical and experimental procedures.
- D Higher resolution experiments will ensure a higher level of accuracy. So, it is important to use maximum resolution where technically feasible.

Question 9.

Experimental errors can come from several sources. Random errors refer to sources of error which are not readily modelled and present as over- or under-estimating a measurement randomly. Systematic errors, however, are consistent over- or under-estimating of measurements.

Temperature can be random or systematic depending on the situation. Which one of these situations listed as random or systematic is incorrect? Consider how you would account for the error.

- A Calibration drift in a thermometer – a thermometer is miscalibrated and reads 1°C higher than it should do – an example of systematic error.
- B Digital noise – a digital thermometer is used to measure the temperature of a room. Electronic noise changes the reading a little bit even though the room remains at a constant temperature – systematic error.
- C Thermal expansion of a ruler – a ruler is used in measurements across the day. In the morning it is significantly cooler than it is in the afternoon – an example of systematic error.
- D Temperature fluctuations – a temperature control lab is used to measure the rate of reaction. When the door to the lab is opened, it affects the temperature of the lab – an example of random error.

Question 10.

‘Resolution’ refers to the smallest possible precision you can measure a physical quantity using an instrument.

What is the minimum precision of a ruler which only has 1 cm markings? There is more than one right answer to this question. Can you figure out how many there are?

- A $\pm 1\text{ cm}$
- B $\pm 0.5\text{ cm}$
- C $\pm 0.25\text{ cm}$
- D $\pm 0.01\text{ cm}$ (1 mm)

2. Electrostatics and magnetism

Question 1.

Coulomb's law of electrostatics is given by:

$$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$$

where F is the force between two charges with charge (Q_1 and Q_2) when separated by a distance r . ϵ_0 is the permittivity of free space (a vacuum).

Which factor **most** significantly affects the strength of the electric field between two point charges?

- A The distance between the charges
- B The medium in which the charges are placed
- C The magnitude of the charges
- D The shape of the charges

Question 2.

What does the value of $\epsilon_0 = 8.85 \times 10^{-12} \text{ Fm}^{-1}$ represent? If you are not sure, you can think about its relevance in the equation in Question 1.

- A It represents the maximum possible electric field strength that can exist in a vacuum.
- B It is a measure of the strength of the electric force between two charges in a medium (such as a vacuum).
- C It is the permeability of a vacuum, indicating how much magnetic field can be established in a vacuum.
- D It is a physical constant that represents how easy it is for an electric field to pass through (or polarise) a vacuum.

Question 3.

Field lines are used to visually represent the behaviour of electric fields. When discussing how field lines represent lines of force, which of the following statements is correct?

- A Field lines represent the path that a charged particle will take if placed in the field.
- B Field lines indicate the direction of the force that a positive test charge would experience if placed at any point in the field.
- C Field lines are only a conceptual tool and do not correspond to any physical reality in terms of force.
- D Field lines represent the regions where the force between charges is weakest.

Question 4.

There are four key quantities we consider in electrostatics:

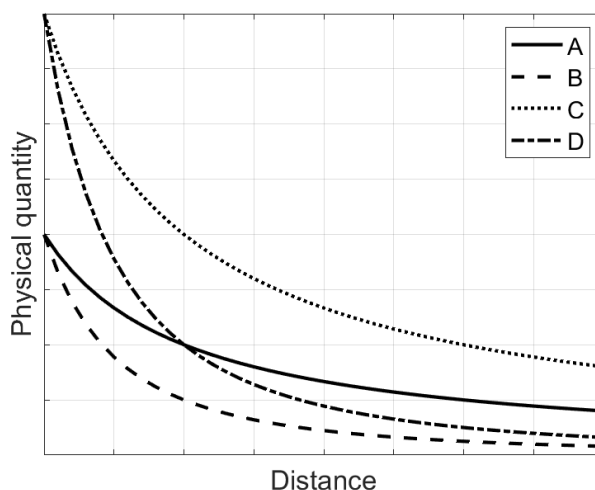
$$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}, \text{ Electrostatic force}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2}, \text{ Electric field strength}$$

$$E_p = \frac{Q_1 Q_2}{4\pi\epsilon_0 r}, \text{ Electric potential energy}$$

$$V = \frac{Q}{4\pi\epsilon_0 r}, \text{ Electric potential}$$

Assuming that Q_1 , and where appropriate, Q_2 , take the value of 2 Coulombs, decide which quantity is depicted by 'A', 'B', 'C' and 'D' on the following graph, **no calculation is needed**.



Give your answer in order of 'Force', 'Field Strength', 'Potential Energy' and 'Potential'.

- A A, B, C, D
- B B, A, D, C
- C D, B, C, A
- D C, D, B, A

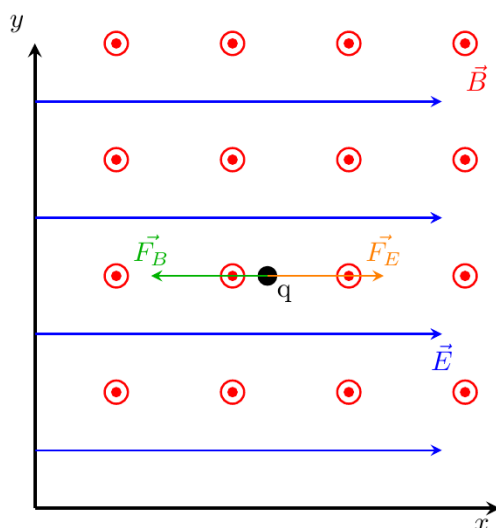
Question 5.

When discussing the electric potential and the electric potential difference, which of the following statements best describes the electric potential at a point in an electric field? Consider how we get from the electrostatic force to the electric potential energy given in Question 3.

- A Electric potential at a point is the amount of energy required to move a positive test charge from infinity to that point, divided by the charge.
- B Electric potential at a point is the amount of work done by the electric field in moving a positive test charge from that point to infinity.
- C Electric potential at a point is the amount of force a positive charge would feel if placed at that point.
- D The electric potential difference between two points is the total charge that flows between them when connected by a conductor.

Question 6.

A charged particle (q) is moving through a region where both a uniform electric field (E) and a uniform magnetic field (B) are present. The electric field is directed parallel to the x -axis, and the magnetic field is directed parallel to the z -axis (coming out of the page).



The particle experiences no net force as it moves. What can be inferred about the velocity of the particle? Is the particle positively or negatively charged (what difference, if any, would it make)?

- A The particle is stationary.
- B The velocity of the particle is parallel to the x -axis.
- C The velocity of the particle is parallel to the z -axis.
- D The velocity of the particle is parallel to the y -axis.

Question 7.

Consider a current-carrying wire placed in a magnetic field. This setup is common in electric motors, where magnetic fields and electric currents interact to produce motion. Understanding how these forces work together is key to explaining the motor effect. When describing how the force due to interacting magnetic fields leads to the motor effect, which of the following statements is correct?

- A The motor effect happens because the magnetic field from the external magnet exerts a force on the moving charges within the wire, causing the wire to move.
- B The motor effect occurs because the magnetic field generated by the current in the wire interacts with the magnetic field of the external magnet, causing the wire to move.
- C The motor effect is a result of the interaction between the magnetic field generated by the current in the wire and the electric field in the surrounding space, creating a force.
- D The motor effect only occurs if the wire is aligned parallel to the magnetic field, maximising the interaction between the fields.

Question 8.

A single loop of wire carrying a current creates a magnetic field. Understanding the shape and direction of this field is useful for applications like magnetic sensors. How does the magnetic field of a single current-carrying loop of wire compare to the field of a straight current-carrying wire?

- A The magnetic field of a single loop is stronger at the centre of the loop compared to the field at a similar distance from a straight wire.
- B The magnetic field of a single loop is weaker at the centre of the loop compared to the field directly next to a straight wire.
- C The magnetic field of a straight wire is non-linear along its axis.
- D The magnetic field of a single loop is uniform and constant along its axis.

Question 9.

Which one of the following is an example of an electromagnet and demonstrates its practical application?

- A A refrigerator door seal that uses a permanent magnet to stay closed.
- B A traditional compass used for navigation.
- C A magnetic levitation system used for frictionless transportation, such as maglev trains.
- D A mechanical wristwatch that uses a balance wheel for timekeeping.

Question 10.

In which of the following scenarios would you correctly apply the formula $F = BIL$ without any modification in order to calculate the force on a current-carrying wire in a magnetic field?

- A A wire carrying a current of 3 A is placed in a magnetic field of 2 T, and the wire is positioned parallel to the magnetic field.
- B A wire of length 0.5 m carries a current of 4 A in a magnetic field of 1.5 T, and the wire is perpendicular to the magnetic field.
- C A wire carrying a current of 2 A is placed in a magnetic field of 1 T, and the length of the wire is 1 m, but the wire is at an angle of 60 degrees to the magnetic field.
- D A wire with a length of 2 m carries a current of 5 A in a magnetic field of 3 T, and the wire is oriented in such a way that the magnetic field is completely enclosed within the wire loop.

3. Electromagnetic induction

Question 1.

A conducting rod of length L is moving with a velocity v in a uniform magnetic field B . The rod is part of a closed circuit. Consider the scenarios below. Which will result in the greatest induced e.m.f. in the rod?

- A The rod is stationary while the magnetic field strength gradually increases
- B The rod moves parallel to the magnetic field lines with velocity v
- C The rod moves perpendicular to the magnetic field lines with velocity v .
- D The rod rotates in a plane parallel to the magnetic field lines, with its axis of rotation aligned with the field

Question 2.

Consider a loop of wire in a uniform magnetic field B , where the magnetic flux through the loop is changing over time. The e.m.f. induced in the loop is given by Faraday's Law:

$$\text{e.m.f.} = -\frac{d\Phi_B}{dt}$$

where $\Phi_B = BA\cos(\theta)$ is the magnetic flux through the loop, with A being the area of the loop and θ the angle between the magnetic field and the normal to the loop.

If the magnetic field B is increasing with time, which of the following describes the correct direction of the induced current in the loop, according to Lenz's Law?

- A Clockwise, to oppose the increasing magnetic field by generating a magnetic field in the opposite direction.
- B Counterclockwise, to oppose the increasing magnetic field by generating a magnetic field in the same direction as the original field
- C Clockwise, to enhance the increasing magnetic field by generating a magnetic field in the same direction.
- D Counterclockwise, to enhance the increasing magnetic field by generating a magnetic field in the opposite direction.

Question 3.

A rectangular coil is rotating with a constant angular velocity ω in a uniform magnetic field B . The coil has N turns and a cross-sectional area A . Which of the following changes would most significantly increase the peak induced e.m.f. in the coil **and** be easiest to practically implement? Remember, induced e.m.f. $= NAB\omega$.

- A Doubling the number of turns (N)
- B Doubling the magnetic field strength (B)
- C Doubling the cross-sectional area (A)
- D Doubling the angular velocity (ω)

Question 4.

A transformer is designed to step down the voltage from 240 V to 12 V to power a household device. The primary coil has 800 turns, and the secondary coil has 40 turns. Assuming the transformer is ideal, which one of the following statements about the transformer and energy loss is correct?

- A The transformer will deliver the same amount of power to the secondary coil as it receives from the primary coil, but the current in the secondary coil will be higher.
- B The root-mean-square (RMS) voltage in the primary coil will be 12 V when the RMS voltage in the secondary coil is 240 V.
- C Energy is lost primarily due to the high current in the primary coil, which causes eddy currents in the transformer core.
- D The current in the secondary coil is lower than in the primary coil, which explains why there is energy loss in transformers.

Question 5.

When designing a transformer for use in an electrical power system, if you could optimise only one of the following, which one would be most effective?

- A The use of direct current (DC) to ensure efficient power transfer because the core is not being magnetised and demagnetised.
- B The use of alternating current (AC) to generate a constantly changing magnetic flux.
- C The efficiency of the transformer's core material in minimising energy losses, regardless of whether AC or DC is used. For example, using laminated cores.
- D The choice of insulation materials to prevent overheating in both AC and DC systems and to minimise eddy currents in the core.

Question 6.

Is nuclear energy renewable? Consider how you would define 'renewable' and the extreme limits of what is 'renewable'

- A Nuclear fission is renewable
- B Nuclear fusion is renewable
- C Both nuclear fission and fusion are renewable
- D Neither nuclear fission nor fusion is renewable.

Question 7.

A factory uses two different types of motors to lift identical loads:

1. Motor X does 500 J of work in 10 seconds and wastes 125 J of energy as heat.
2. Motor Y does 600 J of work in 15 seconds and wastes 140 J of energy as heat.

Based on this information, which of the following statements is correct regarding the power output and overall performance of the motors?

- A Motor X has a higher power output and is more efficient, making it better overall.
- B Motor Y has a higher power output and is more efficient, making it better overall.
- C Motor X has a higher power output, but Motor Y is more efficient.
- D Motor X and Motor Y have the same power output, but Motor X is more efficient.

Question 8.

An electric motor lifts a load of weight W through a vertical height h in time t . The potential difference across the motor is V and the current in it is I .

What is the efficiency of the motor?

- A $\frac{Wh}{VIt}$
- B $\frac{VI}{Wht}$
- C $\frac{Wht}{VI}$
- D $\frac{VIt}{Wh}$

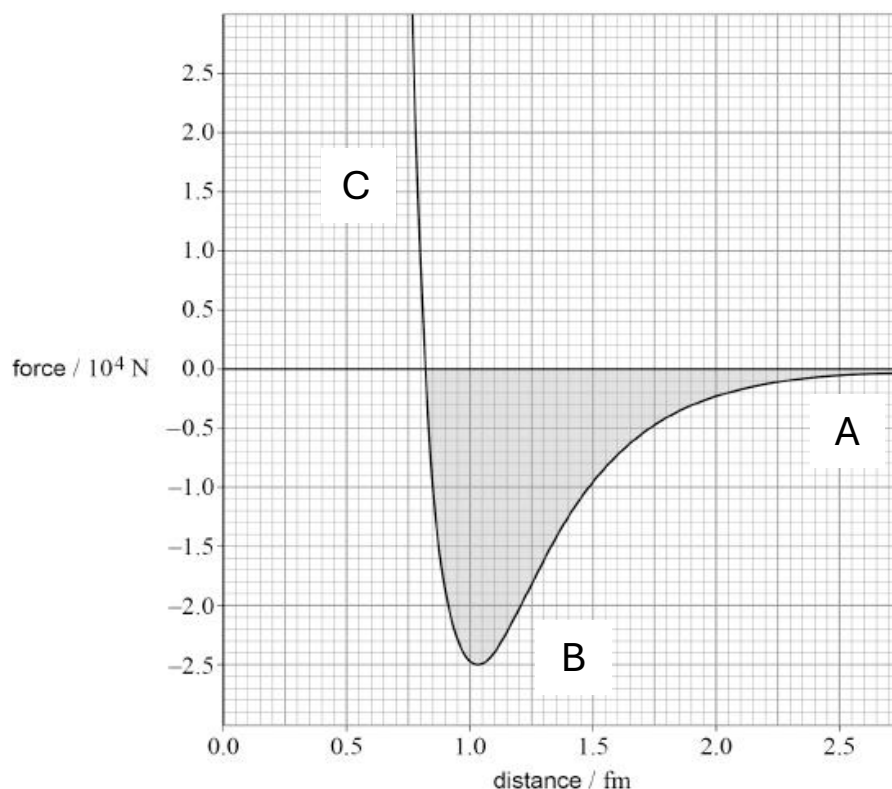
Question 9.

A ball is dropped from a height of 20 meters onto a smooth, hard surface. Assuming air resistance is negligible, which of the following best describes the energy transformation and conservation as the ball falls and bounces back up?

- A The ball's gravitational potential energy is fully converted into kinetic energy as it falls, and during the bounce, it returns to its original height.
- B The ball's gravitational potential energy is fully converted into kinetic energy as it falls, but after the bounce, it reaches a lower height due to energy losses in the system.
- C The ball gains more kinetic energy as it falls, allowing it to reach a higher height after the bounce due to the force from the surface.
- D The ball's gravitational potential energy is not fully converted into kinetic energy as it falls, and it loses more energy to the air as it bounces back.

Question 10.

The graph shows the variation of force with distance between a proton and a neutron and three regions where the electrostatic forces are (A) tending to zero, (B) attractive, and (C) repulsive. Notice the very short separation distances involved.



How would you best explain this behaviour based on the internal quark structure of the particles and the fields involved? Note, quarks have electric charges (up quarks are $+2/3$, down quarks are $-1/3$) so a proton is made up of 2 up and 1 down quark, a neutron has 1 up and 2 down quarks.

- A At short distances, quarks in the proton and neutron interact primarily through gravitational attraction, while at longer distances, the strong nuclear force dominates. At very large distances, the quark fields from both particles weaken, but the interaction remains due to residual strong force effects.
- B At very short distances, the up quarks inside the proton repel the down quarks in the neutron due to their different charges, but at longer distances, the strong nuclear force holds the particles together. At very long distances, the interaction remains strong as the quark fields stretch out.
- C At very short distances, the quarks inside both the proton and neutron generate repulsive electrostatic fields. As they move farther apart, the quarks' electric charges attract each other, but the interaction becomes negligible at large distances due to the proton's weaker field.
- D At very short distances, the quarks inside the proton and neutron are forced too close together, leading to a repulsive interaction. At slightly longer distances, the strong nuclear force becomes attractive, while at large distances, the net mean field from the neutron's quarks tends toward zero.

4. Thermal energy and ideal gases

Question 1.

You are designing a cooling system for a heat exchanger, where heat is transferred from a hot surface to the surrounding air by convection. The following parameters affect the rate of heat transfer by convection:

$$Q = h A (T_1 - T_0)$$

- Surface temperature (T_1): 70°C
- Air temperature (T_0): 25°C
- Convective heat transfer coefficient (h): 10 W/m²K
- Surface area of the heat exchanger (A): 2 m²

Now, consider four possible scenarios:

1. The surface temperature is increased to 90°C
2. The air temperature is increased to 60°C
3. The surface area is doubled to 4 m²
4. The convective heat transfer coefficient is doubled to 20 W/m²K

Which scenario will result in the **greatest increase** in the rate of heat transfer by convection?

- A Increasing the surface temperature to 90°C
- B Increasing the air temperature to 60°C
- C Doubling the surface area to 4 m²
- D Doubling the convective heat transfer coefficient to 20 W/m²K

Question 2.

A hot metal plate is placed in a room with a cooler ambient temperature. The rate of heat loss due to convection from the metal plate depends on several factors.

Which of the following changes would not increase the rate of convection from the metal plate?

- A Increasing the temperature difference between the plate and the surrounding air
- B Increasing the surface area of the metal plate
- C Increasing the thermal conductivity of the metal plate
- D Increasing the speed of the air flow around the plate

Question 3.

A metal plate is heated and begins to emit thermal radiation. The rate of energy transfer by radiation depends on several factors.

Which of the following changes would increase the rate of radiative energy transfer from the plate most significantly?

- A Increasing the temperature of the plate
- B Increasing the emissivity of the plate's surface
- C Increasing the surface area of the plate
- D Increasing the thermal conductivity of the plate

Question 4.

A liquid flows continuously through a chamber that contains an electric heater. When the steady state is reached, the liquid leaving the chamber is at a higher temperature than the liquid entering the chamber. The difference in temperature is Δt .

Which of the following will increase Δt with no other change?

- A Increasing the volume flow rate of the liquid
- B Changing the liquid to one with a lower specific heat capacity
- C Using a heating element with a higher resistance
- D Changing the liquid to one that has a higher density

Question 5.

A car of mass M travelling at speed V comes to rest using its brakes. Energy is dissipated in the brake discs of total mass m and specific heat capacity c . The rise in temperature of the brake discs can be estimated from:

- A $\frac{mV^2}{2Mc}$
- B $\frac{2MV^2}{2mc}$
- C $\frac{MV^2}{2mc}$
- D $\frac{2mc}{MV^2}$

Question 6.

A block of ice is heated at a constant rate. Initially, the temperature of the ice increases, but once the ice reaches 0°C , it begins to melt without any further increase in temperature. Which statement best explains the difference between specific heat capacity and latent heat during this process?

- A Specific heat capacity is the energy required to change the temperature of a substance, while latent heat is the energy required to change its phase without changing its temperature.
- B Specific heat capacity is the energy required to raise the temperature of the substance through its phase change, while latent heat is the energy required to raise the temperature of the substance before the phase change.
- C Specific heat capacity applies only during the heating of the solid phase, while latent heat applies only during the heating of the liquid phase.
- D Specific heat capacity and latent heat both contribute to raising the temperature of a substance, but latent heat is much smaller in magnitude.

Question 7.

The composition of a carbon dioxide (CO_2) molecule is one atom of $^{12}_6\text{C}$ and two atoms of $^{16}_8\text{O}$.

What is the number of molecules of CO_2 in 2.2 kg of the gas?

- A 1.0×10^{22}
- B 3.1×10^{22}
- C 4.7×10^{23}
- D 3.0×10^{25}

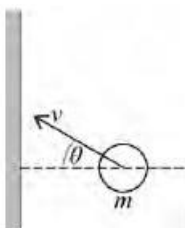
Question 8.

Which is not an assumption about gas particles in the kinetic theory model for a gas?

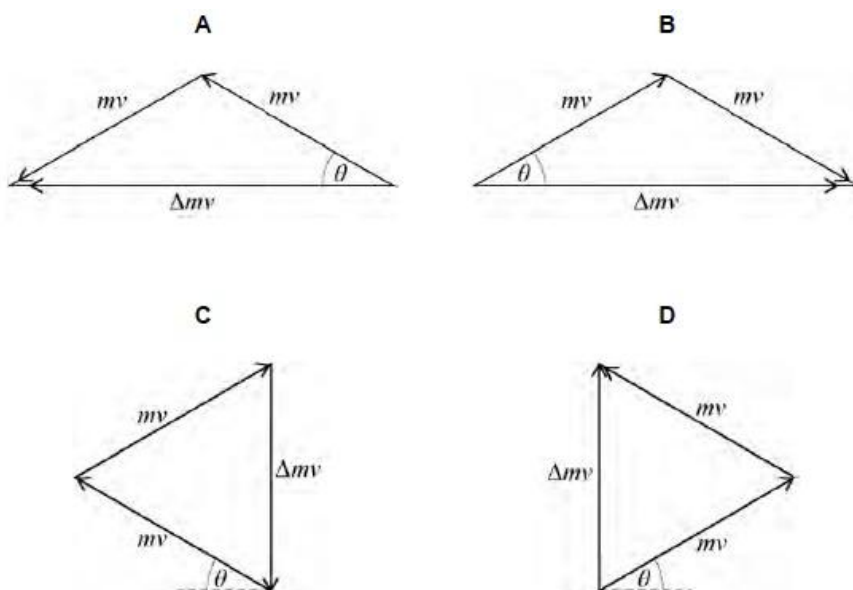
- A They collide elastically with the container walls.
- B They have negligible size compared to the distance between the container walls.
- C They travel between the container walls in negligibly short times.
- D They collide with the container walls in negligibly short times.

Question 9.

The diagram shows a gas particle about to collide elastically with a wall.

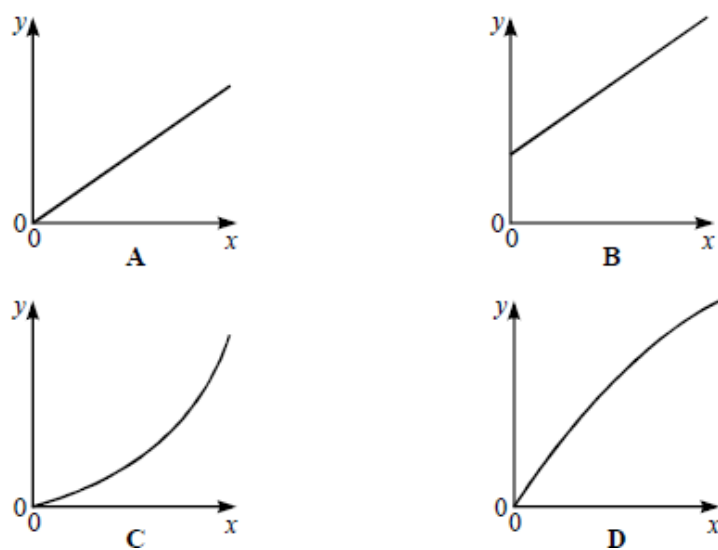


Which diagram shows the correct change in momentum Δmv that occurs during the collision?



Question 10.

Which one of the graphs below shows the relationship between the internal energy of an ideal gas (y -axis) and the absolute temperature of the gas (x -axis)?



5. Thermodynamics, static pressure and fluid dynamics

Question 1.

In thermodynamics, closed systems and isolated systems are both types of non-flow processes where no mass enters or leaves the system. However, they differ in terms of energy transfer. Closed systems allow an exchange of heat energy with the environment, isolated systems do not allow this.

Which variable in the ideal gas law is constant in both closed and isolated systems?

- A V
- B P
- C T
- D N

Question 2.

In a closed system where a reversible chemical reaction is occurring, the system eventually reaches chemical equilibrium. According to the second law of thermodynamics, equilibrium represents a state of maximum entropy.

Which of the following best explains why equilibrium is a state of maximum entropy?

- A At equilibrium, the forward and reverse reaction rates are equal, so there is no further change in the concentrations of reactants and products, resulting in no net change in entropy.
- B At equilibrium, the total energy of the system is minimised, which automatically maximises entropy because energy dissipation is reduced.
- C At equilibrium, the system has reached the most probable distribution of energy among particles, leading to maximum disorder and maximum entropy.
- D At equilibrium, entropy stops increasing because the reactants and products have reached equal concentrations, which balances the system and halts entropy changes.

Question 3.

An ideal heat engine has an efficiency of 0.33. The same engine works in reverse as an ideal refrigerator between the same hot and cold spaces.

Determine the coefficient of performance (COP) of the refrigerator.

- A 1
- B 2
- C 3
- D 4

Question 4.

In a hydraulic system, a fluid is used to transmit force from one piston to another. The fluid is considered incompressible, which allows pressure to be transmitted undiminished throughout the system.

Which of the following best explains why an incompressible fluid transmits pressure?

- A The fluid molecules are too large to move closer together, so the volume of the fluid remains constant under pressure.
- B The fluid molecules are in constant motion, allowing them to transmit pressure in all directions equally.
- C The fluid has a fixed volume, so any applied force results in an immediate transmission of pressure without any loss.
- D The fluid's density increases significantly under pressure, preventing a change in volume and ensuring pressure transmission.

Question 5.

A hydraulic system is used to lift a car in a garage. The system consists of two connected cylinders of different diameters. The smaller cylinder has a diameter of 0.2 m, and the larger cylinder, which lifts the car, has a diameter of 1.0 m. A mechanic applies a force of 200 N to the smaller piston. Assuming an ideal system, what force is exerted by the larger piston for lifting?

- A 1000 N
- B 2000 N
- C 5000 N
- D 25000 N

Question 6.

Fluids can exhibit different types of flow depending on their velocity, viscosity, and the geometry of the system they move through.

Which of the following best describes the difference between laminar flow and turbulent flow?

- A Laminar flow is smooth and orderly with parallel fluid layers, while turbulent flow involves chaotic fluid motion and swirling eddies.
- B Laminar flow occurs when fluid velocity and viscosity are both high, while turbulent flow occurs when the fluid velocity is low and viscosity is low.
- C Laminar flow has less friction and resistance compared to turbulent flow, which tends to create greater energy losses due to its chaotic motion.
- D Laminar flow occurs when the fluid moves in smooth layers at low speeds, while turbulent flow occurs when fluid velocities are extremely high.

Question 7.

A diver descends into the ocean and the pressure she experiences increases as she goes deeper due to the weight of the water above her. The pressure at a given depth in a fluid column is related to the fluid's density, the gravitational field strength, and the depth.

Which of the following best explains how pressure in a fluid column can be used to measure pressure in practical situations, such as with a manometer or barometer?

- A Pressure at any point in a fluid column depends only on the weight of the fluid above, so measuring the height of a liquid column gives an accurate measure of pressure.
- B The pressure in a fluid column is constant at all depths, making it possible to measure atmospheric pressure using a fixed height column of liquid.
- C The pressure at a certain depth in a fluid column is proportional to both the fluid's density and the height of the column, so by measuring the height, you can determine the pressure.
- D In a fluid column, pressure increases uniformly with depth, so you only need to know the total height of the fluid column to measure pressure, regardless of the fluid's density.

Question 8.

A fluid flows through a pipe that narrows from a diameter of 10 cm to a diameter of 5 cm. Assuming the flow is steady and incompressible, which of the following statements correctly describes how the fluid's velocity changes as it moves from the wider section to the narrower section of the pipe, according to the continuity equation?

- A The fluid's velocity increases because the cross-sectional area decreases, resulting in a higher flow speed.
- B The fluid's velocity decreases because the pressure in the narrower section is lower, causing a slowdown.
- C The fluid's velocity remains constant throughout the pipe, regardless of changes in diameter.
- D The fluid's velocity increases only if the fluid is less viscous; if it is highly viscous, the velocity does not change significantly.

Question 9.

A fluid with a density of 1000 kg/m^3 flows through a horizontal pipe at 50 ms^{-1} . At point A, the diameter of the pipe is 8 cm, and the pressure is measured to be 3000 Pa. At point B, the diameter of the pipe is reduced to 4 cm. What is the pressure at point B?

Use Bernoulli's equation: $P_a + \frac{1}{2}\rho v_a^2 + \rho g h_a = P_b + \frac{1}{2}\rho v_b^2 + \rho g h_b$

Where: P = pressure; ρ = density; v = velocity, h = height

- A 1500 Pa
- B 2250 Pa
- C 2500 Pa
- D 3000 Pa

Question 10.

A small metal sphere of radius $r = 5 \text{ mm}$, and density $\rho_s = 7800 \text{ kg/m}^3$ is dropped into a viscous fluid with a density of $\rho_f = 1200 \text{ kg/m}^3$ and a dynamic viscosity $\eta = 0.8 \text{ Pa s}$. According to Stokes' Law, the force of viscous drag F_d acting on a sphere moving through a viscous fluid can be expressed as:

$$F_d = 6\pi\eta r v$$

Where: F_d = force of drag; η = dynamic viscosity of the fluid; r = radius of the sphere; v = velocity of the sphere

Given that the sphere is moving at a steady velocity (terminal velocity) through the fluid, the buoyant force F_b and the weight of the sphere F_g will balance the drag force F_d .

The buoyant force can be calculated using the formula:

$$F_b = \rho_f V g = \rho_f \left(\frac{4}{3} \pi r^3 \right) g,$$

and the weight of the sphere is given by:

$$F_g = \rho_s V g = \rho_s \left(\frac{4}{3} \pi r^3 \right) g.$$

At terminal velocity:

$$F_g - F_b = F_d$$

Calculate the terminal velocity v of the sphere.

- A 0.045 ms^{-1}
- B 0.13 ms^{-1}
- C 0.25 ms^{-1}
- D 0.75 ms^{-1}

6. Scalars, vectors, couples and equilibrium

Question 1.

Which of the following is a pair of vectors?

- A weight and work
- B force and energy
- C displacement and momentum
- D acceleration and power

Question 2.

P and **Q** represent displacements.



What is the resultant displacement when **P** and **Q** are added?

- A 
- B 
- C 
- D 

Question 3.

Which two quantities have the base unit $\text{kg m}^2 \text{s}^{-2}$?

- A kinetic energy and momentum
- B kinetic energy and Young modulus
- C work done and the moment of a couple
- D work done and pressure

Question 4.

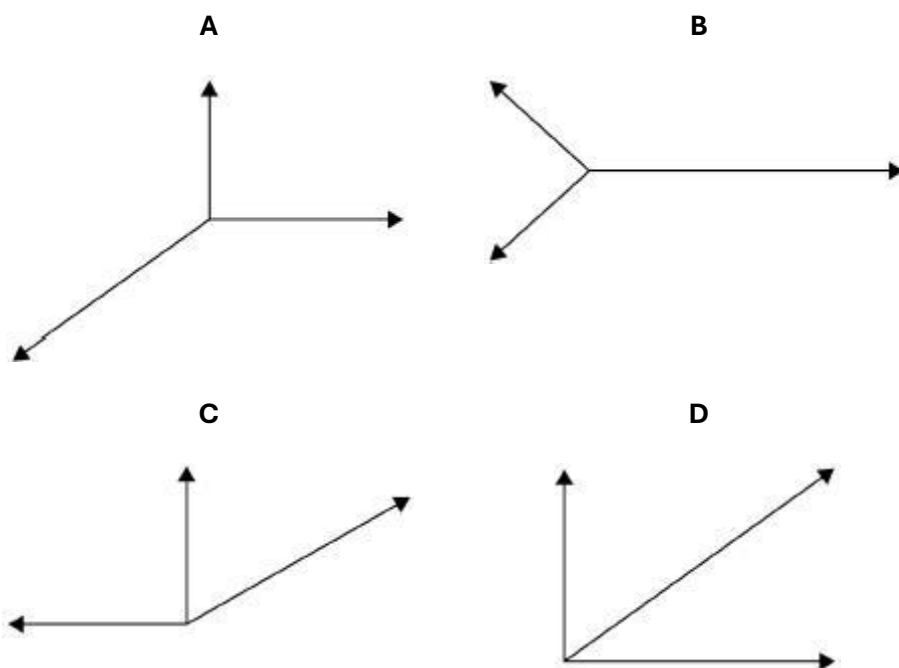
Two forces of 6 N and 10 N act at a point. Which of the following could not be the magnitude of the result?

- A 16 N
- B 8 N
- C 5 N
- D 3 N

Question 5.

An object is in equilibrium when acted on by three coplanar forces.

Which free-body diagram is correct? Each diagram is drawn to scale.

**Question 6.**

A 2-meter-long uniform bench weighing 400 N is supported by two legs, one at each end. A 300 N person sits 0.5 meters from the left end of the bench.

What is the force exerted by the right leg of the bench to keep it in equilibrium?

- A 275 N
- B 300 N
- C 350 N
- D 425 N

Question 7.

Which description of a couple and its unit is correct?

- A consists of two equal parallel forces, Nm^{-1}
- B produces translational motion, Nm
- C consists of two equal and opposite forces, Nm
- D produces rotational motion, Nm^{-1}

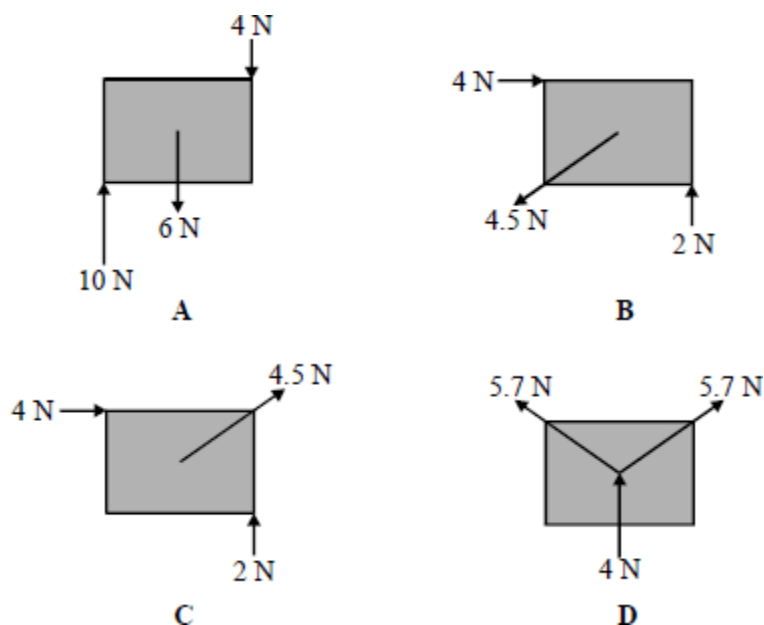
Question 8.

Two equal and opposite forces of 30 N are applied to opposite sides of a steering wheel, each 0.2 meters from the centre. What is the torque (moment of the couple) applied to the steering wheel?

- A 0 Nm
- B 3 Nm
- C 6 Nm
- D 12 Nm

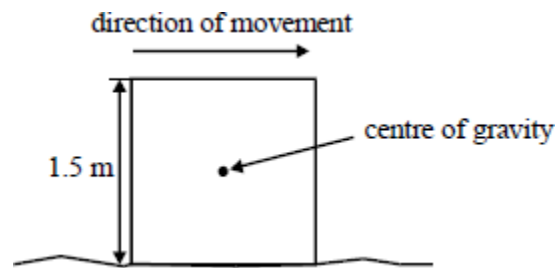
Question 9.

The rectangular objects, A, B, C and D are each 2 cm long and 1 cm high. Which one of the bodies is in equilibrium?



Question 10.

A uniform square block is sliding with uniform speed along a rough surface as shown in the diagram.



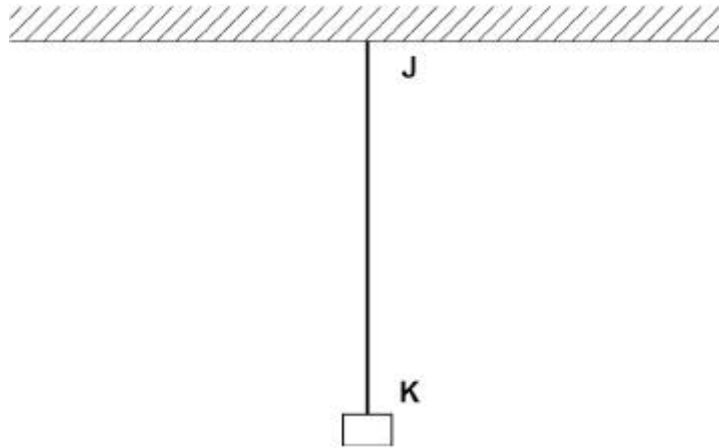
The force used to move the block is 200 N. The moment of the frictional force acting on the block about the centre of gravity of the block is

- A 150 N m, clockwise
- B 150 N m, anticlockwise
- C 300 N m, clockwise
- D 300 N m, anticlockwise

7. Material science, work and friction

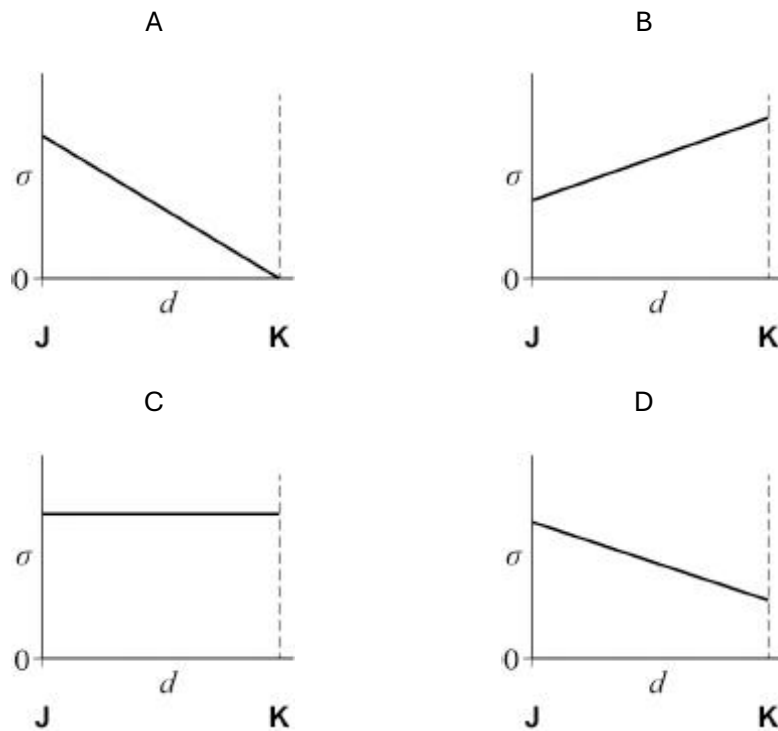
Question 1.

A heavy cable is attached to a fixed support and carries a load at its lower end.



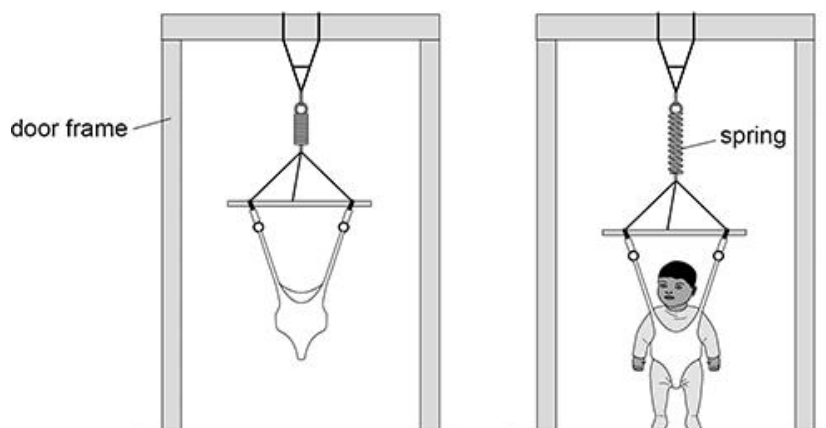
The weight of the cable is **not** negligible. The cable has a constant cross-sectional area and density.

Which graph shows the variation of tensile stress σ in the cable with distance d from J to K?



Question 2.

A baby bouncer consists of an inextensible harness attached to a spring.

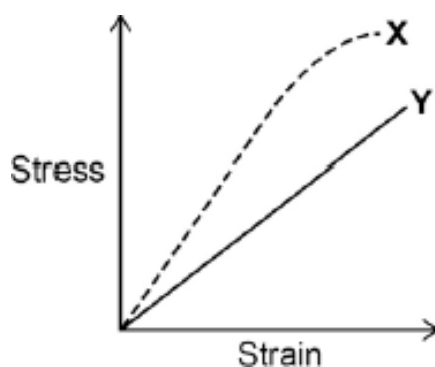


Making reasonable approximations, what is a sensible range for the stiffness of the spring?

- A 1–10 N m⁻¹
- B 10–100 N m⁻¹
- C 100–1000 N m⁻¹
- D 1000–10000 N m⁻¹

Question 3.

The diagram shows how the stress varies with strain for metal specimens X and Y which are different. Both specimens were stretched until they broke.



Which statement is **incorrect**?

- A X is stiffer than Y
- B X has a higher value of the Young modulus
- C X is more brittle than Y
- D Y has a lower maximum tensile stress than X

Question 4.

A person jumps as high as she can from a standing position.

What is a reasonable estimate of her speed just after she leaves the ground?

- A 2 ms^{-1}
- B 4 ms^{-1}
- C 8 ms^{-1}
- D 10 ms^{-1}

Question 5.

A 1,500 W electric motor is used to lift a 200 kg object vertically at a constant speed. The motor is 80% efficient. What happens to the energy input to the motor, and what is the useful energy output?

- A The motor transfers 80% of the input energy to lifting the object, and 20% is wasted as heat and sound energy.
- B The motor transfers all of the input energy to lifting the object because energy is always conserved, but some energy is lost as heat and sound.
- C The motor transfers 80% of the input energy to the object as gravitational potential energy, while 20% is wasted as heat, but no energy is lost to the surroundings.
- D The motor transfers 100% of the input energy to lifting the object, but energy is wasted due to inefficiency in converting electrical energy to mechanical energy.

Question 6.

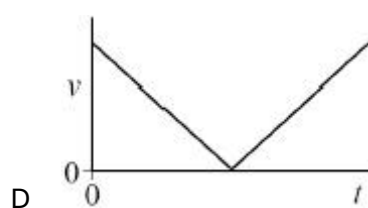
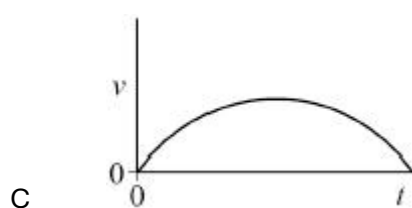
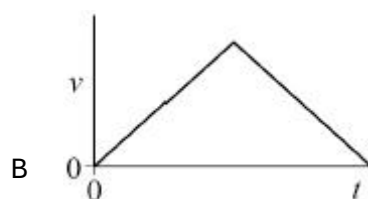
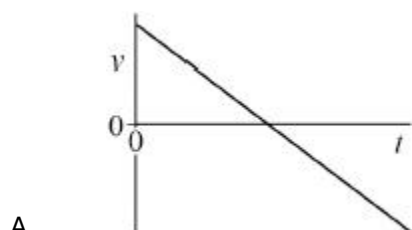
A box is being pulled along a rough, horizontal surface with a rope. The rope makes an angle of 30° above the horizontal, and a constant pulling force of 100 N is applied. The box moves 5 m horizontally. Friction is present between the box and the surface, opposing the motion. How does the work done compare to the ideal situation (without friction), and what can be said about the net work done?

- A The work done is greater than 433 J because friction increases the energy required to move the box.
- B The work done is exactly 433 J because only the horizontal component of the applied force matters, and friction doesn't affect this.
- C The work done is less than 433 J because friction removes energy from the system, reducing the net work done.
- D The work done is 433 J because friction does not affect the work done by the horizontal component of the applied force.

Question 7.

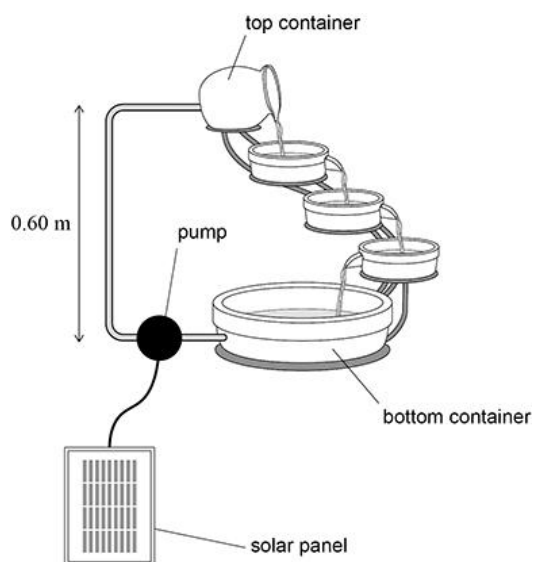
A girl kicks a football vertically upwards at time $t = 0$. Air resistance is negligible.

What is the variation of the vertical component of velocity v of the football with t until it reaches the ground?



Question 8.

A solar panel powers a pump for a water feature.



Solar energy is incident on the solar panel at a rate of 1.5 W .

Water from the bottom container is continually pumped through a vertical height of 0.60 m to the top container.

The overall efficiency of the solar panel and the pump is 20% .

What mass of water can be pumped into the top container each second?

- A 5 g
- B 50 g
- C 100 g
- D 250 g

Question 9.

An object of mass m is accelerated from rest to a velocity v by a constant resultant force F .

What is the work done on the object during this acceleration?

- A $\frac{Fv}{2}$
- B Fv
- C mv^2
- D $\frac{mv^2}{2}$

Question 10.

The drag force on a boat is kv^2 , where v is the speed and $k = 64 \text{ kg m}^{-1}$.

The boat's engine has a useful power output of 8000 W.

What is the maximum speed of the boat?

- A 0.2 ms^{-1}
- B 5 ms^{-1}
- C 11 ms^{-1}
- D 125 ms^{-1}

8. Projectile motion, Newton's laws and momentum

Question 1.

A firework is fired vertically up into the air and subsequently falls to the ground.

Which quantity relating to the motion of the rocket is never zero before it hits the ground? Assume that air resistance is negligible.

- A acceleration
- B velocity
- C momentum
- D kinetic energy

Question 2.

A golf ball was hit from the surface of the Moon. The time of flight was 4.0 s.

What is the best estimate for the maximum height reached by the ball? You can assume acceleration due to gravity on the Moon = 1.6 m s^{-2} .

- A 80 m
- B 40 m
- C 5 m
- D 3 m

Question 3.

An object is dropped from a cliff. How far does the object fall in the third second? Assume that $g = 10 \text{ m s}^{-2}$.

- A 10 m
- B 20 m
- C 25 m
- D 45 m

Question 4.

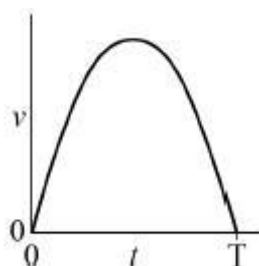
A ball is thrown vertically upwards and returns to its original position 2.4 s later. The effect of air resistance is negligible.

What is the total distance travelled by the ball?

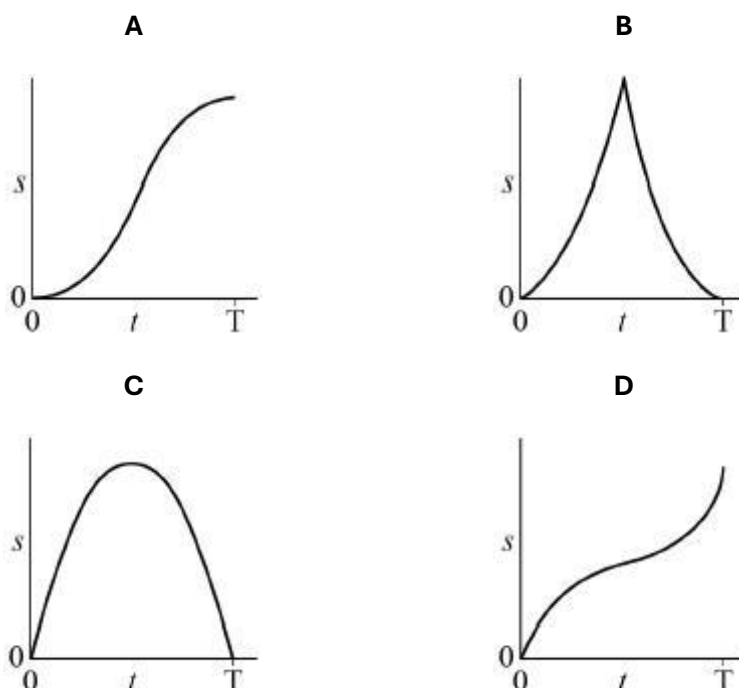
- A 28 m
- B 14 m
- C 7.1 m
- D 3.5 m

Question 5.

The diagram shows how the speed v of an object varies with time t .



Which graph shows the variation of distance s with t for the object?



Question 6.

Two ball bearings **X** and **Y** are projected from horizontal ground at the same time.

X has mass $2m$ and is projected vertically upwards with speed u .

Y has mass m and is projected at 30° to the horizontal with speed $2u$.

Air resistance is negligible.

Which statement is correct?

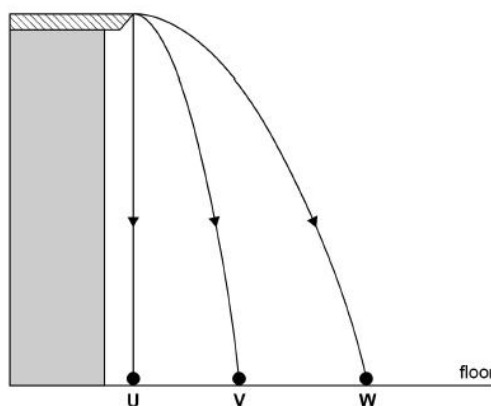
- A **X** and **Y** have the same initial momentum.
- B **X** and **Y** reach their maximum heights at different times.
- C The maximum height reached by **Y** is half that reached by **X**.
- D **X** and **Y** reach the ground at the same time.

Question 7.

Three objects **U**, **V** and **W** leave the edge of a bench at the same time. The objects fall in the same vertical plane with negligible air resistance.

U is released from rest so that it falls vertically. **V** and **W** are projected horizontally.

The paths of the three objects are shown.

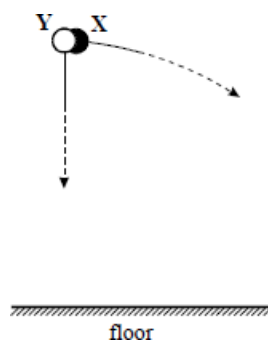


Which statement is correct?

- A **U** hits the floor before **V** and **W**.
- B **W** hits the floor before **V**.
- C **W** hits the floor with the greatest speed.
- D **U** hits the floor with the greatest speed.

Question 8.

A ball **X** is projected horizontally from a certain point at the same time as a ball **Y** of the same diameter but twice the mass is released from rest and allowed to fall vertically from the same level. Air resistance is negligible. Which one of the following will occur?



- A **Y** will hit the floor just before **X**
- B **X** will hit the floor just before **Y**
- C **Y** hits the floor while **X** is halfway to the floor
- D **X** and **Y** will hit the floor at the same time

Question 9.

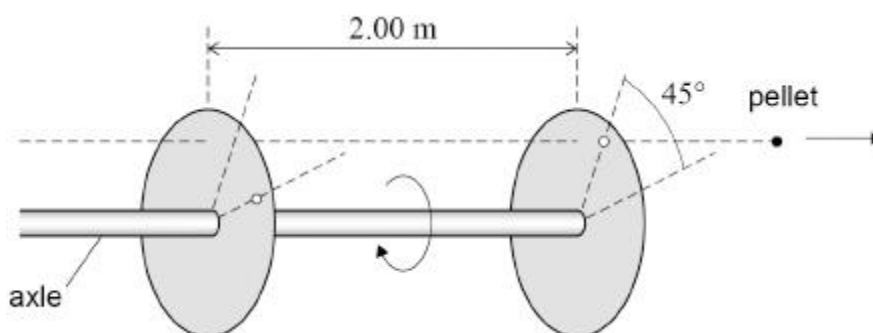
A parachutist descends to the ground at a constant speed with the parachute open.

Which force, together with the parachutist's weight, makes a pair according to Newton's third law of motion?

- A the drag force on the parachutist from the air
- B the tension in the strings of the parachute
- C the gravitational force of the parachutist on the Earth
- D the lift force on the parachute from the air

Question 10.

Two circular discs made of card rotate at constant speed on a common axle.



The discs are 2.00 m apart.

An air-gun pellet is fired parallel to the axle. The pellet makes holes in the discs.

The holes are separated by an angle of 45°.

The speed of the pellet between the discs is 300 m s^{-1} .

How many revolutions does each disc complete in one second?

- A 19
- B 118
- C 740
- D 1074

9. Waves

Question 1.

A pebble is dropped into a calm pond, creating ripples that spread outwards from the point where the pebble entered the water.

Which of the following best describes the sequence of events that leads to the transmission of the disturbance (energy) through the water?

- A The pebble pushes water molecules outward in all directions, causing them to carry energy away from the centre.
- B Water molecules at the surface move outward with the ripples, pushing neighbouring water molecules farther away from the centre.
- C Water molecules are displaced from their equilibrium position by the pebble and then try to return, disturbing their neighbouring molecules in the process.
- D The water molecules near the pebble form a continuous path, transmitting energy outward through direct contact.

Question 2.

A longitudinal wave of frequency 660 Hz travels through a medium.

The wave speed is 330 m s^{-1} .

Which statement describes the motion of a particle in the wave?

- A It is travelling at a speed of 330 m s^{-1} .
- B It oscillates with a time period of 1.5 ms.
- C It moves in phase with a particle in the wave 25 cm away.
- D It changes direction 660 times every second.

Question 3.

Monochromatic light passes from air into water.

Which one of the following statements is true?

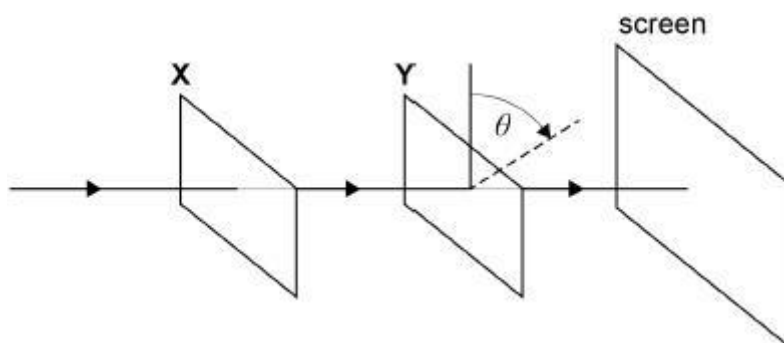
- A The velocity and wavelength change but not the frequency
- B The velocity and frequency change but not the wavelength
- C The velocity, frequency and wavelength all change
- D The frequency and wavelength change but not the velocity

Question 4.

Unpolarised light travels through two polarising filters **X** and **Y** and is then incident on a screen.

When **X** and **Y** are arranged as shown, there is a maximum intensity on the screen.

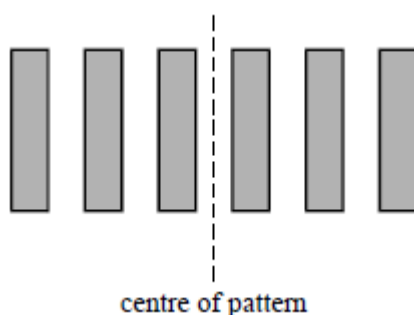
X is held stationary but **Y** is rotated in a plane at right angles to the beam so that θ increases.



What are the next three values of θ , in rad, for which the beam hits the screen with maximum intensity?

- A $\frac{\pi}{2}, \frac{2\pi}{2}, \frac{3\pi}{2}$
- B $\frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}$
- C $\pi, 2\pi, 3\pi$
- D $2\pi, 4\pi, 6\pi$

Question 5.



A double-slit interference experiment is performed using monochromatic light of wavelength λ . The centre of the observed pattern is a bright fringe.

What is the path difference between two waves which interfere to give the third dark fringe?

- A 3.5λ
- B 2.5λ
- C 1.5λ
- D 0.5λ

Question 6.

Which is a description of the pattern produced when monochromatic light passes through a very narrow slit?

- A A series of equally-spaced light and dark fringes.
- B A narrow central maximum with wider side fringes.
- C A few bright fringes that are widely spaced.
- D A wide central maximum with narrower side fringes.

Question 7.

In a Young's double-slit experiment, monochromatic light is incident on two narrow slits and the resulting interference pattern is observed on a screen.

Which change **decreases** the fringe separation?

- A decreasing the separation between the two slits
- B increasing the distance between the slits and the screen
- C using monochromatic light of higher frequency
- D using monochromatic light of longer wavelength

Question 8.

Which property of lasers is most important for interference studies?

- A Coherency
- B Monochromaticity
- C Intensity
- D Polarisation

Question 9.

Why do materials have a natural frequency of vibration?

- A They are composed of atoms that can move freely in any direction.
- B They possess elastic properties that allow them to store and release energy.
- C They absorb all frequencies of sound and convert them into heat.
- D They are rigid and do not deform under stress.

Question 10.

Electrons with a certain kinetic energy pass through a powdered crystalline sample and are incident on a fluorescent screen.

The diagram shows a sketch of the diffraction pattern produced.



A change is made, and this second pattern is produced.



Which change could produce the second pattern?

- A decreasing the kinetic energy of the electrons
- B replacing the electron source with a proton source
- C using a crystalline sample with a wider spacing between its atoms
- D moving the screen closer to the crystalline sample

10. Circular motion and SHM

Question 1.

In a circular track, a runner completes one full lap. If the track has a circumference of 400 meters, how many radians has the runner covered when they finish the lap?

- A 1.37 radians
- B 3.14 radians
- C 6.28 radians
- D 360 radians

Question 2.

A mass on the end of a string is whirled around in a horizontal circle at increasing speed until the string breaks. The subsequent path taken by the mass is:

- A A straight line tangent to the circle at the point of release.
- B A curved path that continues in a circular motion.
- C A straight line towards the centre of the circle.
- D An elliptical path that eventually spirals outward.

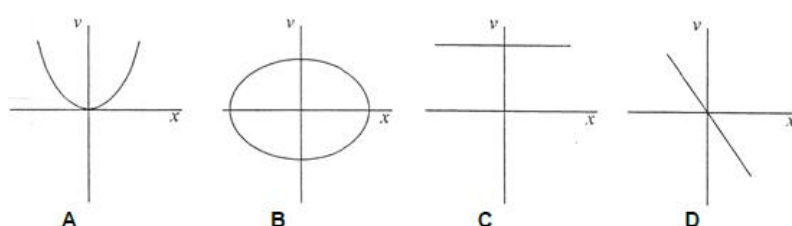
Question 3.

For a particle moving in a circle with uniform speed, which one of the following statements is correct?

- A The momentum of the particle is constant.
- B The force on the particle is in the same direction as the direction of motion of the particle.
- C The kinetic energy of the particle is constant.
- D The displacement of the particle is in the direction of the force.

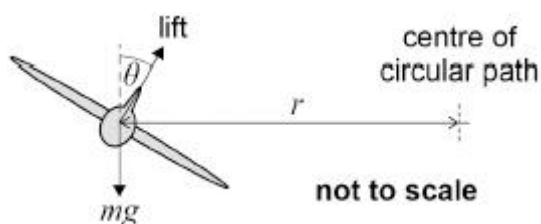
Question 4.

Which graph shows how the velocity v of a body moving with simple harmonic motion varies with its displacement x



Question 5.

When an aircraft turns in a horizontal circular path, it banks at an angle θ .



The aircraft has mass m and travels at constant speed v in a horizontal circular path of radius r .

The lift force acts at the angle θ .

What is $\tan \theta$?

Hint: consider what the vertical and horizontal components of lift would have to be in order to have only horizontal circular motion.

- A $\frac{gv^2}{r}$
- B $\frac{rv^2}{g}$
- C $\frac{rg}{v^2}$
- D $\frac{v^2}{rg}$

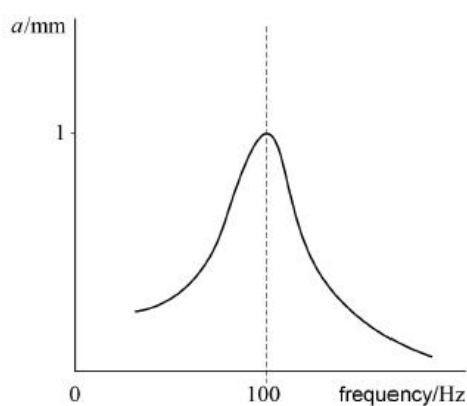
Question 6.

The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same which of the following is also doubled?

- A The time period.
- B The total energy.
- C The maximum velocity.
- D The maximum acceleration.

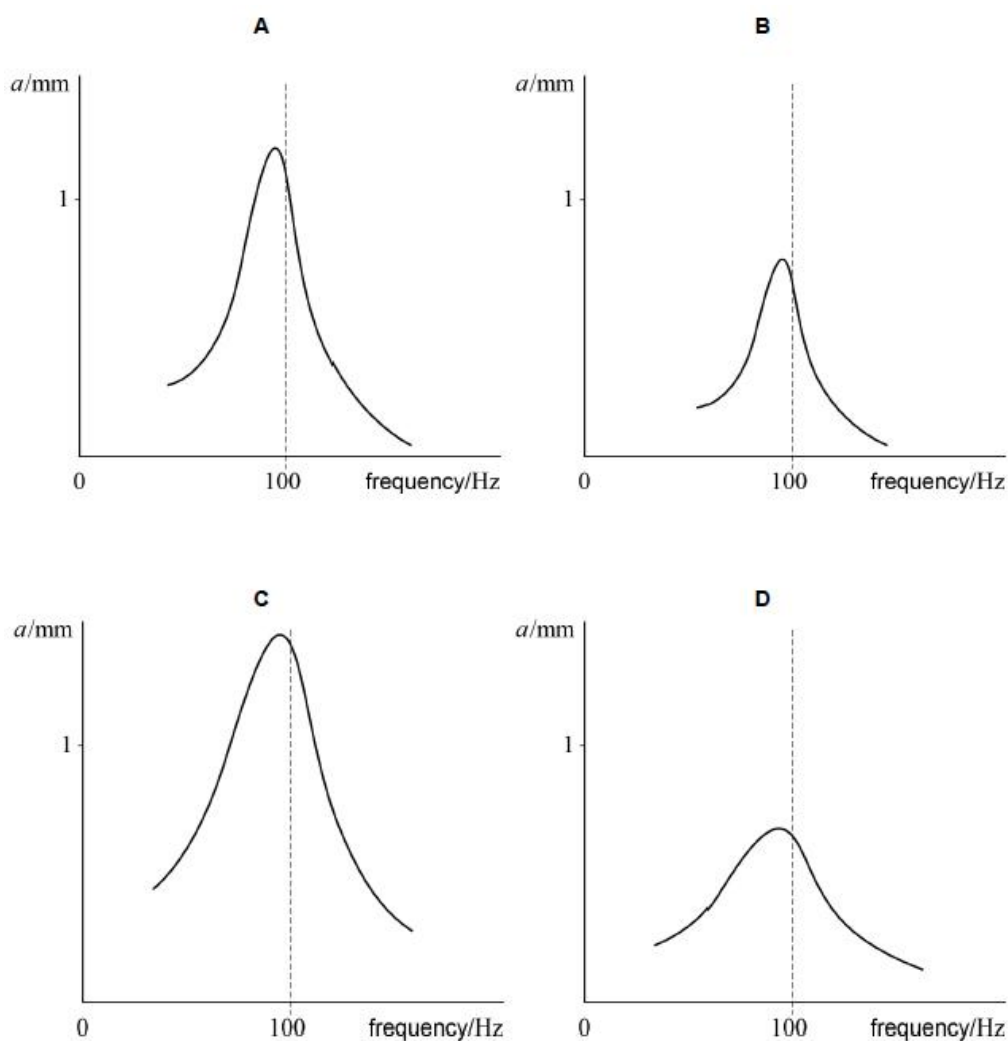
Question 7.

A metal panel is driven to vibrate at different frequencies. The amplitude a of the vibration is measured at each frequency. The graph shows the variation of amplitude with driven frequency.



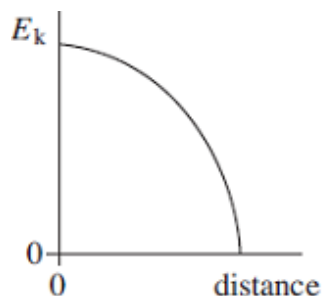
The damping of the metal panel is increased without changing the mass of the panel.

Which graph shows the variation of a with frequency with increased damping?

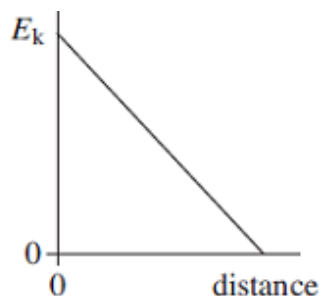


Question 8.

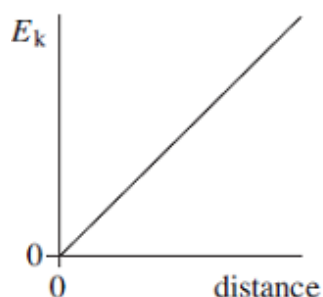
A body executes simple harmonic motion. Which one of the graphs, **A** to **D**, best shows the relationship between the kinetic energy, E_k , of the body and its distance from the centre of oscillation?



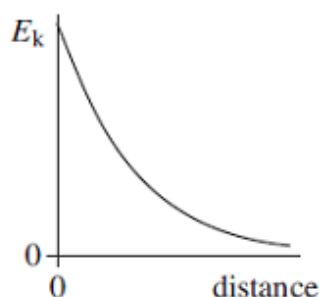
A



B



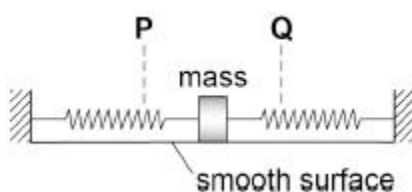
C



D

Question 9.

A mass, attached to two springs, oscillates horizontally between **P** and **Q**. The motion of the system is simple harmonic.



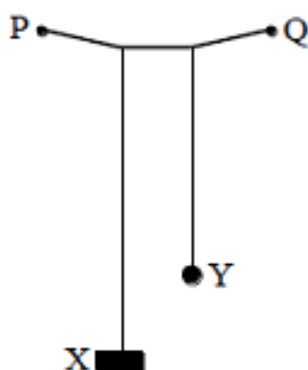
Which quantity has its magnitude at a minimum value when the mass is at **Q**?

- A the acceleration of the mass
- B the kinetic energy of the mass
- C the potential energy of the mass-spring system
- D the resultant force of the springs on the mass

Question 10.

The diagram shows two pendulums suspended from the same thread, PQ. This is known as 'Barton's Pendulum'.

Barton's Pendulum is a basic yet effective demonstration of the principles of simple harmonic motion and resonance. It consists of a pendulum with multiple bobs that swing in unison, showcasing how energy transfer occurs between the pendulum bobs through their synchronised oscillations, illustrating concepts such as phase and frequency in oscillatory systems. The observation of resonance is evident as the bobs with lengths that match specific resonant frequencies will oscillate with greater amplitude, while those with differing lengths will exhibit diminished motion.



X is a heavy pendulum, the frequency f_x of which can be varied. Y is a lighter pendulum of fixed frequency f_y . As the frequency of the oscillation of X is increased by shortening the thread, the amplitude of the oscillation of Y changes.

When the length of the thread for X and Y are close, the amplitude of vibrations should increase due to resonance.

Which one of the following graphs best represents the relationship between the amplitude a_y of the oscillation of Y and the frequency f_x of X?

