May 2010

Time Zone 1

IB SL Key

1. The best estimate for the time it takes light to cross the nucleus of the hydrogen atom is

A. 10^{-23} s.

B. 10^{-20} s.

C. 10^{-15} s.

D. 10^{-7} s.

2. The length of each side of a sugar cube is measured as 10 mm with an uncertainty of ± 2 mm. Which of the following is the absolute uncertainty in the volume of the sugar cube?

A. $\pm 6\,mm^3$

B. $\pm 8\,mm^3$

C. $\pm 400\,mm^3$

D. $\pm 600\,mm^3$

3. The time taken for a stone dropped from rest to fall vertically through 16 m is 2.0 s. Based on these measurements, what is the best estimate for the acceleration of free fall?

A. $4.0\,m\,s^{-2}$

B. $8.0\,m\,s^{-2}$

C. $9.8\,m\,s^{-2}$

D. $10\,m\,s^{-2}$

4. A wooden block is sliding down an inclined plane at constant speed. The magnitude of the frictional force between the block and the plane is equal to

A. zero.

B. the magnitude of the weight of the block.

C. the magnitude of the component of weight of the block parallel to the plane.

D. the magnitude of the component of the normal reaction parallel to the plane.

5. Which of the following is a correct statement of Newton's second law of motion?

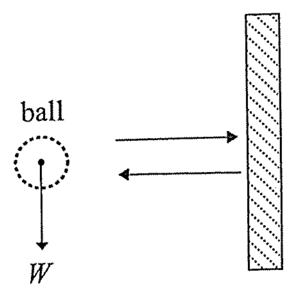
A. A force acting on a body is proportional to the mass of the body.

B. The rate of change of momentum of a body is equal to the net external force acting on the body.

C. The momentum of a body is proportional to the net external force acting on the body.

D. A force acting on a body is proportional to the acceleration of the body.

6. A ball of weight W is travelling horizontally towards a vertical wall. It strikes the wall and rebounds horizontally. The change in the magnitude of the momentum of the ball is Δp. Which of the following is the magnitude of the impulse that the ball imparts to the wall?



A. $W+\Delta p$

B. $W-\Delta p$

C. W

D. Δp

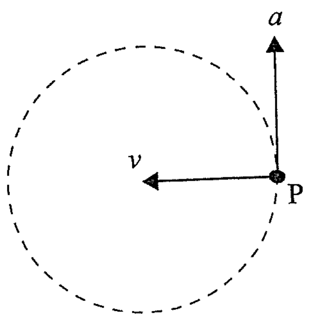
7. Two objects undergo an inelastic collision. Which of the following is correct in respect of both the conservation of momentum and the conservation of total energy of the system?

	Momentum	Total energy
A.	conserved	not conserved
B.	conserved	conserved
C.	not conserved	not conserved
D.	not conserved	conserved

8. A particle P is moving anti-clockwise with constant speed in a horizontal circle.

Which diagram correctly shows the direction of the velocity v and acceleration a of the particle P in the position shown?

A.



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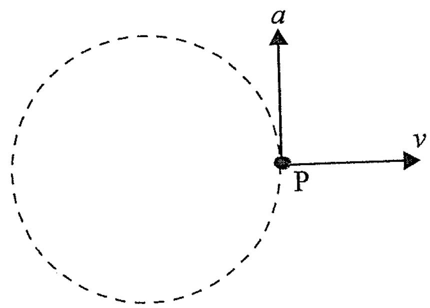

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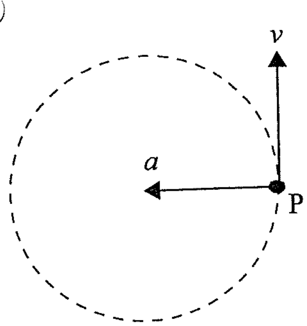
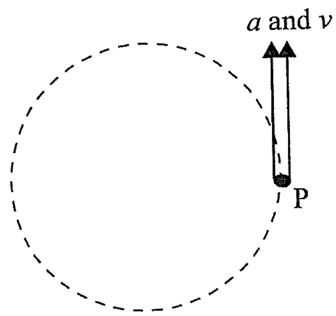


D.



9. Two objects are in thermal contact with each other. Which of the following will determine the direction of the transfer of thermal energy between the bodies?

A. The mass of each body

B. The area of contact between the bodies

C. The specific heat capacity of each body

D. The temperature of each body

10. The mole is defined as

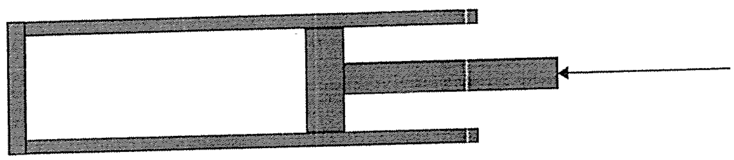
A. $\frac{1}{12}$ the mass of an atom of the isotope carbon-12.

B. the amount of a substance that contains as many elementary entities as the number of atoms in 12 g of the isotope carbon-12.

C. the mass of one atom of the isotope carbon-12.

D. the amount of a substance that contains as many nuclei as the number of nuclei in 12 g of the isotope carbon-12.

11. A gas is contained in a cylinder by a piston.



The gas is compressed rapidly by moving the piston in the direction shown. The best explanation for the resulting increase in temperature of the gas is that the molecules of the gas gain kinetic energy

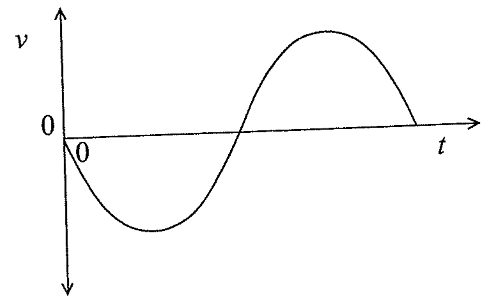
A. from the moving piston.

B. by colliding more frequently with each other.

C. by being pushed closer together.

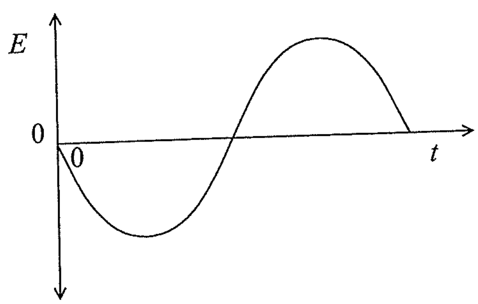
D. by colliding more frequently with the walls of the cylinder.

12. The graph shows how the velocity v of an object undergoing simple harmonic motion varies with time t for one complete period of oscillation.

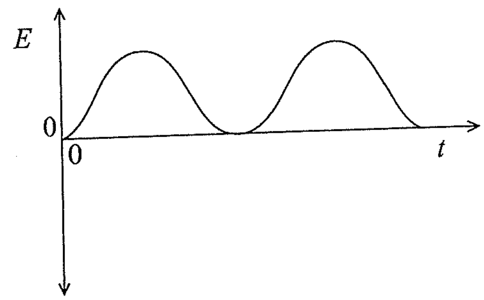


Which of the following sketch graphs best shows how the total energy E of the object varies with t?

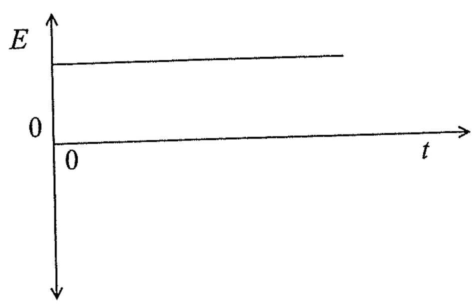
A.



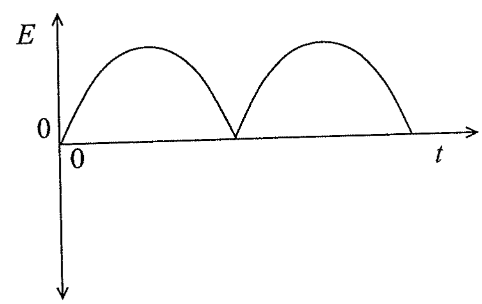
B.



C.



D.



13. A force that varies sinusoidally is applied to a system that is lightly damped. Which of the following must be true of the force for resonance to occur?

A. It must always be in anti-phase with the oscillations of the system.

B. Its direction must always be in the direction of motion of the oscillations of the system.

C. Its frequency must be equal to the frequency of oscillation of the system.

D. Its amplitude must be equal to the amplitude of oscillation of the system.

14. Which of the following is a value of wavelength that is found in the visible region of the electromagnetic spectrum?

A. 4×10^{-5} m

B. 4×10^{-7} m

C. 4×10^{-9} m

D. 4×10^{-11} m

15. Two waves meet at a point in space. Which of the following properties always add together?

A. Displacement

B. Amplitude

C. Speed

D. Frequency

16. A point charge of magnitude $2.0\,\mu C$ is moved between two points X and Y. Point X is at a potential of $+6.0\,V$ and point Y is at a potential of $+9.0\,V$. The gain in potential energy of the point charge is

A. 0.20 μJ.

B. 1.5 μJ.

C. 6.0 μJ.

D. 30 μJ.

X → Y
+6 V +9 V

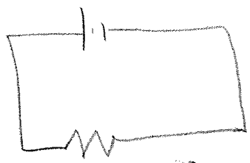
$V = \frac{W}{q}$

$3V = \frac{W}{2\mu C}$

$6\mu J = W$

Turn over

17. A resistor of resistance 12 Ω is connected in series with a cell of negligible internal resistance. The power dissipated in the resistor is *P*. The resistor is replaced with a resistor of resistance 3.0 Ω. What is the power dissipated in this resistor?



A. 0.25 *P*

B. *P*

C. 2.0 *P*

D. 4.0 *P*

18. The electromotive force (emf) of a cell is defined as

A. the power supplied by the cell per unit current from the cell.

B. the force that the cell provides to drive electrons round a circuit.

C. the energy supplied by the cell per unit current from the cell.

D. the potential difference across the terminals of the cell.

19. The weight of an object of mass 1 kg at the surface of Mars is about 4 N. The radius of Mars is about half the radius of Earth. Which of the following is the best estimate of the ratio below?

$$\frac{\text{mass of Mars}}{\text{mass of Earth}}$$

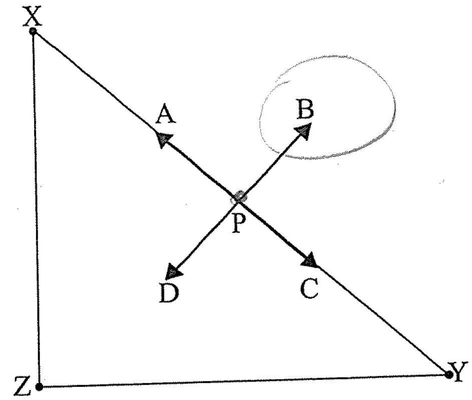
A. 0.1

B. 0.2

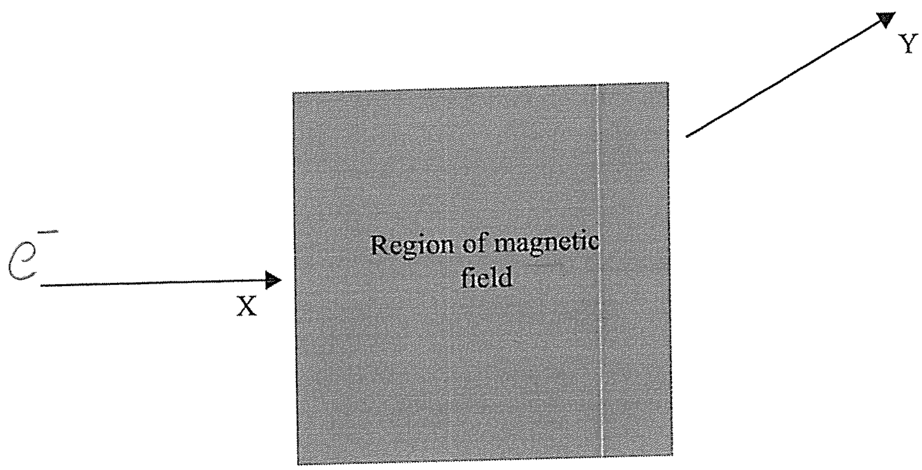
C. 5

D. 10

20. Three positive point charges of equal magnitude are held at the corners X, Y and Z of a right-angled triangle. The point P is at the midpoint of XY. Which of the arrows shows the direction of the electric field at point P?



21. An electron travelling in the direction shown by the arrow X, enters a region of uniform magnetic field. It leaves the region of field in the direction shown by the arrow Y.



The direction of the magnetic field is

A. in the direction of X.

B. into the plane of the paper.

C. in the opposite direction to X.

D. out of the plane of the paper.

22. Emission and absorption spectra provide evidence for

A. the nuclear model of the atom.

B. natural radioactivity.

C. the existence of isotopes.

D. the existence of atomic energy levels.

23. Which of the following is true in respect of both the Coulomb interaction and the strong interaction between nucleons in an atom?

	Coulomb interaction exists between	Strong interaction exists between
A.	protons only	neutrons only
B.	both protons and neutrons	neutrons only
C.	protons only	both protons and neutrons
D.	both protons and neutrons	both protons and neutrons

24. Which of the following correctly identifies the three particles emitted in the decay of the nucleus $^{45}_{20}Ca$ into a nucleus of $^{45}_{21}Sc$?

A. α, β^-, γ

B. $\beta^-, \gamma, \bar{\nu}$

C. $\alpha, \gamma, \bar{\nu}$

D. $\alpha, \beta^-, \bar{\nu}$

$^{45}_{20}Ca \rightarrow {}^{45}_{21}Sc + {}^{0}_{-1}e + \bar{\nu}$

antineutrino

25. The nuclear reaction

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

is an example of

A. nuclear fission.

B. radioactive decay.

C. nuclear fusion.

D. artificial transmutation.

26. Degraded energy is energy that is

A. stored in the Earth's atmosphere.

B. available from non-renewable energy sources.

C. converted into work in a cyclical process.

D. no longer available for the performance of useful work.

27. Which of the following correctly describes both the role of the moderator and of the control rods in a nuclear reactor?

	Moderator	Control rods
A.	slows down the neutrons	maintain a constant rate of fission
B.	cools down the reactor	extract thermal energy
C.	cools down the reactor	maintain a constant rate of fission
D.	slows down the neutrons	extract thermal energy

28. Which of the following correctly shows the energy change in a photovoltaic cell and in a solar heating panel?

	Photovoltaic cell	Solar heating panel
A.	solar → electrical	solar → thermal
B.	electrical → thermal	solar → electrical
C.	solar → electrical	electrical → thermal
D.	electrical → thermal	solar → thermal

29. The albedo for the oceans is lower than that for glaciers. This is because, compared to ice, sea water

A. has a greater density.

B. has a greater specific heat capacity.

C. has a greater coefficient of volume expansion.

D. absorbs a greater amount of radiative power.

30. Which of the following is most likely to reduce the enhanced greenhouse effect?

A. Replace the use of gas powered stations with oil powered stations

B. Replace coal-fired power stations with nuclear power stations

C. Increase the use of all non-renewable energy sources

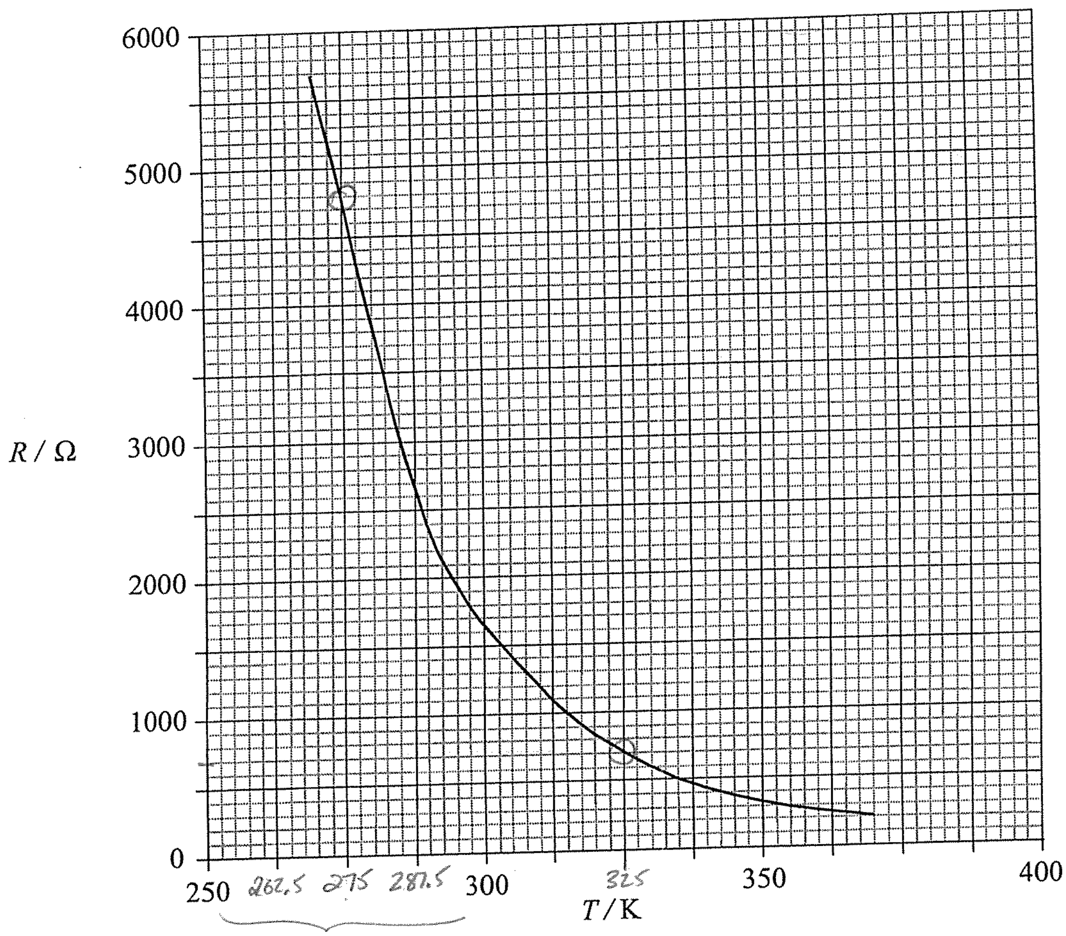
D. Decrease the efficiency of power production

SECTION A

*Answer **all** the questions in the spaces provided.*

A1. This question is about electrical resistance.

The graph shows the variation with temperature T of the resistance R of an electrical component.



(a) A student hypothesizes that the resistance is inversely proportional to the temperature. Use data from the graph to show whether the hypothesis is supported. *[3]*

Read 2 data pts
• 4800 Ω, 275 K ; 700 Ω, 325 K

Calculate a relationship
• Calculate RT : 4800 Ω · 275 K = 1.32×10^6
700 Ω · 325 K = 2.28×10^5

RT is not is not constant

Answer the question
• Hypothesis is not proven

(This question continues on the following page)

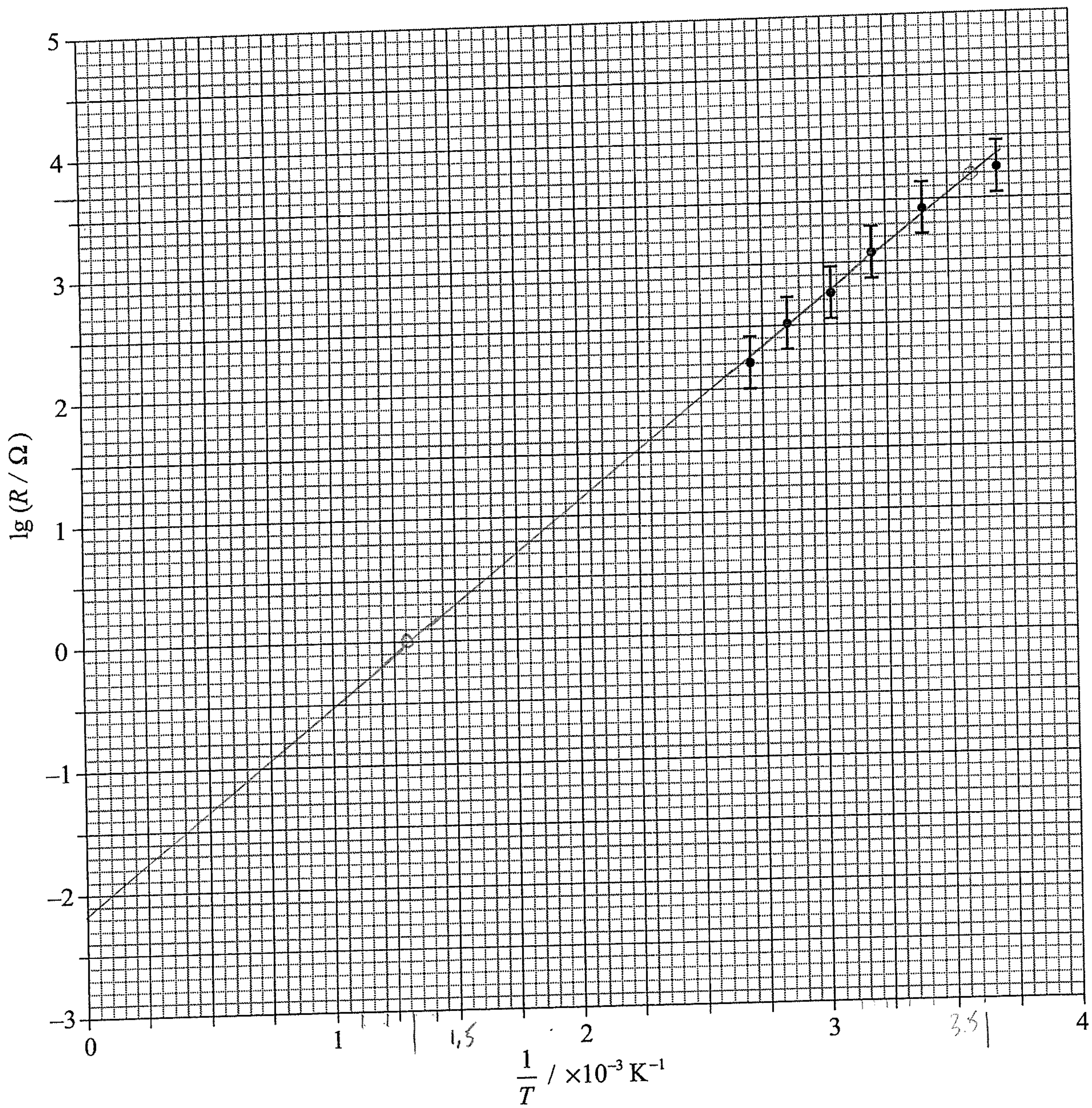
(Question A1 continued)

(b) A second student suggests that the relationship is of the form

$$\lg R = a + \frac{b}{T}$$

where a and b are constants.

The student plots the graph below. Error bars have been included for the sake of clarity.



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(Question A1 continued)

(i) Explain how the graph drawn could be used as evidence to support the student's suggestion. [2]

2 points on line idea • the points can be joined as a straight line.

(ii) Use the graph to determine the constants *a* and *b*. [4]

1pt. draw the line
1pt use of line to determine slope
1pt answer to b

b: the slope $\frac{3.7 - 0}{(3.6 - 1.3) \times 10^{-3}} = 1609 \frac{\Omega}{K}$ = 1600 accept 1500 to 1700

a: −2.1 the y intersept accept −1.7 to −2.3

1pt

Note – max. ½ credit it data points are used for above answers

(iii) Using your answers to (b)(ii), determine a value for the resistance of the component at a temperature of 260 K. [2]

$\lg R = -2.1 + \frac{1600}{260}$

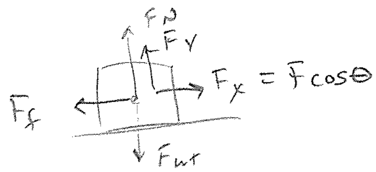
$\lg R = 4.05$

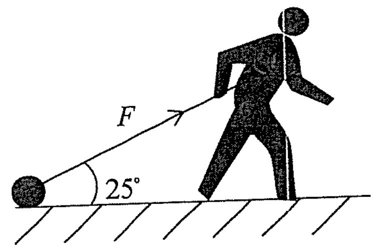
$R = 10^{4.05} = 11220$

$= 11\,000\ \Omega$

A2. This question is about forces.

An athlete trains by dragging a heavy load across a rough horizontal surface.





The athlete exerts a force of magnitude F on the load at an angle of 25° to the horizontal.

(a) Once the load is moving at a steady speed, the average horizontal frictional force acting on the load is 470 N.

Calculate the average value of F that will enable the load to move at constant speed. *[2]*

HORIZ: $F_{net} = ma$
$F\cos\theta - F_f = ma$ $a = 0\ m/s^2$
$F\cos\theta = F_f$
$F = \frac{470\ N}{\cos 25°} = 518\ N$ (520 N)

(b) The load is moved a horizontal distance of 2.5 km in 1.2 hours.

Calculate

need $F_x = 470\ N$

(i) the work done on the load by the force F. *[2]*

$W = F \cdot d = 470\ N(2.5 \times 10^3\ m)$
$= 1.2 \times 10^6\ J$

(ii) the minimum average power required to move the load. *[2]*

$P = \frac{W}{t} = \frac{1.2 \times 10^6\ J}{4.32 \times 10^3\ sec} = 277$ Watts, $= 2.8 \times 10^2$ Watts

$1.2\ h\left(\frac{3600\ s}{h}\right) = 4.32 \times 10^3\ s$

(c) The athlete pulls the load uphill at the same speed as in part (a).

Explain, in terms of energy changes, why the minimum average power required is greater than in (b)(ii). *[2]*

- Work is still done against F_f
- work is also done to raise the object vertically

A3. This question is about solar heating panels.

(a) State the energy change that takes place in a solar panel. *[1]*

Solar energy to thermal/internal energy

(Note not accepted light to heat, must be Energy terms.)

(b) A village consists of 120 houses. It is proposed that solar panels be used to provide hot water to the houses.

The following data are available.

average power needed per house to heat water $= 3.0\,\text{kW}$
average surface solar intensity $= 650\,\text{W m}^{-2}$
efficiency of energy conversion of a solar panel $= 18\%$

Calculate the minimum surface area of the solar panels required to provide the total power for water heating. *[3]*

Total Power needed: 3.0×10^3 Watts × 120 house × $\frac{1}{.18}$

$= 2.0\times10^6$ Watts.

2.0×10^6 Watts $\left(\frac{1\,m^2}{650\,\text{Watts}}\right) = 3.1\times10^3\,m^2$

(c) Suggest **two** disadvantages of using solar power to provide energy for heating water. *[2]*

1: Surface solar intensity changes with weather conditions (seasonal changes)

2: no solar energy available at night

others • very large surface area required.

SECTION B

This section consists of three questions: B1, B2 and B3. Answer ***one*** *question.*

B1. This question is in **two** parts. **Part 1** is about solar radiation. **Part 2** is about kicking a football.

Part 1 Solar radiation

(a) State the Stefan–Boltzmann law for a black body. *[2]*

Power = $\sigma A T^4$ where A = area of the surface
T = temp in K
σ the constant
Power per unit area is proportional to Absolute temp to the 4th Power

(b) The following data relates to the Earth and the Sun.

Earth-Sun distance	$= 1.5 \times 10^{11}$ m
radius of Earth	$= 6.4 \times 10^{6}$ m
radius of Sun	$= 7.0 \times 10^{8}$ m
surface temperature of Sun	$= 5800$ K

(i) Use data from the table to show that the power radiated by the Sun is about 4×10^{26} W. *[1]*

$P = 5.67 \times 10^{-8} \left(\frac{W}{m^2 K}\right)(4\pi)(7 \times 10^8 m)^2 (5800 K)^4$

$= 4 \times 10^{26}$ W

(ii) Calculate the solar power incident per unit area at a distance from the Sun equal to the Earth's distance from the Sun. *[2]*

$I = \frac{P}{4\pi r^2} = \frac{4 \times 10^{26} W}{4\pi (1.5 \times 10^{11} m)^2} \cong 1400 \frac{W}{m^2}$

E-S distance

see St. G. p72
b/c the total rad spreads out equally in all directions only a "piece of" the pie is incident on Earth

(This question continues on the following page)

(Question B1, part 1 continued)

(iii) The average power absorbed per unit area at the Earth's surface is 240 W m^{-2}. State **two** reasons why the value calculated in (b)(ii) differs from this value. *[2]*

1: Earth's albedo – Some radiation is reflected (30% Avg)

2: Earth's surface is not always ⊥ to the incident radiation

(iv) Show that the value for power absorbed per unit area of 240 W m^{-2} is consistent with an average equilibrium temperature for the Earth of about 255 K. *[2]*

$P = \sigma A T^4$

$\frac{P}{m^2} = \sigma T^4$

$\frac{\text{Power}}{m^2} = \sigma T^4$

$= (5.67 \times 10^{-8} \frac{W}{m^2 K})(255\ K)^4$

$= 240 \frac{W}{m^2}$

(c) Explain, by reference to the greenhouse effect, why the average temperature of the surface of the Earth is greater than 255 K. *[3]*

- Earth radiates IR
- Greenhouse gases absorb IR
- Gases re emit IR back to Earth

(d) Suggest why the burning of fossil fuels may lead to an increase in the temperature of the surface of the Earth. *[3]*

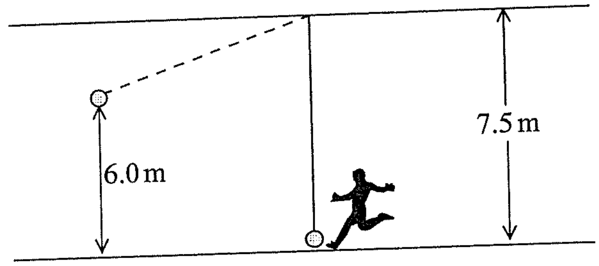
- burning fossil fuels produces CO_2 + H_2O (greenhouse gases)
- more gases result in more re-radiated energy toward Earth
- enhanced greenhouse effect

(This question continues on the following page)

(Question B1 continued)

Part 2 Kicking a football

A ball is suspended from a ceiling by a string of length 7.5 m. The ball is kicked horizontally and rises to a maximum height of 6.0 m.



(a) Assuming that the air resistance is negligible, show that the initial speed of the ball is $11\,\text{m s}^{-1}$. [2]

(PE + KE) bottom = (PE + KE) top

$\frac{1}{2} m (V_{bottom})^2 = mgh$

$V_{bottom} = \sqrt{2(9.81\frac{m}{s^2})(6.0\,m)} = 10.8\frac{m}{s} \approx 11\frac{m}{s}$ ☺

(b) The mass of the ball is 0.55 kg and the impact time of the kicker's foot with the ball is 150 ms. Estimate the average force exerted on the ball by the kick. [2]

$Ft = m\Delta V$

$F = \frac{m\Delta V}{t} = \frac{(0.55\,kg)(11\,m/s - 0\,m/s)}{150 \times 10^{-3}\,sec} = 40.\,N$

(c) (i) Explain why the tension in the string increases immediately after the ball is kicked. [3]

- the ball begins to swing in a circle, acceleration is into the center
- the string provides the centripetal force to keep the ball moving in the circular path, with a force into the center.
- the centripetal force adds to the tension in the string.

(ii) Calculate the tension in the string immediately after the ball is kicked. Assume that the string is vertical. [3]

T ↑, $F_{wt} = mg$ ↓

$F_{net} = ma_c$

$T - mg = \frac{mv^2}{r}$

$T = \left(\frac{mv^2}{r} + mg\right) = \frac{(.55\,kg)(11\,m/s)^2}{7.5\,m} + (.55\,kg)(9.81\frac{m}{s^2})$

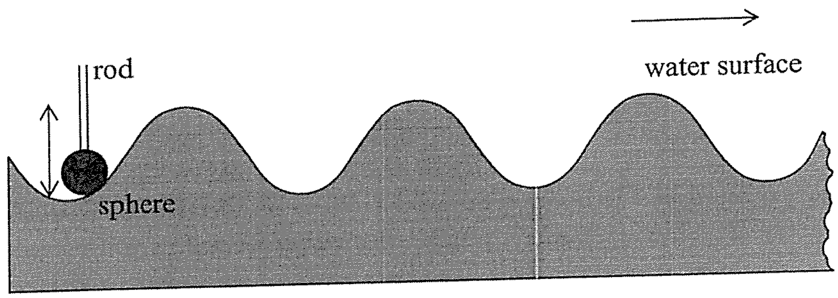
$= 8.87 + 5.40$

$= 14\,N$

B2. This question is in **two** parts. **Part 1** is about water wave motion. **Part 2** is about nuclear processes.

Part 1 Water waves

A small sphere, mounted at the end of a vertical rod, dips below the surface of shallow water in a tray. The sphere is driven vertically up and down by a motor attached to the rod. The oscillations of the sphere produce travelling waves on the surface of the water.



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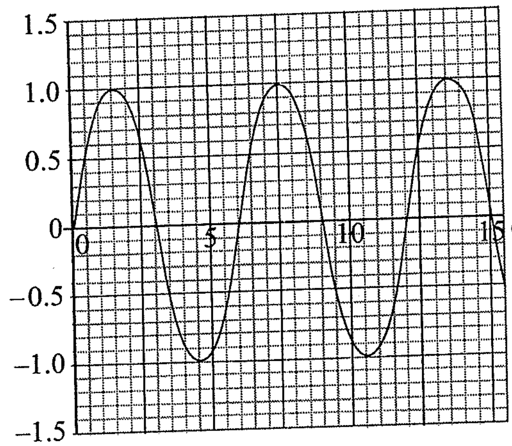
(Question B2, part 1 continued)

(a) The diagram shows how the displacement of the water surface at a particular instant in time varies with distance from the sphere. The period of oscillation of the sphere is 0.027 s.



Use the diagram to calculate, for the wave,

(i) the amplitude. *[1]*

1.0 mm

(ii) the wavelength. *[1]*

6.0 mm

(iii) the frequency. *[1]*

$f = \frac{1}{T} = \frac{1}{.027s} = 37\ Hz.$

(iv) the speed. *[1]*

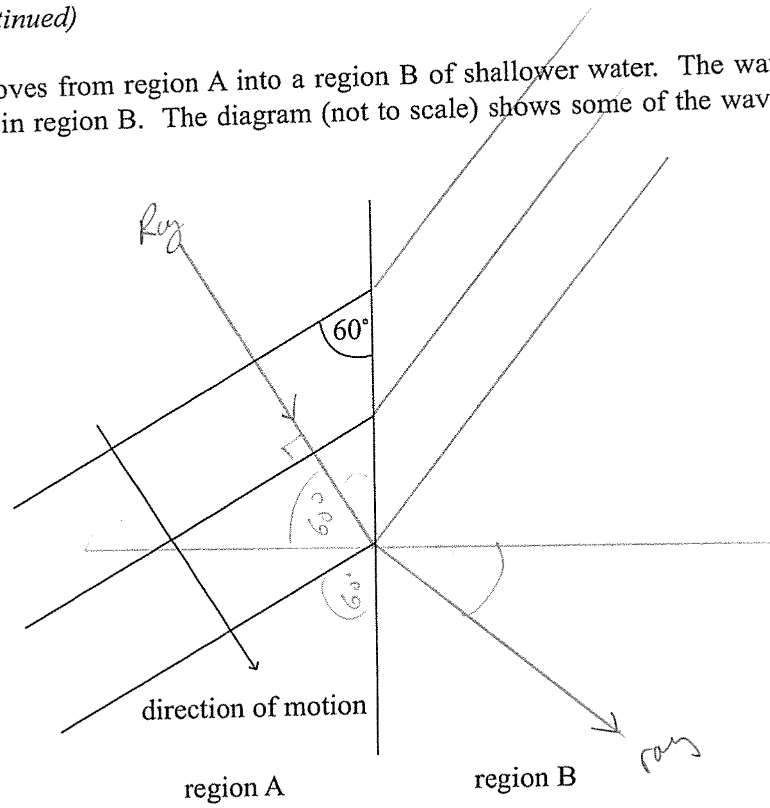
$V = f\lambda$

$= (37 Hz)(6 \times 10^{-3} m) = 0.22 m/s$

(This question continues on the following page)

(Question B2, part 1 continued)

(b) The wave moves from region A into a region B of shallower water. The waves move more slowly in region B. The diagram (not to scale) shows some of the wavefronts in region A.



θ between wavefront & boundary = θ1

(i) With reference to a wave, distinguish between a ray and a wavefront. [2]

• the ray is the direction of wave travel (energy travels)
• wavefronts are a line connecting points on ajacent waves with the same phase

(ii) The angle between the wavefronts and the interface in region A is 60°. The refractive index ${}_{A}n_{B}$ is 1.4.

HARD TO Read $n_B = 1.4$

Determine the angle between the wavefronts and the interface in region B. [2]

$n_A \sin\theta_A = n_B \sin\theta_B$ $\sin\theta_B = .619$

$\frac{n_A}{n_B}\sin\theta_A = \sin\theta_B$ $\sin\theta_B = 38°$

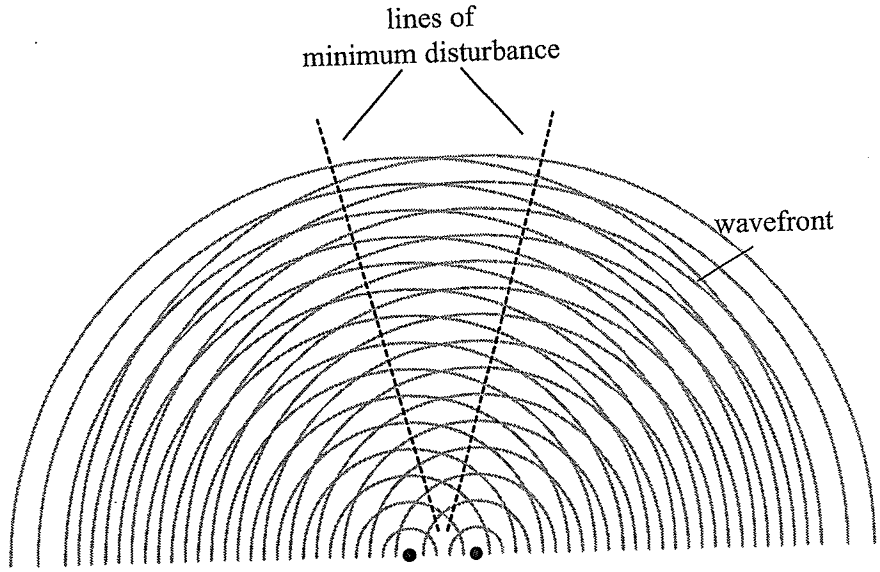
$\frac{1}{1.4}\sin 60° = \sin\theta_B$ slower, smaller θ ✓

(iii) On the diagram above, construct **three** lines to show the position of three wavefronts in region B. [2]

(This question continues on the following page)

(Question B2, part 1 continued)

(c) Another sphere is dipped into the water. The spheres oscillate in phase. The diagram shows some lines in region A along which the disturbance of the water surface is a minimum.



(i) Outline how the regions of minimum disturbance occur on the surface. *[3]*

- When 2 waves meet in a medium the amplitudes add
- min disturbance occurs where the 2 waves are out of phase
- The amplitudes sum to zero.

(ii) The frequency of oscillation of the spheres is increased.

State **and** explain how this will affect the positions of minimum disturbance. *[2]*

- An increase in frequency causes a decrease in wavelength
- The positions of minimum disturbance will be closer together

$s = \frac{\lambda D}{d}$, f ↑, λ ↓ so s ↓ — ok

(This question continues on the following page)

(Question B2 continued)

Part 2 Nuclear processes

(a) A nucleus of radium-91 $\left({}^{226}_{91}\text{Ra}\right)$ undergoes alpha particle decay to form a nucleus of radon (Rn).

${}^{226}_{91}Ra \rightarrow {}^{222}_{89}Rn \quad {}^{4}_{2}He$

(i) Identify the proton number and nucleon number of the nucleus of Rn. [2]

Proton number: 89

Nucleon number: 222

(ii) The half-life of radium-91 is 1600 years. Determine the length of time taken for 87.5% of the radium to disintegrate. [2]

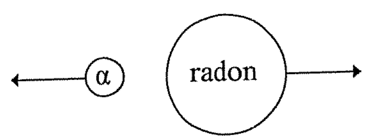
$1 \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \frac{1}{8}$ .5 .25 .125

$T_{1/2}$ = 1600 yrs

100 − 87.5 = 12.5% remains → n = 3

1600 yrs · 3 = 4800 yrs

(b) Immediately after the decay of a stationary radium nucleus, the alpha particle and the radon nucleus move off in opposite directions and at different speeds.



Outline the reasons for these observations. [3]

- momentum must be conserved
- momentum of α must be equal to momentum of Rn
- so different speeds & different speeds but in opposite directions

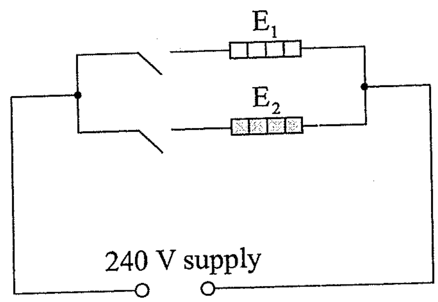
(c) Outline why a beta particle has a longer range in air than an alpha particle of the same energy. [3]

- Energy = ½mv²
  The beta particle has a smaller mass than alpha so beta has larger speed
- beta has smaller charge
- beta less likely to interact with the air molecules

B3. This question is in **two** parts. **Part 1** is about an electrical heater. **Part 2** is about heating a liquid.

Part 1 Electrical heater

An electrical heater consists of two heating elements E_1 and E_2. The elements are connected in parallel. Each element has a switch and is connected to a supply of emf 240 V. The supply has negligible internal resistance.



Element E_1 is made from wire that has a cross-sectional area of $6.8 \times 10^{-8}\,m^2$. The resistivity of the wire at the operating temperature of the element is $1.1 \times 10^{-6}\,\Omega m$.

(a) (i) The total length of wire is 4.5 m. Show that the resistance of E_1 is 73 Ω. *[1]*

$R = \frac{\rho L}{A} = \frac{(1.1\times10^{-6}\,\Omega m)(4.5m)}{6.8\times10^{-8}\,m^2} = 73\,\Omega$

(ii) Calculate the power output of E_1 with only this element connected to the supply. *[2]*

$P = IV = \frac{V^2}{R} = \frac{(240V)^2}{73\,\Omega} = 790$ Watts

(iii) Element E_2 is made of wire of the same cross-section and material as E_1. The length of wire used to make E_2 is 1.5 m. Determine the total power output when both E_1 and E_2 are connected to the supply. *[3]*

($r \approx \frac{1}{2}$ so $R \approx \frac{1}{3}$)

$R = \frac{(1.1\times10^{-6}\,\Omega m)(1.5m)}{6.8\times10^{-8}\,m^2} = 24\,\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{73\,\Omega} + \frac{1}{24\,\Omega}$ $R_T = \frac{1}{.05536} = 18\,\Omega$

$P_{Total} = \frac{V^2}{R} = \frac{(240\,Volts)^2}{18\,\Omega} = 3200$ Watts

(This question continues on the following page)

(Question B3, part 1 continued)

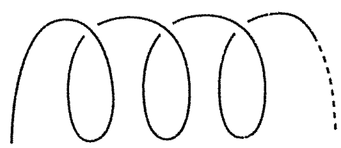
(iv) With reference to the power output, explain why it would be inappropriate to connect the heating elements in series. *[3]*

– In series R_{total} would be larger

– Therefore current would be less and Power depends upon I^2 $P = I^2R$

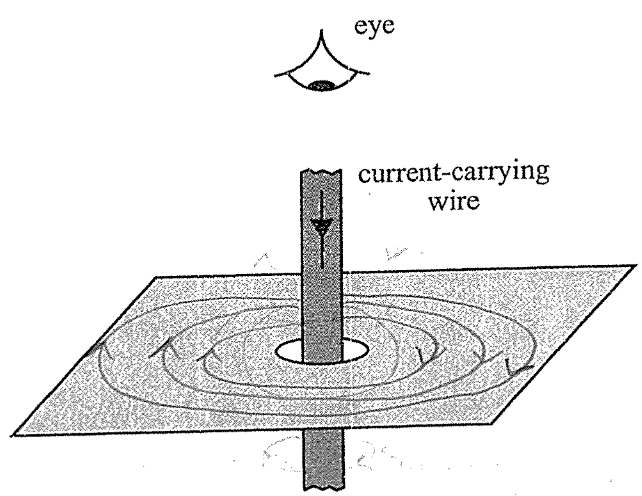
– thus Power would be less

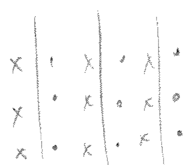
(b) Each element in the electrical heater is wound as a coil as shown.



Each turn of the coil may be considered to act as a current-carrying long straight wire.

(i) On the diagram, draw the magnetic field around a current-carrying long straight wire. The arrow shows the direction of the current. *[3]*





note – minimum of 3 circles

(ii) State **and** explain whether the turns of wire will attract or repel one another. *[3]*

– each wire has the magnetic field in the same direction

– between wires the magnetic fields are opposite

– opposite magnetic fields attract

(This question continues on the following page)

(Question B3 continued)

Part 2 Heating a liquid

(a) Suggest why, in terms of the molecular model, the energy associated with melting is less than that associated with boiling. *[2]*

• To vaporize Energy is needed to break the bonds between molecules and separate the molecules

• To melt the energy is needed only to break the bonds between molecules

(b) Milk in a cup is heated to boiling point by passing steam through it. Whilst cooling subsequently, some milk evaporates.

(i) Distinguish between evaporation and boiling. *[2]*

• boiling is a rapid change from liquid to gas throughout the liquid when the vapor pressure equals atmospheric pressure at the boiling point only

• evaporation takes place only at the surface, at all temperatures (vapor pressure < atmospheric)

(ii) The cup contains 0.30 kg of milk at an initial temperature of 18 °C. Estimate the minimum mass of steam at 100 °C that is required to heat the milk to 80 °C. *[4]*

Specific latent heat of vaporization of water $= 2.3\times10^{6}\,\text{J kg}^{-1}$
Specific heat capacity of water $= 4200\,\text{J kg}^{-1}\text{K}^{-1}$
Specific heat capacity of milk $= 3800\,\text{J kg}^{-1}\text{K}^{-1}$

heat gained by milk = heat lost by the steam

$mc\Delta T_{milk} = Q$

$(.3\,\text{kg})(3800\,\frac{\text{J}}{\text{kg}^\circ\text{K}})(80-18^\circ\text{C}) = Q$ (62°)

$Q = 7.1\times10^{4}\,\text{J} = mL_s + mc\Delta T_{water}$

$= m(2.3\times10^{6}\,\frac{\text{J}}{\text{kg}} + 4200\,\frac{\text{J}}{\text{kg K}}(20^\circ\text{K}))$

$m = .030\,\text{kg}$

(This question continues on the following page)

(Question B3, part 2 continued)

(iii) State **two** reasons, other than evaporation, why the answer to (b)(ii) is likely to be different from the actual mass of condensed steam. *[2]*

1: Energy may be lost to the surroundings

2: Some energy is used to heat the cup

(steam can escape from the system)

Option B — Quantum physics and nuclear physics

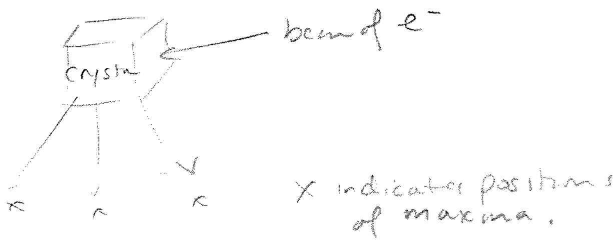
B1. This question is about the wave nature of matter.

(a) Describe the de Broglie hypothesis. *[2]*

- all particles have an associated wavelength
- $p = \frac{h}{\lambda}$ so $\lambda = \frac{h}{mv}$ where h is Planck's constant

(b) Outline an experiment to verify the de Broglie hypothesis. *[3]*

- a beam of electrons are accelerated through a potential difference (in a vacuum)
- the beam is incident on a crystal
- the scattered beam produces maxima & minima at specific positions



(c) Show that the de Broglie wavelength of electrons accelerated from rest through a potential difference of 150 V is 1.0×10^{-10} m. *[3]*

$V = \frac{W}{q}$

$W = Vq = (150\,V)(1.6 \times 10^{-19}\,C)$
$= 2.4 \times 10^{-17}\,J$

$W = \Delta KE$

$2.4 \times 10^{-17}\,J = \frac{1}{2}(9.11 \times 10^{-31}\,kg)(v_f^2 - v_i^2)$, $v_i = 0$

$v_f = \sqrt{5.27 \times 10^{13}} = 7.26 \times 10^{6}\,\frac{m}{s}$

$\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}\,J \cdot s}{(9.11 \times 10^{-31}\,kg)(7.26 \times 10^{6}\,\frac{m}{s})}$

$\lambda = 1.0 \times 10^{-10}\,m.$

Turn over

B2. This question is about alpha (α) particle scattering.

An experiment is carried out in which alpha (α) particles of initial kinetic energy 5.0 MeV are fired at a piece of gold foil. The proton number of gold is 79.

Determine the distance of closest approach of an alpha (α) particle to a gold nucleus. *[4]*

$KE_{initial} = E_P$ $\quad 5.0 \times 10^{6} eV \left(1.6 \times 10^{-19} \frac{J}{eV}\right)$

$= 8 \times 10^{-13} J$

$E_P = W = F \cdot d = \frac{k q_1 q_2}{d^2} d$ $\quad \alpha \quad$ nucleus

$8 \times 10^{-13} J = \frac{(8.99 \times 10^{9} \frac{Nm^2}{C^2})[2 \times 1.6 \times 10^{-19} C][76 \times 1.6 \times 10^{-19} C]}{d}$

$d = 4.4 \times 10^{-14} m$

B3. This question is about β^+ (positron) decay.

(a) In a β^+ decay, a positron is emitted along with a neutrino, and a γ-ray photon. Although the energy spectrum for γ-rays involved is discrete, the energy spectrum for the positrons is continuous.

(i) State the difference between a discrete energy spectrum and a continuous energy spectrum. *[1]*

In a discrete energy spectrum the energy is restricted to specific values.

(ii) Explain how the existence of the neutrino accounts for the continuous nature of the positron energy spectrum. *[2]*

total energy of decay is constant
energy is shared between the positron and the neutrino

(This question continues on the following page)

(Question B3 continued)

(b) Sodium-22 is a radioisotope used in nuclear medicine that undergoes β^+ decay. The half-life of sodium-22 is 2.6 years. A sample of sodium-22 has an initial activity of 6.2×10^9 Bq. $= A_0$

(i) Define *decay constant.* [1]

The probability of decay of a nucleus per unit time.
(or $\lambda = \frac{\ln 2}{T_{1/2}}$ where $T_{1/2}$ is the time for ½ a sample to decay.)

(ii) Calculate the decay constant of sodium-22. [1]

$\lambda = \frac{\ln 2}{2.6 \text{ years}} = 0.27$ per year.

(iii) Calculate the activity of the sample of sodium-22 after 8.0 years. [3]

$A = A_0 e^{-\lambda t}$

$= (6.2\times10^9 \text{ Bq}) e^{-(.27/\text{yrs})(8 \text{ years})}$

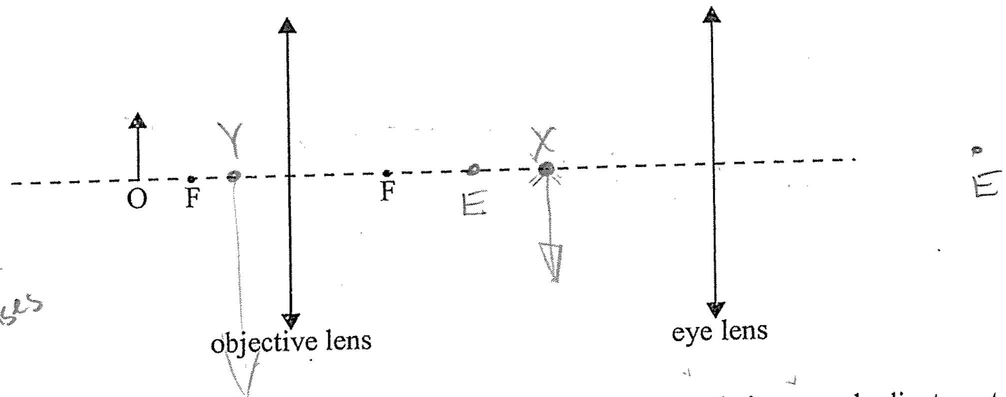
$= 7.2 \times 10^8$ Bq.

✓

Option G — Electromagnetic waves

G1. This question is about a compound microscope, spherical aberration and chromatic aberration.

(a) An object O is placed in front of the objective lens of a compound microscope as shown below.



note final image near obj. but not between lenses

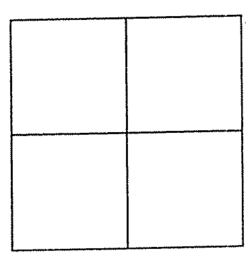
The focal points of the objective lens are at F. The microscope is in normal adjustment. Without drawing a ray diagram, label the approximate positions, on the principal axis, of

(i) the image produced by the objective lens (label this position X). *[1]*

(ii) the focal points of the eye lens (label these points E). *[1]*

(iii) the final image (label this image Y). *[1]*

(b) An object is viewed through a convex lens that has been corrected for spherical aberration. For a particular object distance, the image of the object is as shown below.

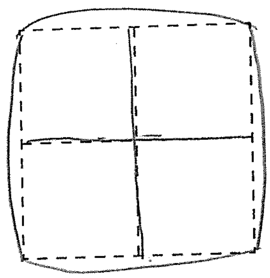


(This question continues on the following page)

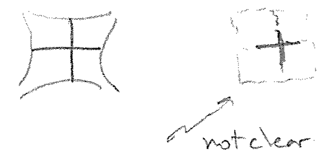
(Question G1 continued)

Another convex lens of the same focal length, but not corrected for spherical aberration, is now used to view the object. The object distance is unchanged.
In the space below, draw the image as it would be seen through this second lens.
The image as seen through the corrected lens is shown as a broken line. *[2]*

ok show edges curved IN



or



(c) Explain how chromatic aberration arises when an object is viewed through a single lens. *[2]*

• the index of refraction is different for different wavelengths of light

• So each color (wavelength) has a different focal length.

G2. This question is about the scattering of light.

(a) State an approximate wavelength for

(i) red light. *[1]*

7×10^{-7} m		allow $6.20 - 7.80 \times 10^{-7}$ m

(ii) blue light. *[1]*

4×10^{-7} m		allow $3.20 - 4.80 \times 10^{-7}$ m

} can be given in nm

(b) With reference to your answers in (a), discuss why the setting Sun appears reddish in colour. *[3]*

• The shorter λ of blue light are scattered by the dust particles in the atmosphere

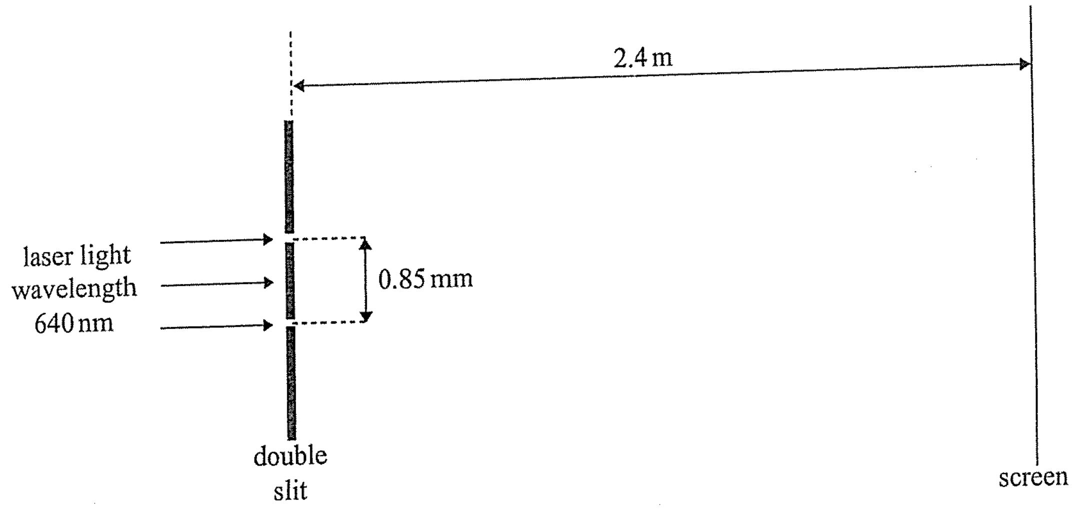
• At sunset we observe the sun through a greater distance of atmosphere

• The sunset appears red b/c the blue was scattered out

✓

G3. This question is about two-source interference.

A double slit is arranged so that its plane is normal to a beam of laser light, as shown below.



The wavelength of the light is 640 nm. The slit separation in the double slit arrangement is 0.85 mm. Coherent light emerges from the slits and an interference pattern is observed on a screen. The screen is parallel to the plane of the double slits. The distance between the slits and the screen is 2.4 m.

(a) (i) State what is meant by coherent light. *[1]*

The light waves passing through the slits are in phase

(ii) Explain how an interference pattern is formed on the screen. *[3]*

- There is a path difference to the screen from each of the slits.

- When the path difference is even # of ½ λ constructive interference results.
- When the path difference is odd # of ½ λ destructive interference results

(b) Calculate the separation of the fringes in the interference pattern on the screen. *[2]*

$S = ?$ $\quad S = \frac{\lambda D}{d}$

$\lambda = 640\text{nm} = 640 \times 10^{-9}\text{m}$

$d = .85\text{mm} = .85 \times 10^{-3}\text{m}$ $\quad = \frac{(640 \times 10^{-9}\text{m})(2.4\text{m})}{.85 \times 10^{-3}\text{m}} = 1.8 \times 10^{-3}\text{m}$

$D = 2.4\text{m}$

(This question continues on the following page)

(Question G3 continued)

(c) The interference pattern in (b) consists of a series of alternate light and dark fringes. The intensity of the light from one slit is now reduced. Suggest the effect on the appearance of the fringes. *[2]*

- bright fringes are less bright
- dark fringes are less dark (brighter)