A-Level Physics - Exam Style Questions

Group A: Multiple Choice Questions

50 questions (20 × 1 mark, 20 × 2 marks, 10 × 4 marks), 100 marks total

Recommended Time: 2 hours 15 minutes.
Approximate Grade Boundaries (marks): A* > 80, A > 70, B > 60.
Content coverage is based on the OCR Specification.

Section A. Multiple Choice Questions

A1. A paper cone is held above the ground and dropped. It falls vertically and reaches terminal velocity before it hits the ground.

The resultant force on the falling cone before it reaches terminal velocity is

① decreasing and upwards
② decreasing and downwards
③ increasing and upwards
④ increasing and downwards [1 mark]

A2. A solid molecular substance is supplied with energy and it starts to melt.

Which pair of quantities remains the same as the substance melts?

A Kinetic energy of molecules
B Potential energy of molecules
C Internal energy of molecules
D Temperature of substance

① **A** and **C**
② **A** and **D**
③ **B** and **C**
④ **B** and **D** [1 mark]

Section A. Multiple Choice Questions

A3. Coherent radio waves from transmitters **X** and **Y** are emitted in phase. The waves interfere constructively at point **Z**.

The distance **XZ** is 16.0 m and the distance **YZ** is 20.0 m. The radio waves have wavelength λ.

Which value of λ is **not** possible?

① 1.0 m
② 2.0 m
③ 3.0 m
④ 4.0 m [1 mark]

A4. The potential difference across the cathode and the anode of an X-ray tube is V. The minimum wavelength of the X-ray photons emitted from the tube is λ_0.

Which of the following is/are true?

A λ_0 is halved when V is doubled.
B λ_0 is unchanged when the temperature of the cathode is increased.
C λ_0 is independent of the cathode material.

① **A** and **B** only
② **B** only
③ **A** and **C** only
④ **A**, **B** and **C** [1 mark]

Section A. Multiple Choice Questions

A5. Which of these statements about the photoelectric effect is true?

① The photoelectric current produced in the circuit increases with the intensity of the incident light.

② The stopping potential is the equilibrium potential difference between two identical plates of photoelectric material when light is incident on one and electrons travel to the other.

③ The work function of a photoelectric material is the energy required to eject one electron from the lowest energy level of a surface atom.

④ The De Broglie wavelength of the fastest photoelectrons is less than the wavelength of the incident light.

[1 mark]

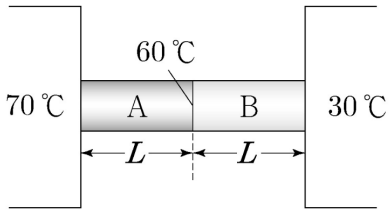
A6. A particle has a momentum of 30 Ns and a kinetic energy of 150 J.

The mass of the particle is

① 1 kg
② 2 kg
③ 3 kg
④ 4 kg [1 mark]

Section A. Multiple Choice Questions

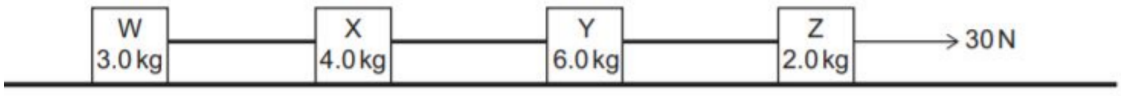
A7. Two heat baths at fixed temperatures of 70 °C and 30 °C respectively are connected by two straight metal rods in series, each with length L and equal cross-sectional area. When the system, which is insulated from its surroundings, has reached thermal equilibrium, the temperature at the interface between the two rods is measured as 60 °C.



What is the value of the ratio $\frac{thermal\ conductivity\ of\ rod\ A}{thermal\ conductivity\ of\ rod\ B}$?

① 1 / 4
② 1 / 3
③ 3
④ 4 [1 mark]

A8. The diagram shows four objects W, X, Y and Z, of masses 3.0 kg, 4.0 kg, 6.0 kg and 2.0 kg respectively, connected by light, inextensible rods. The objects are pulled along a smooth, horizontal surface by a constant force of 30 N in the direction indicated.



What is the force in the rod connecting X and Y, and is the force tensile or compressive?

① 14 N (tensile)
② 105 N (tensile)
③ 14 N (compressive)
④ 105 N (compressive) [1 mark]

Section A. Multiple Choice Questions

A9. A helium balloon is held by a light taut inextensible string in the middle of the back of a very powerful truck. The back of the truck is sufficiently large that the balloon cannot hit the sides if it sways forwards or backwards on the string.

The truck now accelerates rapidly forwards. What happens to the balloon?

(The back of the truck is completely enclosed with no airflow from the outside.)

① The balloon sways backwards.
② The balloon sways forwards.
③ The balloon expands slightly without moving.
④ The balloon falls vertically to the floor. [1 mark]

A10. The existence of the Chandrasekhar limit is a direct result of

① The Schwarzchild radius of a black hole being less than the radius of the white dwarf of the same mass.

② The mass of a star in its red giant phase being higher than the mass of the same star in its protostar stage.

③ The electron degeneracy pressure being constant despite variation in stellar mass.

④ The neutron degeneracy pressure being constant despite increased density at the core of a red supergiant.

[1 mark]

Section A. Multiple Choice Questions

A11. Two identical cylindrical pipes of length 20 cm are closed at one end and open at the other. A musician can produce a sound by blowing gently across the top of their pipe. The frequency of the sound changes if there is some water filling up the bottom of the pipe.

The musician plays a chord which requires the frequencies of the sounds to be in the ratio 3 : 4, which is done by pouring water to a depth of h into one pipe.

(Assume only the fundamental frequency is played. Ignore end effects.)

What is the value of h?

① 5 cm
② 7 cm
③ 10 cm
④ 14 cm [1 mark]

A12. The secondary coil of an ideal, 100% efficient transformer is connected to a resistor by cables of total resistance 1500 Ω. The current in the primary coil is 4.0 A.

There are 240 turns in the primary coil and 4800 turns in the secondary coil.

What is the power produced as heat in the cables?

① 60 W
② 330 W
③ 6 kW
④ 13 kW [1 mark]

Section A. Multiple Choice Questions

A13. A neutron is absorbed by a uranium-235 nuclide. The resulting nuclide undergoes fission to produce a bromine-88 nuclide, a lanthanum-145 nuclide and some neutrons.

The lanthanum-145 (^{145}La) nuclide is radioactive and undergoes β^- decay.

How many neutrons are emitted in the fission reaction and how many neutrons are there in the nuclide formed by the decay of lanthanum-145?

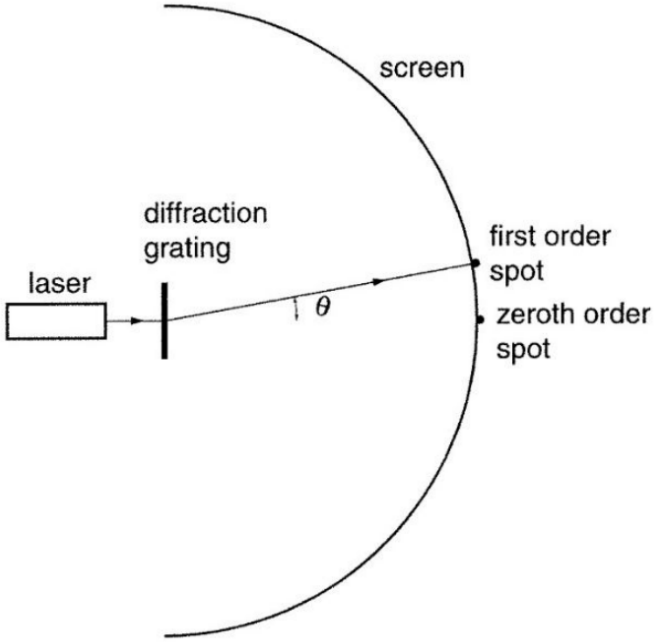
(Element symbols and proton numbers: uranium (U) = 92, bromine (Br) = 35)

[1 mark]

	neutrons emitted in fission	neutrons in ^{145}La decay product
①	2	88
②	2	90
③	3	90
④	3	89

Section A. Multiple Choice Questions

A14. A parallel beam of red light of wavelength 630 nm from a laser is incident normally on a diffraction grating. A semi-circular screen subtending an angle of 180° is centred at the point of diffraction, oriented normal to the plane of the diffracted laser light as shown.



The grating has 300 lines per millimetre. How many spots appear on the screen?

(Assume all spots are of sufficient intensity to be viewed correctly.)

① 5
② 6
③ 10
④ 11 [1 mark]

A15. Which of these radionuclides is most commonly used in medical diagnoses?

① uranium-238
② technetium-99m
③ polonium-209
④ promethium-145 [1 mark]

Section A. Multiple Choice Questions

A16. Below is a table of mechanical properties relevant for the ultrasound imaging of biological tissue.

Material	Density / kg m^{-3}	Speed of ultrasound / ms^{-1}
Air	1.3	330
Water	1000	1500
Muscle	925	1450
Fat	1075	1590
Bone	1650	4080

Which pair of materials would have the smallest intensity reflection coefficient?

① air into bone
② water into muscle
③ fat into water
④ muscle into fat [1 mark]

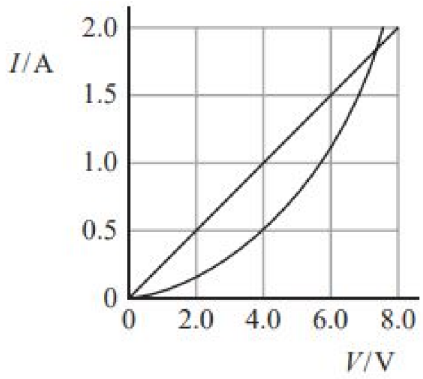
A17. A spring is suspended vertically in an initially unloaded state and extends under its own weight by 5 mm from its natural length. When a mass of 21 grams is attached, the spring extends to a total of 3.5 cm from its natural length.

What is the mass of the spring?

① 2.5 g
② 3.0 g
③ 3.5 g
④ 4.0 g [1 mark]

Section A. Multiple Choice Questions

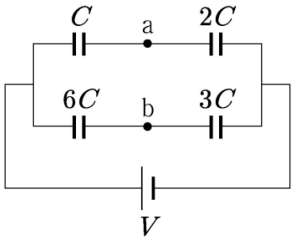
A18. The I-V characteristics of a particular resistor and thermistor are shown.



The resistor and thermistor are connected in series to a 6 V battery with negligible internal resistance. The current in the circuit is

① 0.5 A
② 1.0 A
③ 1.5 A
④ 2.0 A [1 mark]

A19. A circuit of capacitors is charged completely by a cell with potential difference V. The capacitances of each capacitor are C, $2C$, $3C$ and $6C$.

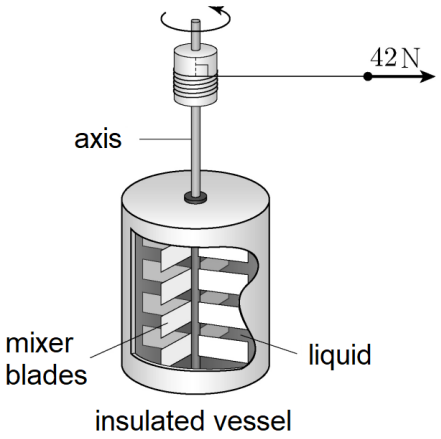


An ideal voltmeter connected between points a and b would read a potential difference with magnitude

① 0
② $\frac{1}{3}V$
③ $\frac{1}{4}V$
④ $\frac{2}{3}V$ [1 mark]

Section A. Multiple Choice Questions

A20. A mixer is driven by unwinding a cable by a total distance of 5.0 m under a constant tension of 42 N. As a result of this, it is found that the temperature of the liquid inside the mixer increases by an amount ΔT.



The mass and specific heat capacity of the liquid inside are 0.1 kg and 4200 J kg^{-1} K^{-1} respectively. Which calculation(s) is/are correct?

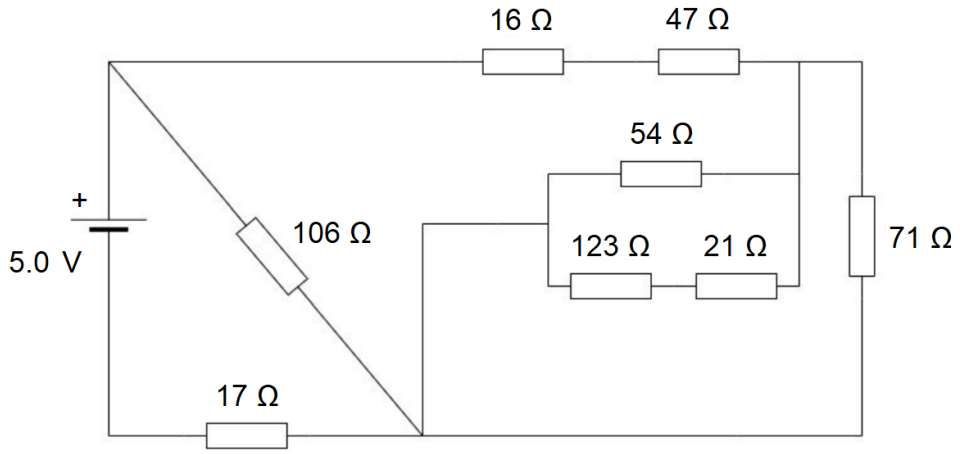
(Neglect the heat transfer to the blades or shaft, and neglect friction.)

A The work done by the force pulling the string is 210 J.
B The heat absorbed by the liquid is 420 J.
C $\Delta T = 0.6$ °C.

① **A** only
② **C** only
③ **A** and **B** only
④ **B** and **C** only [1 mark]

Section A. Multiple Choice Questions

A21. The resistor network shown is connected across a 5.0 V cell with negligible internal resistance.



What is the total thermal power dissipated in the resistor network?

① 77 mW
② 150 mW
③ 380 mW
④ 550 mW [2 marks]

A22. A transverse wave with an amplitude of 4.0 cm and a frequency of 10 Hz travels along a rope at a speed of 2.4 ms^{-1}.

What is the total distance travelled by a particle in the rope in a time of 20 s?

① 24 m
② 32 m
③ 48 m
④ 96 m [2 marks]

Section A. Multiple Choice Questions

A23. The line spectrum of the Sun shows changes in wavelength due to the Doppler effect. As the Sun rotates about its axis, one edge of the Sun is approaching the Earth, and the other edge is receding.

The apparent wavelength of a line of original wavelength 589 nm is measured from photographs showing opposite ends of the diameter of the Sun. The difference between the readings is 7.80 pm.

The radius of the Sun is 6.96×10^8 m. Calculate $\frac{angular\ speed\ of\ Earth}{angular\ speed\ of\ the\ Sun}$.

① 25.5
② 41.9
③ 75.5
④ 99.1 [2 marks]

A24. A radio transmitter transmits a signal at 600 MHz to a receiver 1 km away. In an attempt to double the strength of the signal at the receiver, a second antenna is added at the transmitter, 1 m away alongside the original one, and fed by the same signal.

An engineer notes that instead of improving reception, diffraction effects might actually make reception much worse.

Which of the following provides a valid argument to either support or refute the engineer's prediction?

① Diffraction effects would not be a problem because the waves are too low frequency to produce diffraction effects.

② Diffraction effects would not be a problem as the transmitting antennas are too far apart to produce diffraction effects.

③ Diffraction effects will occur, but the maxima would be sufficiently close together that this would not be a problem.

④ Diffraction effects could be a problem because the distance between the transmitting antennas is comparable to the wavelength. [2 marks]

Section A. Multiple Choice Questions

A25. The Digest of UK Energy Statistics (2015) reports that in the UK in 2014 the total amount of electricity generated was 3.4×10^5 GW h, and it also states that total electricity consumption was 3.0×10^5 GW h.

Which of the following is the main reason for the difference between the figures quoted for generation and consumption?

① Power stations in the UK are on average only about 88% efficient.

② Electrical appliances in the UK are on average only about 88% efficient.

③ About 12% of the electricity generated is lost in the distribution network.

④ The data on consumption are incomplete. [2 marks]

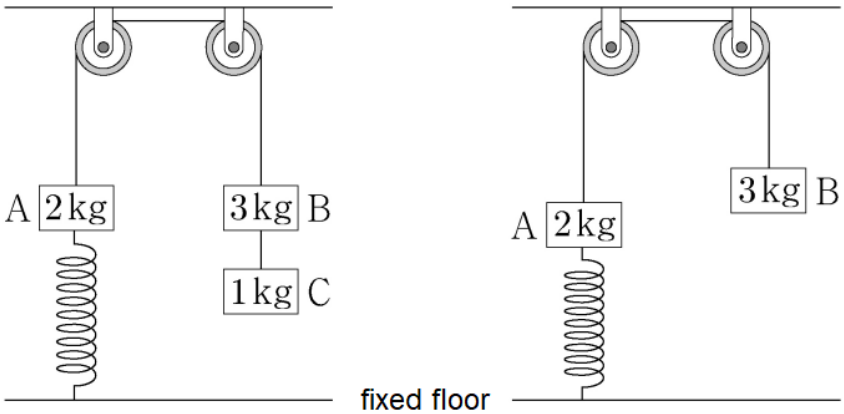
A26. A car is driving along a road and approaches a 50 metre long bridge and begins accelerating at 5 ms^{-2} when it enters the bridge. The car reaches the end of the bridge with a speed of 30 ms^{-1}.

The time taken to drive across the bridge was closest to

① 2 seconds
② 4 seconds
③ 5 seconds
④ 10 seconds [2 marks]

Section A. Multiple Choice Questions

A27. A system of block masses, frictionless pulleys, inextensible strings and an ideal spring in a vertical plane is shown. The spring has force constant 200 N m^{-1} and has negligible natural length. Use $g = 10$ ms^{-2}.



(state **1**, equilibrium) (state **2**)

In the equilibrium state (**1**), the extension of the spring is x m. When the string connecting B and C is cut as shown in (**2**), the masses A and B begin to execute simple harmonic motion each with amplitude y m.

What is the value of $x + y$? (Use $g = 10$ ms^{-2}.)

① 0.06
② 0.10
③ 0.12
④ 0.15 [2 marks]

Section A. Multiple Choice Questions

A28. An incandescent bulb has a thin filament of tungsten that is heated to several thousand degrees Celsius by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament.

If the bulb is powered at constant voltage, which of these is true?

① The temperature distribution over the filament is uniform.

② The resistance over small sections of the filament decreases with time.

③ The filament emits more light at a lower band of frequencies before it breaks up.

④ The filament consumes less electrical power towards the end of the life of the bulb.

[2 marks]

A29. A liquid at 30 °C is poured very slowly into a copper beaker which is at a temperature of 110 °C. The boiling point of the liquid is 80 °C. It is found that the first 5 grams of the liquid completely evaporates. After pouring in another 80 grams, the equilibrium temperature is measured to be 50 °C.

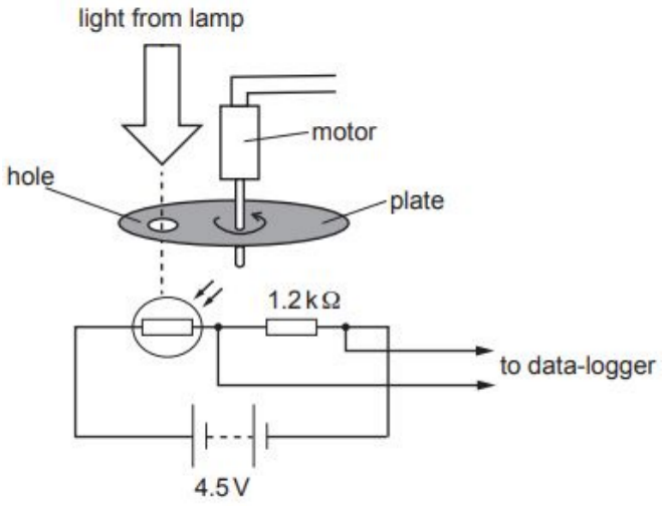
Find the value of $\frac{specific\ latent\ heat\ of\ vaporisation\ of\ the\ liquid}{specific\ heat\ capacity\ of\ the\ liquid}$.

(Neglect heat exchange with the surroundings. Use a consistent system of units.)

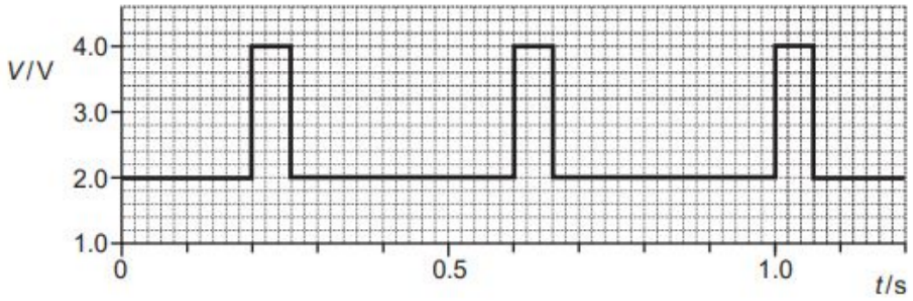
① 118 K
② 270 K
③ 395 K
④ 420 K [2 marks]

Section A. Multiple Choice Questions

A30. A metal circular plate is rotated at a constant frequency by an electric motor. The plate has a small hole close to its rim.



A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger. The graph shows the variation of V with time t.



Which of these statements, if any, is/are true?

① The angular frequency of the rotating plate is about 16 rad s^{-1}.

② The resistance of the LDR when exposed to the lamp is ten times that of when it is shielded from the lamp.

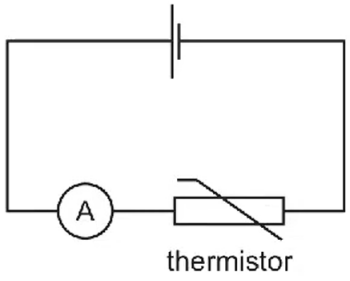
③ Both of the above.

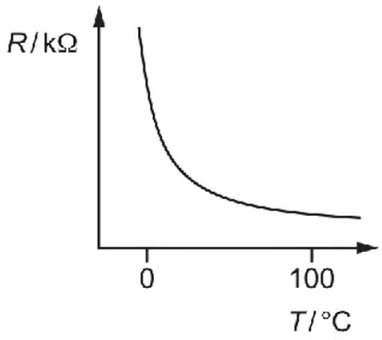
④ None of the above. [2 marks]

Section A. Multiple Choice Questions

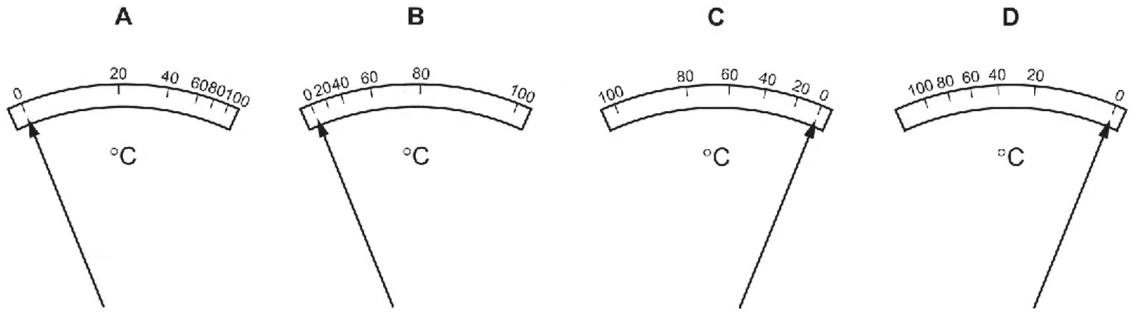
A31. An analogue ammeter is to be recalibrated as a thermometer by connecting to a circuit in series with a cell of negligible internal resistance and an NTC thermistor.

The circuit is shown on the left and the variation of temperature with the resistance of the thermistor is shown on the right.





Which diagram could represent the temperature scale on the ammeter?

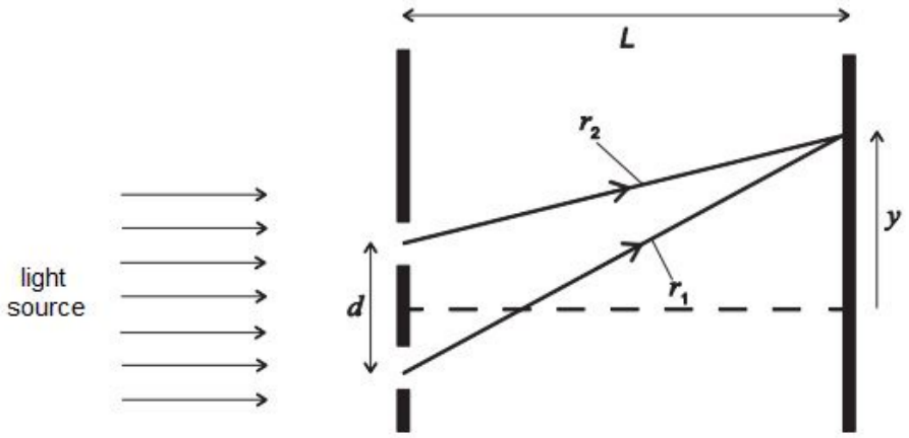


① **A**
② **B**
③ **C**
④ **D**

[2 marks]

Section A. Multiple Choice Questions

A32. The diagram shows the geometry for two slit diffraction of light, with the slits on the left and the viewing screen on the right, with slit separation d and distance L such that $d << L$.



The pair of slits is illuminated by coherent laser light of wavelength $\lambda = 600$ nm. A diffraction pattern appears on the viewing screen.

A thin piece of transparent material, thickness 300 nm and in which the speed of light is half that in air, is now placed immediately behind **one** of the two slits.

What happens to the diffraction pattern and why?

① The diffraction pattern is unchanged because the light is still coherent.

② The diffraction pattern disappears because the light from the two slits is no longer in phase.

③ The complete diffraction pattern shifts in the y-direction because the path difference required for a maxima to appear has changed.

④ Each maximum is replaced by two because the material halves the wavelength of the light coming from it.

[2 marks]

Section A. Multiple Choice Questions

A33. A man drops a heavy stone into a well of unknown depth. A digital stopwatch is started at the time of releasing the stone, which have been erroneously pressed early or late by up to 100 milliseconds. When the sound of the stone hitting the bottom of the well is heard by the man at the top, he stops the timer with a reaction time assumed to be between 200 and 300 milliseconds.

The stopped timer reads 4.405 seconds.

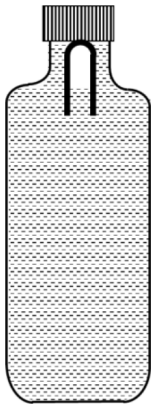
What is the man's calculation for the depth of the well and its associated uncertainty?

(Use g = 9.81 ms^{-2} and the speed of sound is 343 ms^{-1}; neglect the uncertainty in these quantities, neglect the effect of air resistance, and assume the timer value is not rounded.)

① 75.9 ± 5.8 m
② 75.9 ± 2.9 m
③ 84.7 ± 6.1 m
④ 84.7 ± 3.1 m [2 marks]

Section A. Multiple Choice Questions

A34. A soft plastic bottle, filled with water of density 1 g cm^{-3}, carries an inverted glass test-tube with some air (an ideal gas) trapped as shown in the figure. The test-tube has a mass of 5 g, and it is made of a thick glass of density 2.5 g cm^{-3}.



Initially the bottle is sealed at atmospheric pressure $p_0 = 10^5$ Pa so that the volume of the trapped air is $v_0 = 3.3$ cm^3. When the bottle is squeezed from outside at constant temperature, the pressure inside rises and the volume of the trapped air reduces.

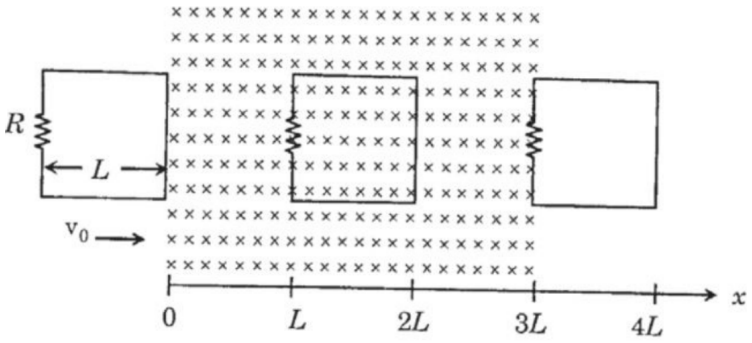
It is found that the test tube begins to sink at pressure $p_0 + \Delta p$ without changing its orientation. At this pressure, the volume of the trapped air is $v_0 - \Delta v$.

You may assume that the mass of trapped air is much less than the mass of the test tube. Find the values of Δv and Δp.

① $\Delta v = 0.3$ cm^3; $\Delta p = 2 \times 10^4$ Pa
② $\Delta v = 0.3$ cm^3; $\Delta p = 1 \times 10^4$ Pa
③ $\Delta v = 0.6$ cm^3; $\Delta p = 2 \times 10^4$ Pa
④ $\Delta v = 0.6$ cm^3; $\Delta p = 1 \times 10^4$ Pa [2 marks]

Section A. Multiple Choice Questions

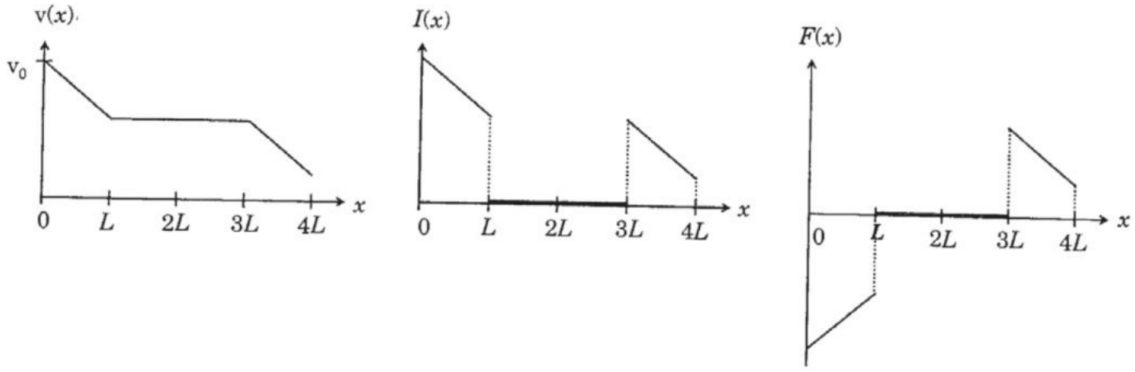
***A35.** A rigid square wire of side length L, resistance R and mass m is moving along the x-axis in the plane of the paper. At time $t = 0$, the leading edge of the square enters a uniform magnetic field region pointing into the plane of the paper.



For a sufficiently large initial speed v_0 into the magnetic field, the loop crosses the region and emerges at the other side. Let x be the position of the leading edge of the loop on the length-scale shown. Let v, I and F be the velocity of the loop, current in the loop and force exerted on the loop respectively.

(Positive values of I represent currents directed anti-clockwise. Neglect gravity.)

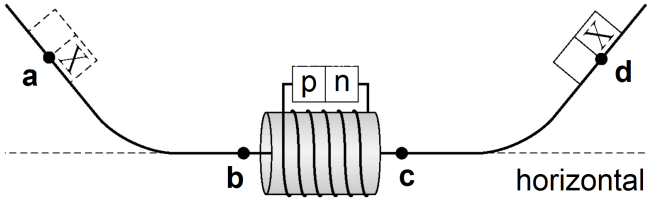
Which graph, if any, of v, I or F as a function of x could be correct?



① the graph of $v(x)$
② the graph of $I(x)$
③ the graph of $F(x)$
④ none of the graphs are correct [2 marks]

Section A. Multiple Choice Questions

***A36.** A p-n junction, the semiconducting component of an LED, is connected to the ends of a solenoid. A permanent magnet is free to slide on a frictionless, nonmagnetic track passing through points **a**, **b**, **c** and **d** as shown, and passing through the solenoid air core. X is either the North or South pole of the magnet.



When the magnet descends from **d** and passes through **c**, it is observed that the p-n junction emits light. The magnet changes direction at **a** before descending again through **b**.

Which of these statements must be true?

(Assume that the reverse bias current of the p-n junction is zero.)

A X is the North pole of the magnet.

B When the magnet descends through **b** after changing direction at **a**, the p-n junction also emits light.

C The mechanical energy of the magnet is the same at **a** and **d**.

① **A** and **B** only
② **B** and **C** only
③ **A** and **C** only
④ **A**, **B** and **C** [2 marks]

Section A. Multiple Choice Questions

A37. ^{131}I is an isotope of iodine that β-decays to a stable isotope of xenon with a halflife of 8 days. A small amount of a serum labelled with ^{131}I is injected into the blood of a person. The activity of the amount of ^{131}I injected was 2.4×10^5 Bq. It is known that the injected serum will get distributed uniformly in the bloodstream in less than half an hour.

After 11.5 hours, 2.5 ml of blood is drawn from the person's body, and gives an activity of 115 Bq.

The total volume of blood in the person's body is

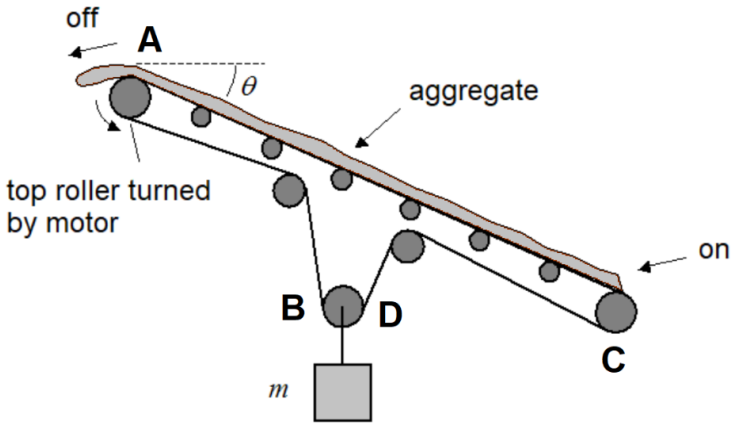
① 1.0 litres
② 1.4 litres
③ 5.0 litres
④ 7.9 litres [2 marks]

Section A. Multiple Choice Questions

A38. A heavy conveyor belt loop transports a continuous stream of aggregate material of density ρ at a steady speed. The belt is powered by a motor which exerts a constant anticlockwise torque M on the top roller, which has radius r.

The inclination of the stream is θ and the belt passes over a series of pulleys as shown, which may not be smooth. The belt is held taut everywhere by a hanging mass m.

Four points on the belt, **A**, **B**, **C** and **D**, are labelled at the positions shown.



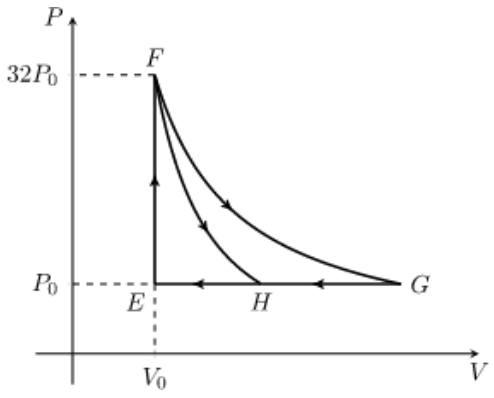
Identify the locations of maximum and minimum tension along the conveyor belt.

[2 marks]

	maximum tension at	minimum tension at
①	**A**	**C**
②	**C**	**A**
③	**B**	**D**
④	**D**	**B**

Section A. Multiple Choice Questions

A39. A fixed quantity of an ideal gas undergoes a cycle of five processes through states $E \rightarrow F \rightarrow H \rightarrow E \rightarrow F \rightarrow G$ as shown on the pressure-volume diagram.



Given that $F \rightarrow G$ is an isothermal process, which statement is true about the other four processes?

① In process $E \rightarrow F$, the work done on the gas is 31 P_0V_0.

② In process $F \rightarrow H$, the temperature of the gas increases.

③ In process $H \rightarrow E$, the r.m.s. speed of the gas molecules decreases.

④ In process $G \rightarrow E$, the energy released as heat by the gas is equal to the decrease in the internal energy of the gas.

[2 marks]

Section A. Multiple Choice Questions

A40. Stellar nucleosynthesis begins with the nuclear fusion of hydrogen into helium, which occurs in three steps through helium-3 intermediate nuclei as shown:

$$ {}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + e^{+} + \nu_{e} $$

$$ {}^{2}_{1}H + {}^{1}_{1}H \rightarrow {}^{3}_{2}He + \gamma $$

$$ {}^{3}_{2}He + {}^{3}_{2}He \rightarrow \alpha + {}^{1}_{1}H + {}^{1}_{1}H $$

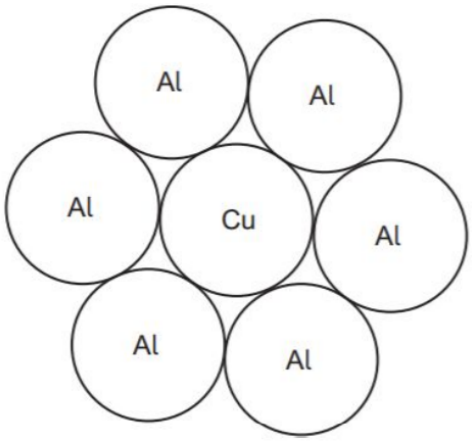
In an artificial fusion reactor, when one mole of hydrogen-1 gas ($^{1}H_{2}$) is heated into its plasma state and undergoes complete, 100% efficient nuclear fusion into helium-4, what quantity of nuclear energy is released?

(Rest masses: ^{1}H = 1.00783 amu, ^{4}He = 4.00260 amu, e^{+} = 0.000548 amu.)

① 622 GJ
② 1.24 TJ
③ 622 TJ
④ 1.24 PJ [2 marks]

Section A. Multiple Choice Questions

A41. A power cable consists of a cylindrical copper (Cu) wire surrounded by six cylindrical aluminium (Al) wires. All the wires are of the same cross-sectional area as shown:



The densities of aluminium and copper are d and $3d$ respectively. The resistivities of aluminium and copper are 3ρ and 2ρ respectively. The cable has mass M and length L.

The resistance R between the two ends of the cable is

① $\frac{28\rho dL^2}{3M}$

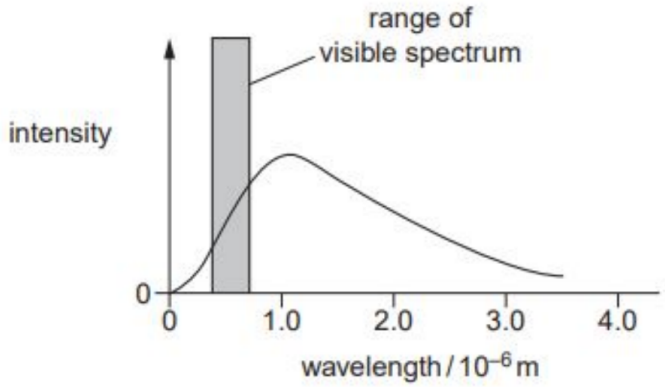
② $\frac{21\rho dL^2}{M}$

③ $\frac{180\rho dL^2}{7M}$

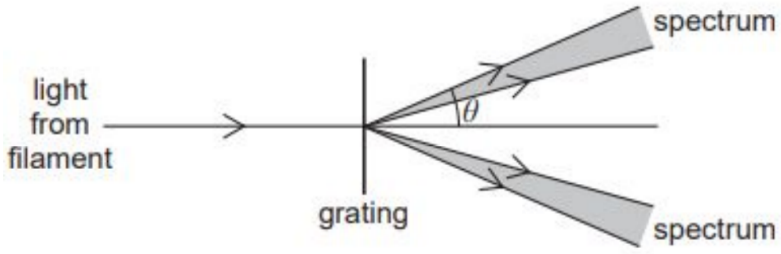
④ $\frac{18\rho dL^2}{5M}$ [4 marks]

Section A. Multiple Choice Questions

A42. The tungsten filament of a 12 V / 24 W lamp glows white hot emitting photons across a continuous spectrum of energies. The intensity variation with the wavelength of the electromagnetic radiation from the filament is shown below.



When the light from the filament is focussed through a diffraction grating having 300 lines per millimetre, the continuous first-order visible spectrum is seen on a hemispherical screen normal to the light between the angles of $\theta = 7°$ and 12°.

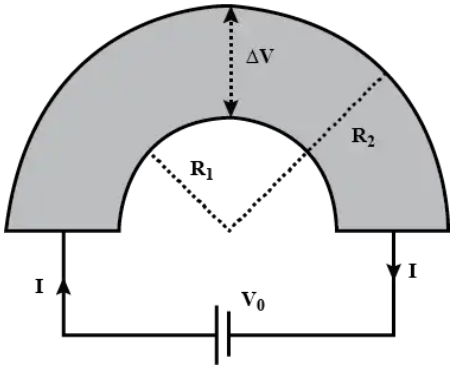


At angles of $\theta = 7°$ and 12° , the colours and relative intensities seen on the screen are, respectively, [4 marks]

	at $\theta = 7°$	at $\theta = 12°$
①	red (brightest)	violet (dimmest)
②	red (dimmest)	violet (brightest)
③	violet (brightest)	red (dimmest)
④	violet (dimmest)	red (brightest)

Section A. Multiple Choice Questions

A43. A semicircular metallic strip with thickness t is connected at both ends to a cell of constant potential difference V_0. A constant current I flows in the circuit.



After some time, it is observed that an additional transverse voltage ΔV develops across the inside and outside edges of the strip.

Which statement explains why this occurs, and correctly identifies which edge is at the higher potential?

① The current I heats the strip, increasing its resistivity. As the outside edge has a longer effective length than the inside edge, the resulting resistance is highest on the outside, allowing less current to flow there, giving the outside edge lower potential and the **inside edge higher potential**.

② The current I sets up magnetic field loops which point out of the page on the outside edge and into the page on the inside edge. This generates a force which pushes the electrons towards the inside edge, giving the **outside** edge **higher voltage**.

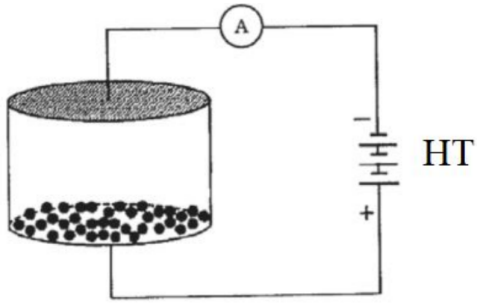
③ The electrons moving on the outside must have a higher drift velocity v than those on the inside. Since $I = Anev$, there must be a larger current on the outside, requiring a potential difference with a **higher voltage outside** since the strip resistivity can be assumed uniform.

④ The circular path of the electrons means there must be a centripetal force F, which acts inwards. This is caused by an electric field E, given by $F = eE = m_e v^2 / r$ where v is the drift velocity. The direction of the electric field must therefore be outwards, giving **higher potential on the inside**.

[4 marks]

Section A. Multiple Choice Questions

***A44.** An evacuated cylindrical chamber of height h consisting of two parallel metal conducting plates. At time $t = 0$, a high-voltage (HT) source is connected as shown, with the bottom plate at potential $+V_0$ and the top plate at potential $-V_0$:



Inside the cylinder are a large number of small, light spherical balls, initially at rest on the bottom plate. The surfaces of the balls are conducting, and as a result, the balls will get charged, become equipotential with the bottom plate and be repelled by it. Eventually the balls will collide with the top plate.

(Assume the electric field inside the cylinder can be modelled as that of a parallel-plate capacitor, and that the balls are very small. Neglect gravity.)

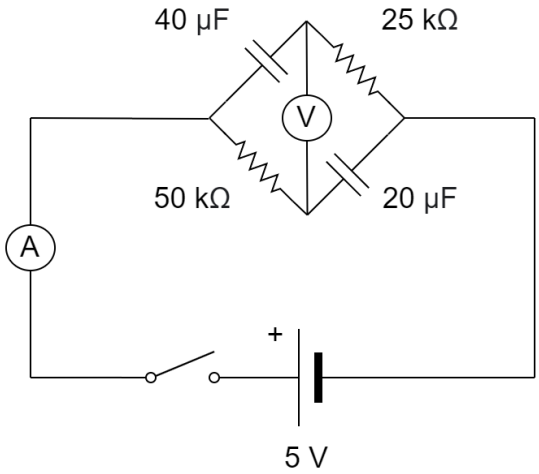
Determine either: [4 marks]

- what happens to the balls next?
- how the average current I_{avg} registered by the ammeter as $t \to \infty$ varies?

	What happens to the balls next?	Variation of I_{avg}?
①	The balls will stick to the top plate and remain there.	$I_{avg} = 0$
②	The balls will execute simple harmonic motion between the two plates.	$I_{avg} \propto \sqrt{V_0}$
③	The balls will bounce back to the bottom plate, carrying the same charge (both magnitude and sign) as they went up with.	$I_{avg} \propto V_0$
④	The balls will bounce back to the bottom plate, carrying the opposite charge (same magnitude, opposite sign) as they went up with.	$I_{avg} \propto V_0^2$

Section A. Multiple Choice Questions

A45. An RC network is connected to a switch and ideal cell as shown. All capacitors are initially completely discharged and at time $t = 0$, the switch is closed.

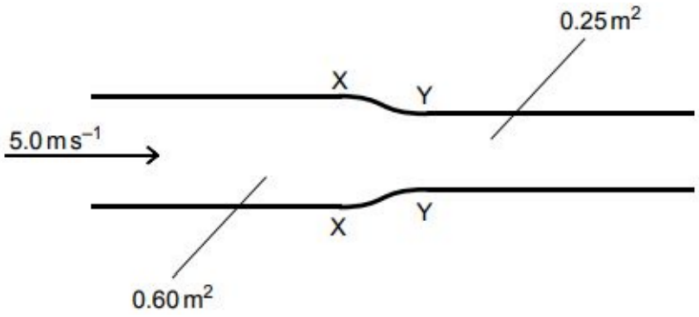


The voltmeter reading follows an exponential variation with a time constant of

① 0.5 seconds
② 1 second
③ 2 seconds
④ 5 seconds [4 marks]

Section A. Multiple Choice Questions

A46. Oil of density 800 kg m^{-3} is being pumped through a pipe of cross-sectional area 0.60 m^2 at a speed of 5 ms^{-1}. Between points X and Y, the oil passes through a contraction to a new cross-sectional area of 0.25 m^2 before leaving the pipe.



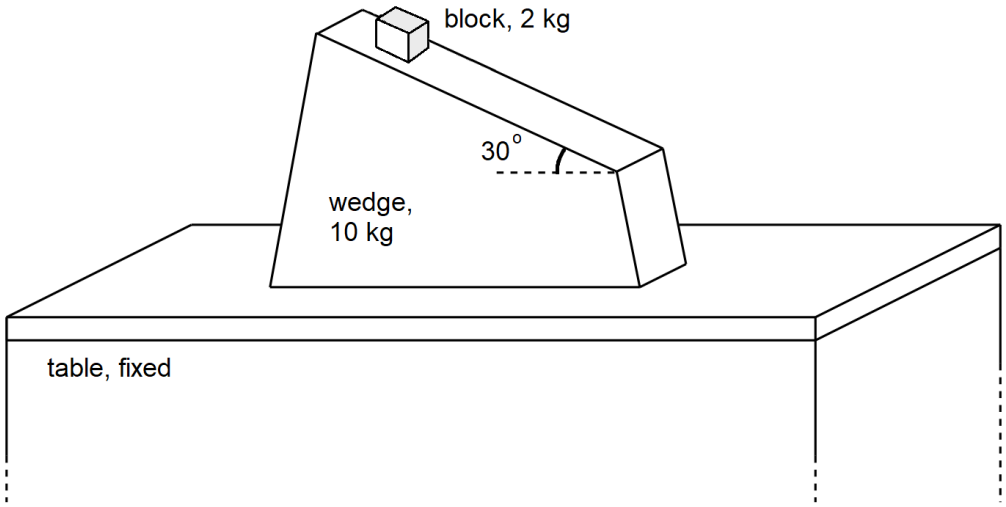
What is the resultant force F exerted on the oil as it passes from X to Y, and what is the power P required to maintain the flow in this section of the pipe?

(Assume that the oil is incompressible, and the pipe is frictionless and flowing at maximum capacity.)

① F = 7.0 kN to the right; P = 35 kW
② F = 7.0 kN to the right; P = 58.8 kW
③ F = 16.8 kN to the right; P = 84 kW
④ F = 16.8 kN to the right; P = 143 kW [4 marks]

Section A. Multiple Choice Questions

***A47.** A small dense block of mass 2 kg is free to slide on the surface of a hollow glass wedge of mass 10 kg, which is inclined at an angle of 30° to the horizontal. The wedge is **also** free to slide on a fixed horizontal table. All sliding is frictionless.



By applying Newton's Second Law to both the wedge and the block individually, which of the following resultant acceleration calculations can be deduced?

(Assume that the block maintains full contact with the wedge, and without any object falling off its support. g is the gravitational acceleration. Use exact values.)

A The acceleration of the wedge relative to the table is $\frac{\sqrt{3}g}{21}$, to the left.

B The acceleration of the block relative to the table is $\frac{(3+2\sqrt{3})g}{42}$, in the direction parallel to the slope and downward.

C The acceleration of the block relative to the **wedge** is $\frac{15g}{14}$, with a positive component to the right.

① **A** and **B** only
② **A** and **C** only
③ **A** only
④ **C** only [4 marks]

Section A. Multiple Choice Questions

A48. A spherical bubble of gas forms at the bottom of a glass containing a fizzy drink. The radius of the bubble at the point of formation, at the bottom of the drink, is R. The depth of the liquid in the glass is h, and the density of the liquid of the drink is ρ. Atmospheric pressure is P. As the bubble rises, its radius changes.

Which expression gives the radius of the bubble when it is at a depth x below the surface of the drink? (Gravitational field strength $= g$; the mass of the gas in the bubble is constant and the process is isothermal throughout.)

① $R \times \left(\frac{h\rho g + P}{x\rho g + P}\right)^{1/3}$

② $R \times \left(\frac{h}{x}\right)^{1/3}$

③ $R \times \left(\frac{x\rho g + P}{h\rho g + P}\right)^{1/3}$

④ $R \times \left(\frac{x\rho g - P}{h\rho g - P}\right)^{1/3}$ [4 marks]

A49. Two identical moving coil galvanometers have 10 Ω resistance and show full scale deflection at 2 μA current. One of them is converted into a voltmeter of 100 mV full scale reading and the other into an ammeter of 1 mA full scale current using appropriate resistors. These are then used to measure the voltage and current in the Ohm's law experiment using a resistor known to have a resistance of exactly 1 kΩ.

Which statement, if any, is true?

① The resistor required to make the voltmeter is 100 kΩ, connected in series with the galvanometer.

② The resistor required to make the ammeter is 40 mΩ, connected in parallel with the galvanometer.

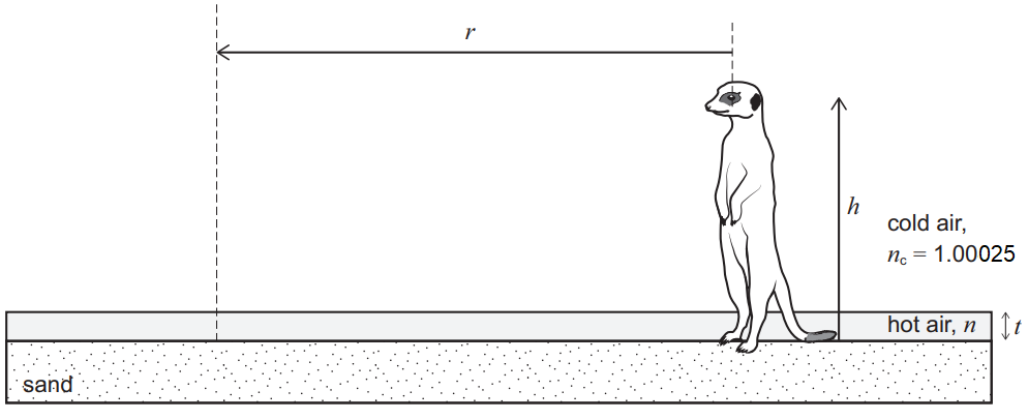
③ The calculated resistance of the resistor will be 980 Ω to the nearest integer, and is independent of the e.m.f. and internal resistance of the cell.

④ None of the above. [4 marks]

Section A. Multiple Choice Questions

A50. A meerkat is in a desert on a hot day with a clear blue sky above the sand. A thin layer of air, of thickness t, above the sand is so hot that it has a lower density, and hence a lower refractive index, n, than the cooler air directly above it, which has refractive index $n_c = 1.00025$.

The meerkat has height h where $h \gg t$. The meerkat believes that he is standing on an 'island' of sand of radius r, with what appears to be water all around him. He thinks that there is water because at distances greater than r away from him, he sees a reflection of the blue sky when he is looking below the horizon towards the ground. This effect is known as a 'mirage'.



By considering how critical (limiting) rays of light reach the meerkat's eyes, find an expression for the radius *r* of the meerkat's mirage island.

① $r = \dfrac{hn}{\sqrt{n_c^{\,2} + n^2}}$

② $r = \dfrac{hn^2}{n_c^{\,2} + n^2}$

③ $r = \dfrac{hn}{\sqrt{n_c^{\,2} - n^2}}$

④ $r = \dfrac{hn^2}{n_c^{\,2} - n^2}$

[4 marks]