M16/4/PHYSI/SPM/ENG/TZ0/XX

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 1

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4/29/17

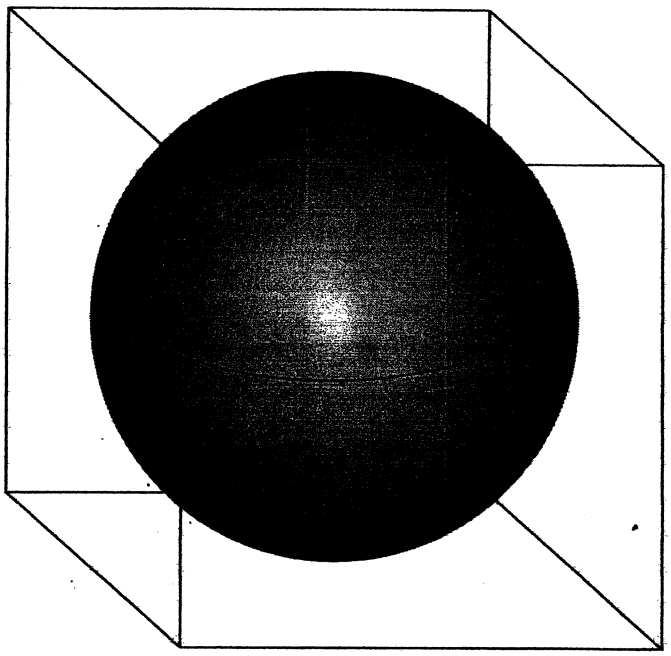
Friday 6 May 2016 (morning)

45 minutes

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[30 marks]**.

1. A sphere fits inside a cube.



The length of the cube and the diameter of the sphere are 10.0±0.2 cm.

What is the ratio $\frac{\text{percentage uncertainty of the volume of the sphere}}{\text{percentage uncertainty of the volume of the cube}}$?

A. $\frac{3}{4\pi}$

B. 1

C. 2

D. 8

$V_{sphere} = \left(\frac{4}{3}\pi\right) r^3 = \frac{4}{3}\pi\left(\frac{L}{2}\right)^3 = \left(\frac{4}{3}\pi\,\frac{1}{4}\right) L^3$

$V_{cube} = L^3$

$\frac{\Delta V}{V} = \frac{\Delta L}{L} + \frac{\Delta L}{L} + \frac{\Delta L}{L}$

$\frac{\Delta V_{sphere}}{\Delta V_{cube}} = \frac{\frac{\Delta V}{V} = \frac{\Delta L}{L} + \frac{\Delta L}{L} + \frac{\Delta L}{L}}{\frac{\Delta V}{V} = \frac{\Delta L}{L} + \frac{\Delta L}{L} + \frac{\Delta L}{L}}$

2. A swimming pool contains 18×10^6 kg of pure water. The molar mass of water is 18 g mol^{-1}. What is the correct estimate of the number of water molecules in the swimming pool?

A. 10^4

B. 10^{24}

C. 10^{25}

D. 10^{33}

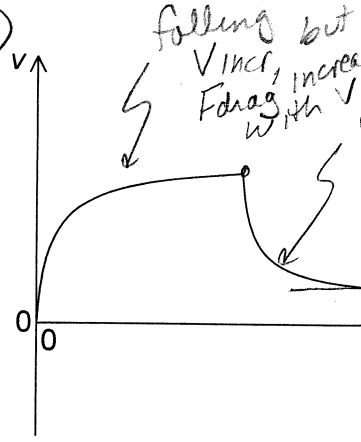
$\left(18 \times 10^6 \text{ kg}\right)\left(\frac{1 \times 10^3 \text{ g}}{1 \text{ kg}}\right)\left(\frac{1 \text{ mol}}{18 \text{ g}}\right)\left(6.23 \times 10^{23} \frac{\text{molecules}}{\text{mol}}\right)$

$= \frac{18 \times 10^6 \times 10^3 \times 6.23 \times 10^{23}}{18}$

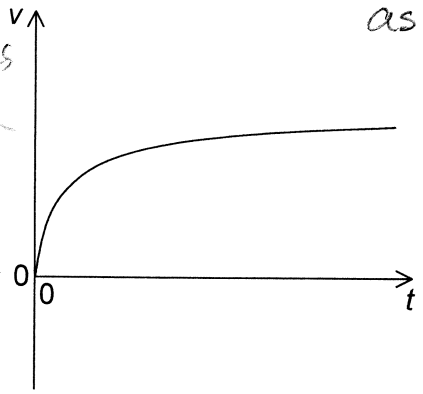
$= 6.23 \times 10^{32} \approx 10^{33}$

3. An aircraft is moving horizontally. A parachutist leaves the aircraft and a few seconds later opens her parachute. Which graph shows the variation of the vertical speed v with time t for the parachutist from the time she leaves the aircraft until just before landing?

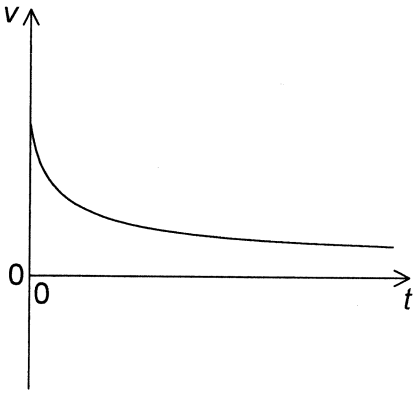
A.



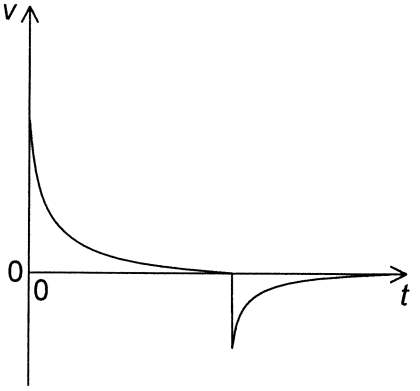
B.



C.



D.



falling but V incr, increases F_{drag} with V

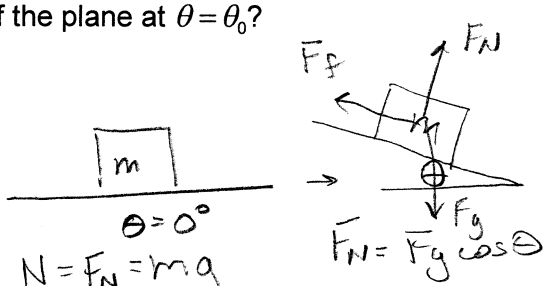
Parachute V decreases terminal V

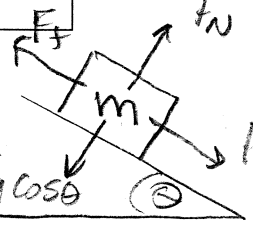
$V_{y_i} = 0\ m/s$ as it falls No parachute V incr. to ≈ terminal velocity as V incr. F_{drag} incr. Parachute opens V decr. to new lower terminal velocity

4. An object of mass m rests on a horizontal plane. The angle θ that the plane makes with the horizontal is slowly increased from zero. When $\theta = \theta_0$, the object begins to slide. What are the coefficient of static friction μ_s and the normal reaction force N of the plane at $\theta = \theta_0$?

	μ_s	N
A.	$\sin\theta_0$	$mg\cos\theta_0$
B.	$\tan\theta_0$	$mg\sin\theta_0$
C.	$\sin\theta_0$	$mg\sin\theta_0$
D.	$\tan\theta_0$	$mg\cos\theta_0$

FBD





remember Resolved FBD

$F_f = F_g \sin\theta$

$F_f = \mu F_N$

$\mu = \frac{F_f}{F_N} = \frac{F_g\sin\theta}{F_g\cos\theta} = \tan\theta$

5. A stone is falling at a constant velocity vertically down a tube filled with oil. Which of the following statements about the energy changes of the stone during its motion are correct?

I. The gain in kinetic energy is less than the loss in gravitational potential energy.

II. The sum of kinetic and gravitational potential energy of the stone is constant.

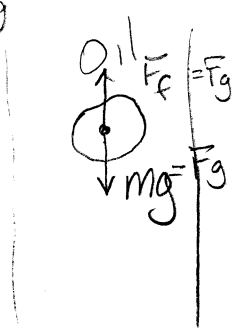
III. The work done by the force of gravity has the same magnitude as the work done by friction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III



ΔKE = zero bc V is constant
KE RTS
PEg decreases bc h lower

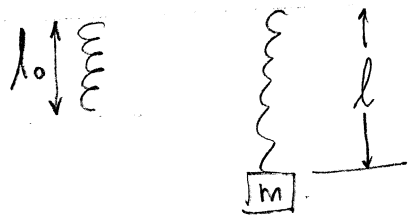
6. A spring of negligible mass and length l_0 hangs from a fixed point. When a mass m is attached to the free end of the spring, the length of the spring increases to l. The tension in the spring is equal to $k\Delta x$, where k is a constant and Δx is the extension of the spring. What is k?

A. $\frac{mg}{l_0}$

B. $\frac{mg}{l}$

C. $\frac{mg}{l - l_0}$

D. $\frac{mg}{l_0 - l}$



tension = $F_s = kx$

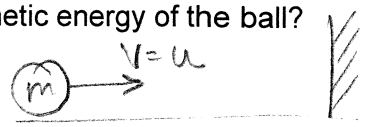
$F_s = F_g = mg$

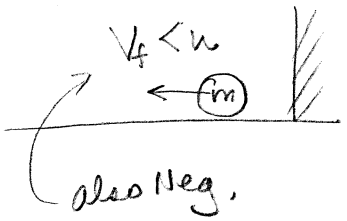
$mg = k\Delta x$

$\frac{mg}{l - l_0} = k$

7. A ball with mass m moves horizontally with speed u. The ball hits a vertical wall and rebounds in the opposite direction with speed $v < u$. The duration of the collision is T. What are the magnitude of the average force exerted by the wall on the ball and the loss of kinetic energy of the ball?

	Average force	Loss of kinetic energy
A.	$\frac{m(u+v)}{T}$	$\frac{m(u^2-v^2)}{2}$
B.	$\frac{m(u+v)}{T}$	$\frac{m(u-v)^2}{2}$
C.	$\frac{m(u-v)}{T}$	$\frac{m(u^2-v^2)}{2}$
D.	$\frac{m(u-v)}{T}$	$\frac{m(u-v)^2}{2}$





$F = ma$

$F = \frac{m\Delta V}{t} = \frac{m}{t}(-V-u)$

$F = \frac{m}{T}(V+u)$

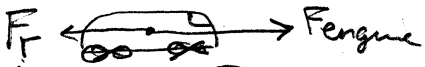
$\Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$= \frac{1}{2}m(v^2 - u^2)$

8. A train on a straight horizontal track moves from rest at constant acceleration. The horizontal forces on the train are the engine force and a resistive force which increases with speed. Which graph represents the variation with time t of the power P developed by the engine?

$V_i = 0\,ms$

$a = \text{constant}$



resistive

$F_r < F_e$

$F_{net} = F_e - F_r = ma$

$= \text{Constant } a$

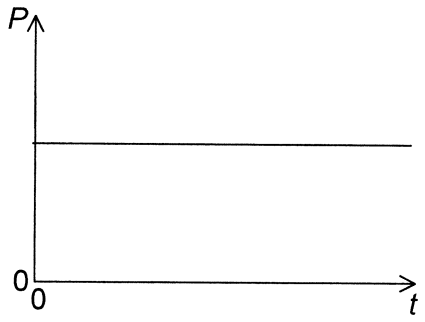
$F_{net} = \text{Constant}$

F_r increases with V

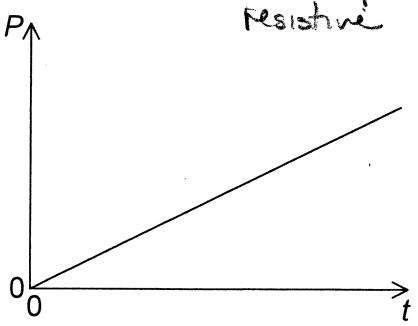
then F_e also incr with V

but $F_{net} = \text{zero}$

A.



B.



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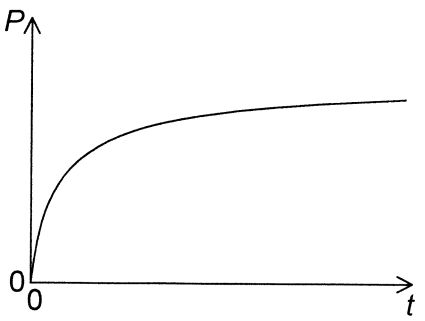
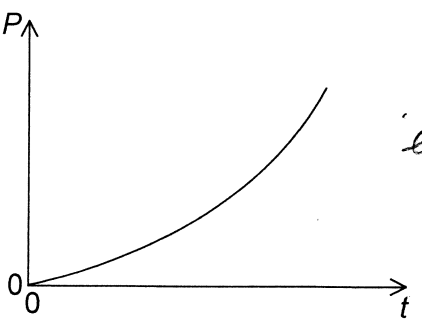


D.

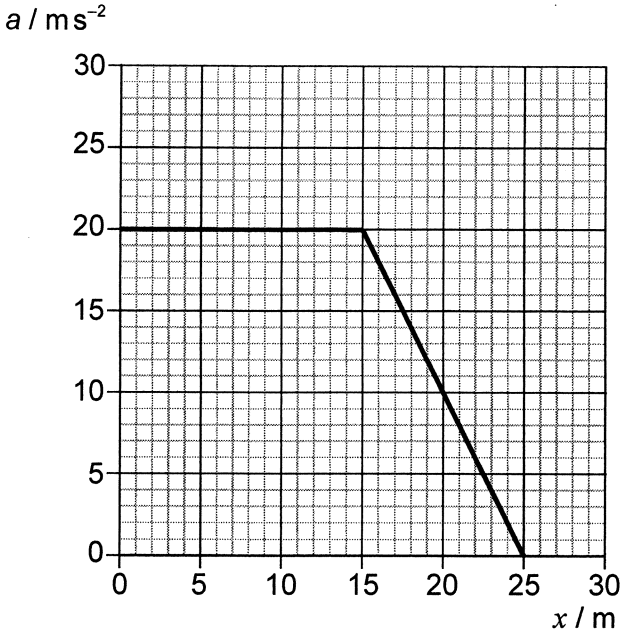


$P = \frac{W}{t} = \frac{Fd}{t}$

engine $P_e = F_e v$

both incr with time

9. The graph shows how the acceleration a of an object varies with distance travelled x.



The mass of the object is 3.0 kg. What is the total work done on the object?

A. 300 J

B. 400 J

C. 1200 J

D. 1500 J

area under a vs d

$W = F \cdot d \qquad F = ma$

$W = (ma)d = m(a \cdot d)$

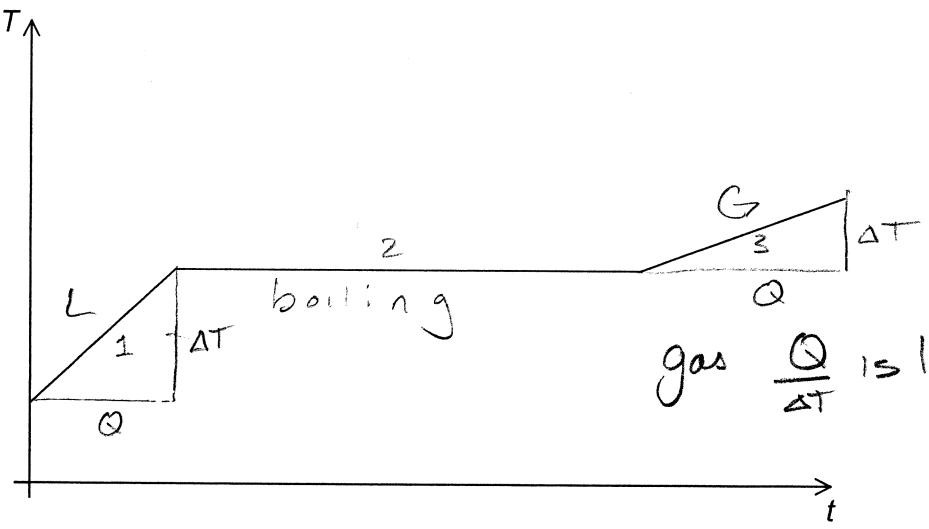
$= 3(20)(15) + 3(10)\left(\frac{20}{2}\right)$

$= 900 + 300$

$= 1200 \text{ J}$

10. A substance is heated at constant power. The graph shows how the temperature T of the substance varies with time t as the state of the substance changes from liquid to gas.

$P = \frac{W}{t} = \text{Constant}$



$Q = mc\Delta T$

$C = \frac{Q}{m\Delta T}$

gas $\frac{Q}{\Delta T}$ is larger

What can be determined from the graph?

A. The specific heat capacity of the gas is smaller than the specific heat capacity of the liquid.

B. The specific heat capacity of the gas is larger than the specific heat capacity of the liquid.

C. The specific latent heat of fusion of the substance is less than its specific latent heat of vaporization.

D. The specific latent heat of fusion of the substance is larger than its specific latent heat of vaporization.

11. Which of the following is **not** an assumption of the kinetic model of ideal gases?

A. All particles in the gas have the same mass.

B. All particles in the gas have the same speed.

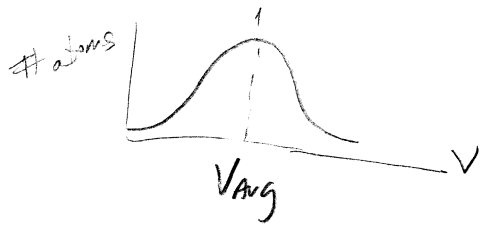
C. The duration of collisions between particles is very short.

D. Collisions with the walls of the container are elastic.

Temp is a measure of the Avg KE of the molecules

$KE_{Avg} = \frac{1}{2} m v_{Avg}^2$

Individual Velocities vary



12. Under what conditions of density and pressure is a real gas best described by the equation of state for an ideal gas?

A. Low density and low pressure

B. Low density and high pressure

C. High density and low pressure

D. High density and high pressure

13. A point source emits sound waves of amplitude A. The sound intensity at a distance d from the source is I. What is the sound intensity at a distance $0.5d$ from the source when the source emits waves of amplitude $2A$?

A. $16I$

B. $4I$

C. I

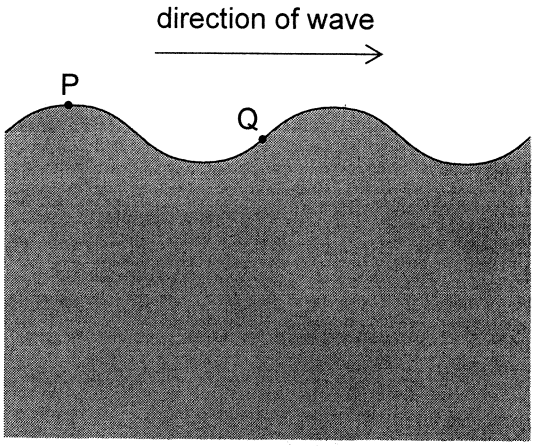
D. $\frac{1}{4}I$

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}} = \frac{\text{Energy/time}}{\text{area}}$$

$$I = \frac{A^2/\text{sec}}{4\pi r^2}$$ ← area of a sphere

$$I_{new} = \frac{2^2/\text{sec}}{1 \cdot (.5)^2} I = \frac{4}{\frac{1}{4}} I = 16I$$

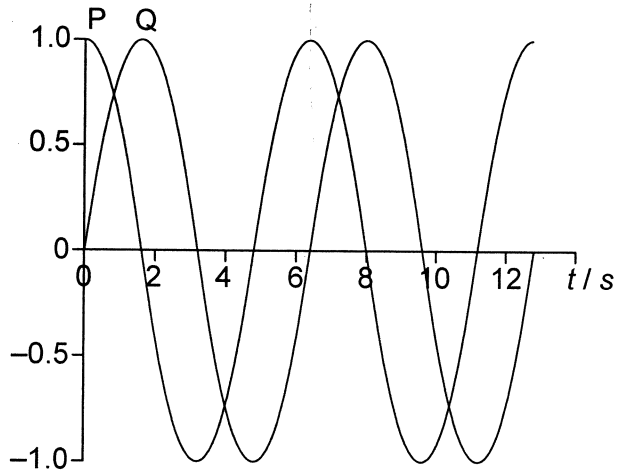
14. A water wave moves on the surface of a lake. P and Q are two points on the water surface. The wave is travelling towards the right.



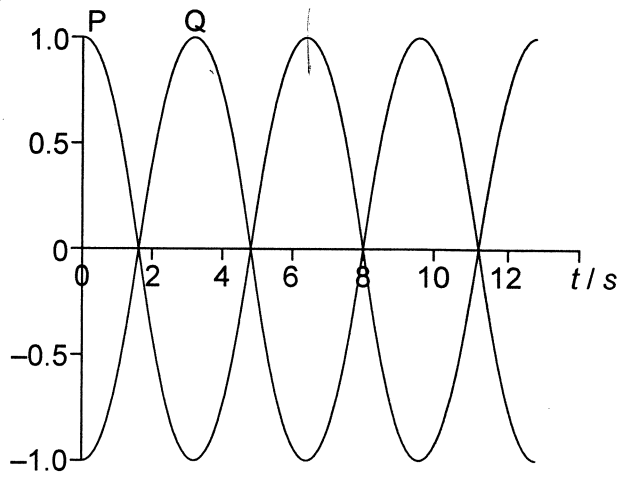
P at a crest
So it will go ↑
Q at Eq. going ↑
" is 3/4 wave ahead of P
T ≈ 6 sec

The diagram shows the wave at time $t=0$. Which graph shows how the displacements of P and Q vary with t?

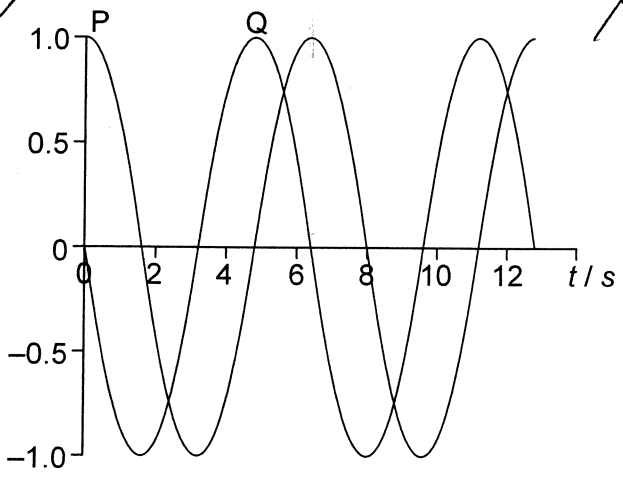
A.



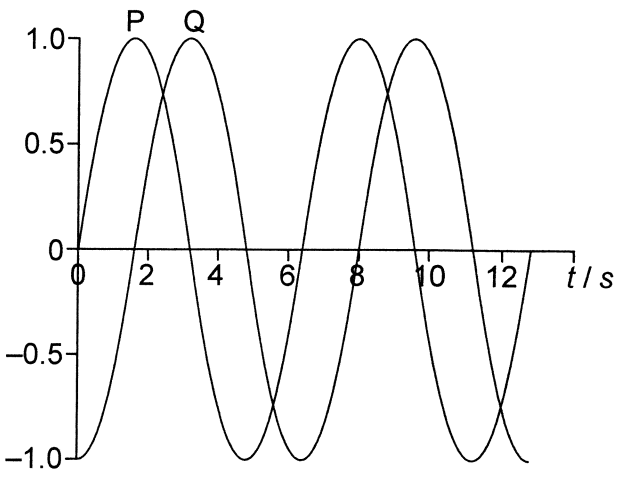
B.



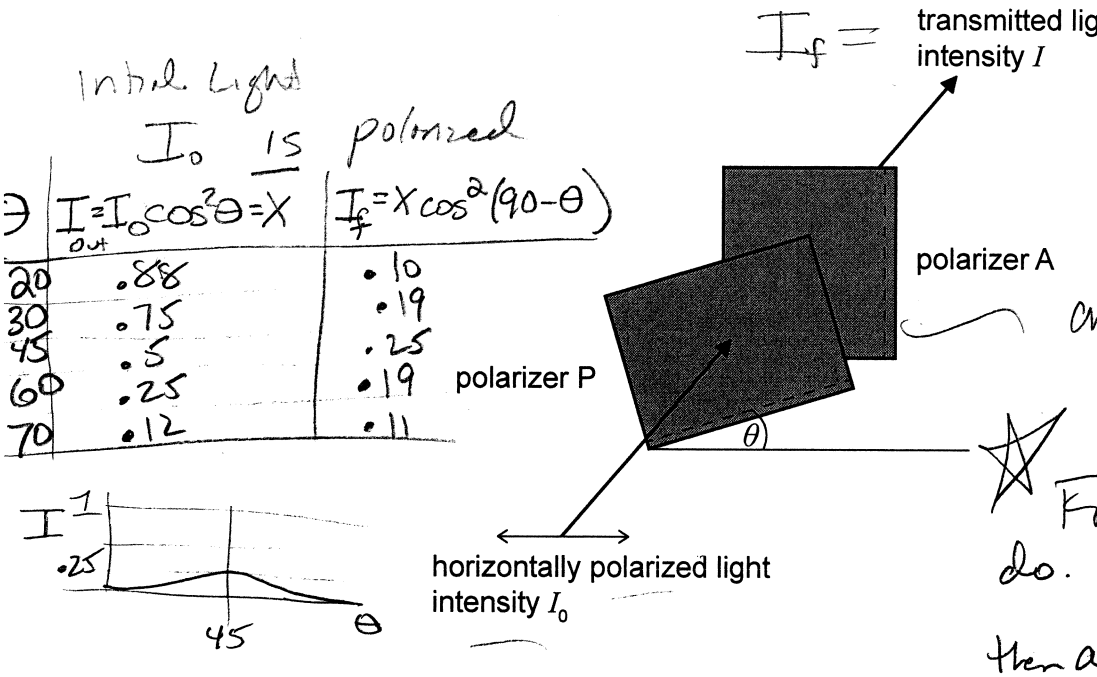
C.



D.



15. Horizontally polarized light of intensity I_0 enters a polarizer P whose polarization axis makes an angle of θ degrees with the horizontal. Light from P is then incident on a polarizer A with fixed vertical polarization axis.



Initial Light I_0 is polarized

θ	$I = I_0\cos^2\theta = X$	$I_f = X\cos^2(90-\theta)$
20	.88	.10
30	.75	.19
45	.5	.25
60	.25	.19
70	.12	.11

angle = $90-\theta$

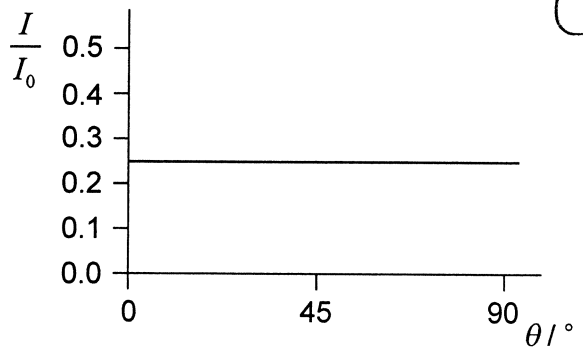
For a Quick Solution do. $\theta = 0°$ then 2nd $\theta = 90°$ so Transmitted = 0.

then a max when $\theta = 45°$ 2nd angle also $45°$

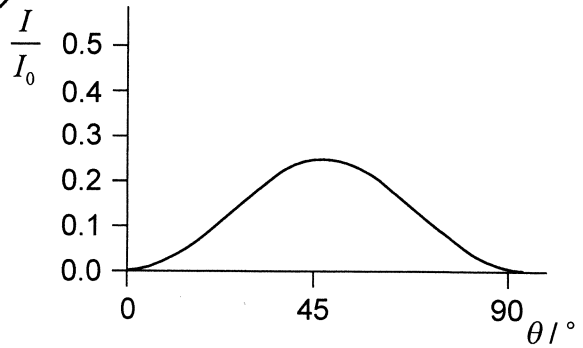
Should recognize bell curve.

The angle θ is varied from 0 to 90 degrees. Which of the following represents the variation with θ of the intensity I of the light transmitted through A?

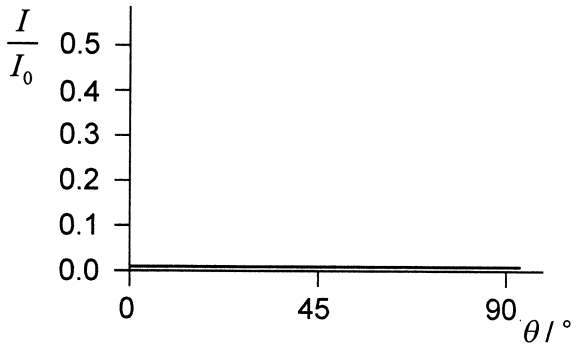
A.



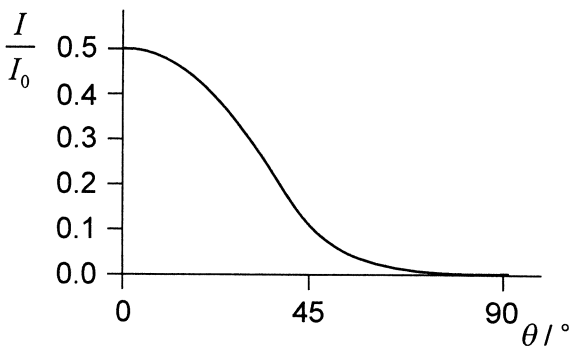
B.



C.



D.



16. A pipe of length L has two open ends. Another pipe of length L' has one open end and one closed end.

The frequency of the first harmonic of both pipes is the same. What is $\frac{L'}{L}$?

A. 2

B. $\frac{3}{2}$

C. 1

D. $\frac{1}{2}$

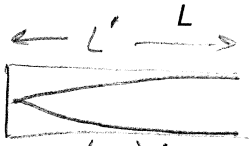
$L = \lambda/2$

$2L = \lambda$

$V = f\lambda$

$V = f(2L)$

$\frac{V}{2L} = f$



$L' = \lambda/4$

$\lambda = 4L'$

$V = f\lambda$

$V = f(4L')$

$\frac{V}{4L'} = f$

So

$\frac{V}{2L} = \frac{V}{4L'}$

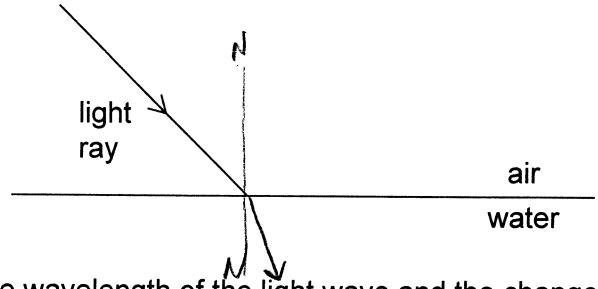
V = speed of sound in air some V

$\frac{1}{2L} = \frac{1}{4L'}$

$4L' = 2L$

$\frac{L'}{L} = \frac{2}{4} = \frac{1}{2}$

17. A light ray passes from air to water as shown.



What are the change in the wavelength of the light wave and the change in the angle the ray makes with the normal to the surface?

	Wavelength	Angle with normal
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

air water

n 1.00 < 1.33

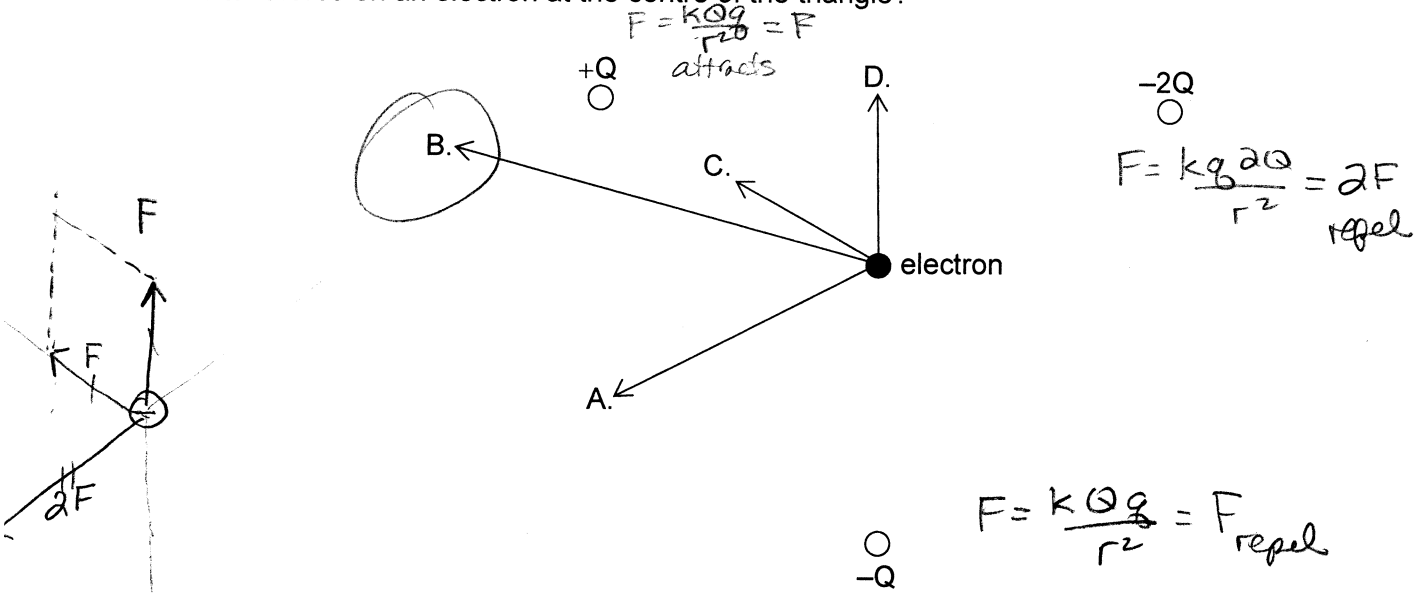
V $3\times10^8 \frac{m}{s}$ > less

$V = f\lambda$ $\lambda_{air} > \lambda_{water}$

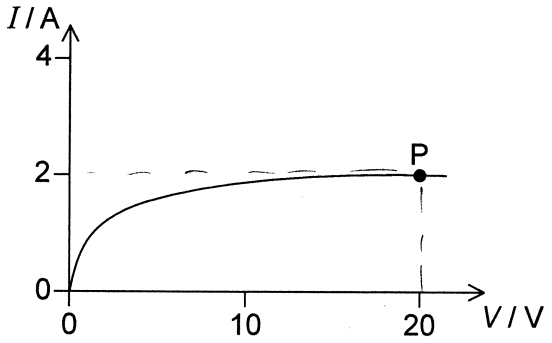
f some $\theta_{air} > \theta_{water}$

$n_{air}\sin\theta_{air} = n_{water}\sin\theta_{water}$

18. Three fixed charges, +Q, –Q and –2Q, are at the vertices of an equilateral triangle. What is the resultant force on an electron at the centre of the triangle?



19. The graph shows the variation of current I in a device with potential difference V across it.



What is the resistance of the device at P?

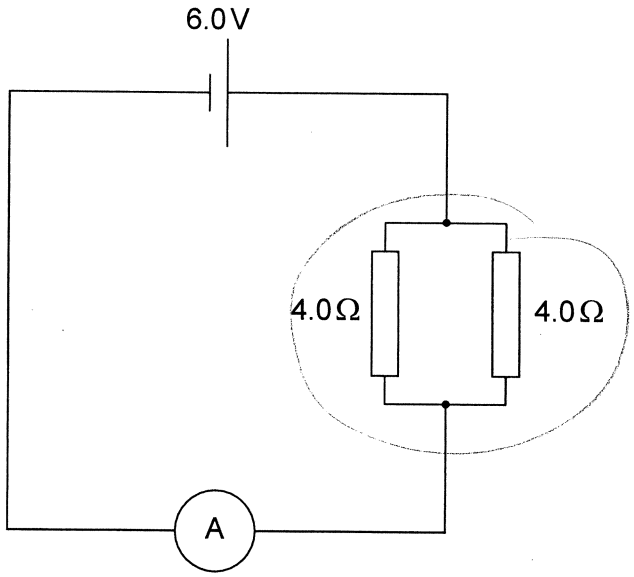
A. zero

B. 0.1 Ω

C. 10 Ω

D. infinite

20. A circuit consists of a cell of electromotive force (emf) 6.0 V and negligible internal resistance connected to two resistors of 4.0 Ω.



$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4}$

$R_{Eq} = 2\Omega$

The resistance of the ammeter is 1.0 Ω. What is the reading of the ammeter?

A. 2.0A

B. 3.0A

C. 4.5A

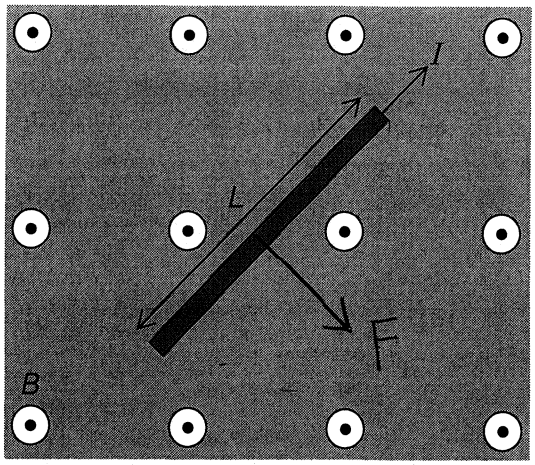
D. 6.0A

$R_T = \frac{V_T}{I_T}$

$1\Omega + 2\Omega = \frac{6V}{I_T}$

$I_T = \frac{6}{3} = 2A$

21. A wire carrying a current I is placed in a region of uniform magnetic field B, as shown in the diagram.



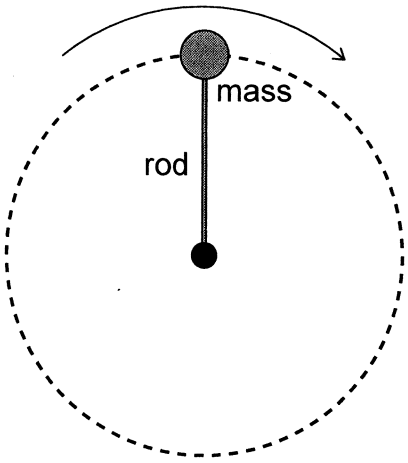
RHR

The direction of the field B is out of the page and the length of the wire is L. What is correct about the direction and magnitude of the force acting on the wire?

	Direction	Magnitude
A.	↘	equal to BIL
B.	↘	smaller than BIL
C.	↗	equal to BIL
D.	↗	smaller than BIL

I is ⊥ to B
F is max
$F = BIL$

22. A mass connected to one end of a rigid rod rotates at constant speed in a vertical plane about the other end of the rod.



The force exerted by the rod on the mass is

A. zero everywhere.

B. constant in magnitude.

C. always directed towards the centre.

D. a minimum at the top of the circular path.

23. Planet X has mass M and radius R. Planet Y has mass $2M$ and radius $3R$. The gravitational field strength at the surface of planet X is g. What is the gravitational field strength at the surface of planet Y?

$F_g = F_g$

$mg = \frac{Gm_1m_2}{r^2}$

$\frac{g_y}{g_x} = \frac{1 \cdot 2}{(3)^2}$

$g_y = \frac{2}{9}g$

A. $\frac{2}{9}g$

B. $\frac{2}{3}g$

C. $\frac{3}{2}g$

D. $\frac{9}{2}g$

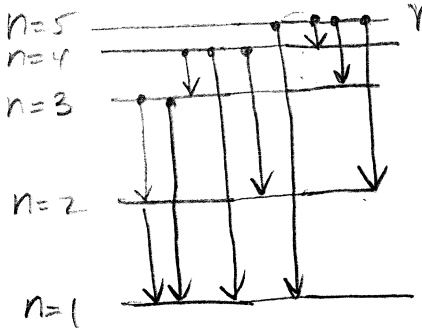
24. A simple model of an atom has five energy levels. What is the maximum number of different frequencies in the emission spectrum of that atom?

A. 4

B. 6

C. 10

D. 25



3 diff f
6 diff f
10 diff f

Rule
$\# = \frac{n(n-1)}{2}$
$= \frac{5(5-1)}{2} = 10$

25. Which of the following is the correct definition of the binding energy of a nucleus?

A. The product of the binding energy per nucleon and the nucleon number

B. The minimum work required to completely separate the nucleons from each other

C. The energy that keeps the nucleus together

D. The energy released during the emission of an alpha particle

26. Which of the following lists three fundamental forces in increasing order of strength?

A. electromagnetic, gravity, strong nuclear

B. weak nuclear, gravity, strong nuclear

C. gravity, weak nuclear, electromagnetic

D. electromagnetic, strong nuclear, gravity

gravity weakest
strong strongest

27. For which reason were quarks first introduced?

A. To explain the existence of isotopes

B. To describe nuclear emission and absorption spectra

C. To account for patterns in properties of elementary particles

D. To account for the missing energy and momentum in beta decay

28. A solar panel has surface area $0.40\,m^2$ and efficiency 50 %. The average intensity of radiation reaching the surface of the panel is $0.25\,kWm^{-2}$. What is the average power output from an array of 10 of these solar panels?

A. 0.5 W

B. 5 W

C. 50 W

D. 500 W

$I = \frac{P}{A}$

$P = IA = (.25 \times 10^3 \frac{W}{m^2})(0.40 m^2) = .10 W$ Per Panel

$(.10 \frac{W}{Panel})(10 Panels)(.50_{eff}) = .5$ Watts

29. What is the correct order of energy transformations in a coal power station?

A. thermal → chemical → kinetic → electrical

B. chemical → thermal → kinetic → electrical

C. chemical → kinetic → thermal → electrical

D. kinetic → chemical → electrical → thermal

Coal → Burned → Steam turns turbine

Chem → Thermal → KE

30. A black body of surface $1.0\,m^2$ emits electromagnetic radiation of peak wavelength 2.90×10^{-6} m. Which of the following statements about the body are correct?

I. The temperature of the body is 1000 K.

II. The energy radiated by the body in one second is 5.7×10^4 J.

III. The body is a perfect absorber of electromagnetic radiation.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

$\lambda_{max} = \frac{2.90 \times 10^{-3}}{T \text{ Kelvin}}$ $T = \frac{2.90 \times 10^{-3}}{2.90 \times 10^{-6}} = 10^3$

$P = e\sigma A T^4$

$= e(5.67 \times 10^{-8})(1 m^2)(10^3)^4$

$= e\ 5.67 \times 10^4$ J/sec

$e = 1$ a perfect black body = absorber = emitter

$e = 0$

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Friday 6 May 2016 (morning)

1 hour 15 minutes

Candidate session number

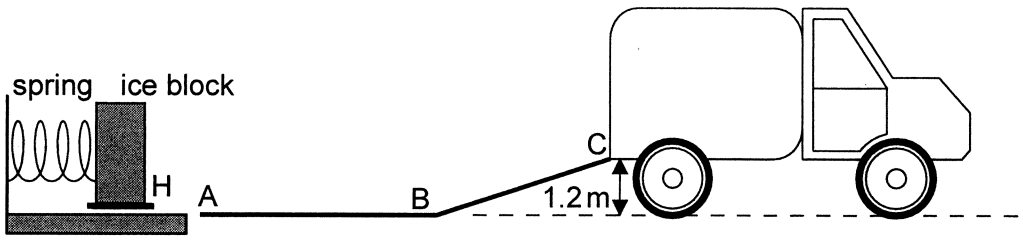
Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2216–6505

Answer **all** questions. Write your answers in the boxes provided.

1. A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.



Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

(a) (i) The block arrives at C with a speed of $0.90\,m\,s^{-1}$. Show that the elastic energy stored in the spring is 670 J. [2]

$PE_S = TE = (PE_g + KE)_C = (mgh + \frac{1}{2}mv^2)_C$

$= (55kg)(9.81\,m/s^2)(1.2m) + \frac{1}{2}(55kg)(0.90\,m/s)^2$

$= 647.5 + 22.3$

$= 670\,J$ ✓ ③

(ii) Calculate the speed of the block at A. [2]

$TE_A = TE_C$

$670\,J = (PE_g + KE)_A$ at A $h = zero$

$670 = \frac{1}{2}(55kg)v_A^2$ $\quad v_A = 4.9\,m/s$

(This question continues on the following page)

(Question 1 continued)

(b) Describe the motion of the block

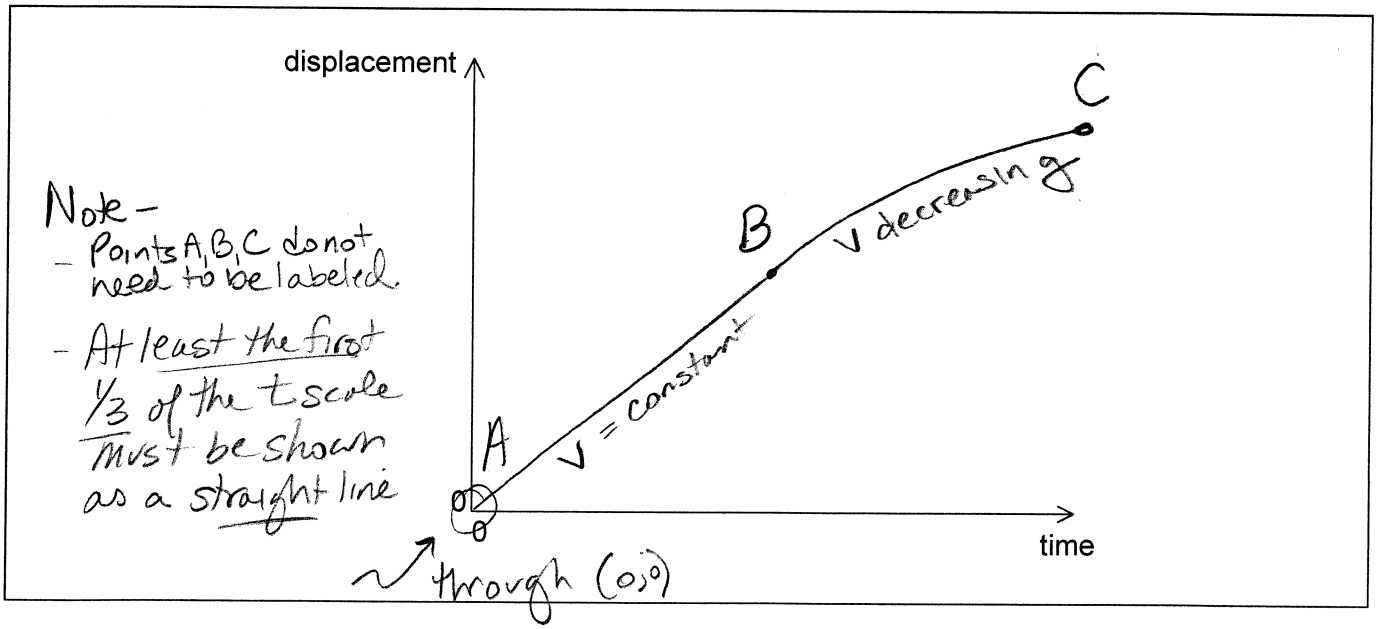
(i) from A to B with reference to Newton's first law. [1]

The block moves at a constant speed because Fnet is zero.

(ii) from B to C with reference to Newton's second law. [2]

- Fnet is not zero. A component of the block's weight = $F_{g\parallel}$ acts down the ramp.
- The blocks speed decreases (B to C)

(c) On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) [2]



(This question continues on the following page)

(Question 1 continued)

(d) The spring decompression takes 0.42 s. Determine the average force that the spring exerts on the block. [2]

$Ft = m\Delta v$

$F(.42s) = (55kg)(4.9 m/s - 0 m/s)$

$F = 640\ N$

(e) The electric motor is connected to a source of potential difference 120 V and draws a current of 6.8 A. The motor takes 1.5 s to compress the spring.

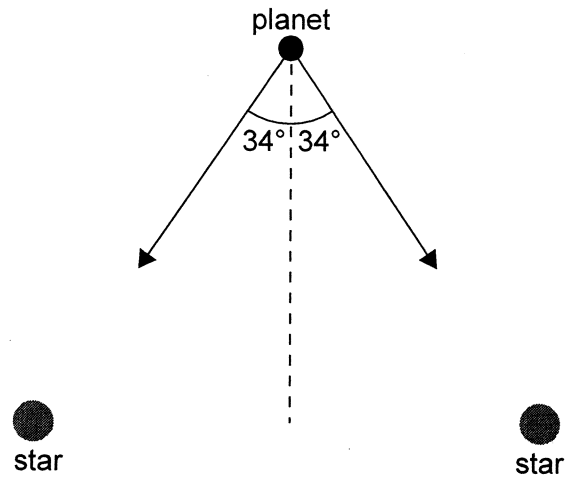
Estimate the efficiency of the motor. [2]

$P = \frac{W}{t}$ $W = Pt = IVt = (6.8A)(120V)(1.5s)$

$W = 1220\ J$

$\text{efficiency} = \frac{W_{out}}{W_{IN}} \times 100\% = \frac{670\ J}{1220\ J} \times 100\% = 55\%$

2. The two arrows in the diagram show the gravitational field strength vectors at the position of a planet due to each of two stars of equal mass *M*.



Each star has mass $M = 2.0 \times 10^{30}$ kg. The planet is at a distance of 6.0×10^{11} m from each star.

(a) Show that the gravitational field strength at the position of the planet due to **one** of the stars is $g = 3.7 \times 10^{-4}$ N kg^{-1}. [1]

$g = ?$

$F_g = F_g$

$mg = \frac{GMm}{r^2}$

$g = \frac{(6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2)(2.0 \times 10^{30}\ \text{kg})}{(6.0 \times 10^{11}\ \text{m})^2}$

$g = 3.7 \times 10^{-4}$ N/kg

(b) Calculate the magnitude of the resultant gravitational field strength at the position of the planet. [2]

$g\sin\theta \leftarrow \bullet \rightarrow g\sin\theta$

$g\cos\theta \quad g\cos\theta$

resolved FBD

$g_{net} = 2(g\cos\theta)$

$= 2(3.7 \times 10^{-4}\ \text{N/kg})(\cos 34°)$

$g_{net} = 6.1 \times 10^{-4}$ N/kg

3. In an experiment to determine the specific latent heat of fusion of ice, an ice cube is dropped into water that is contained in a well-insulated calorimeter of negligible specific heat capacity. The following data are available.

note:
$\Delta T_K = \Delta T\,^{\circ}C$

Mass of ice cube	= 25 g
Mass of water	= 350 g
Initial temperature of ice cube	= 0 °C
Initial temperature of water	= 18 °C
Final temperature of water	= 12 °C
Specific heat capacity of water	= 4200 $J\,kg^{-1}\,K^{-1}$

(a) Using the data, estimate the specific latent heat of fusion of ice. [4]

Heat lost by Liq. water = Heat gained by ice

$mc\Delta T_{\text{liquid water}} = mL_{\text{ice}} + mc\Delta t_{\text{ice}}$

$(.350\,kg)\left(4200\,\frac{J}{kgK}\right)(12-18\,K) = (.025\,kg)L + (.025\,kg)\left(4200\,\frac{J}{kg\,K}\right)(12-0\,K)$

$8820 = .025L + 1260$

$\frac{7560}{.025} = L$

$L = 3.0 \times 10^5\,\frac{J}{kg}$

(b) The experiment is repeated using the same mass of crushed ice.

Suggest the effect, if any, of crushing the ice on

(i) the final temperature of the water. [1]

Assuming ideal situation – no Energy lost to surroundings then T_{final} will not change

(ii) the time it takes the water to reach its final temperature. [1]

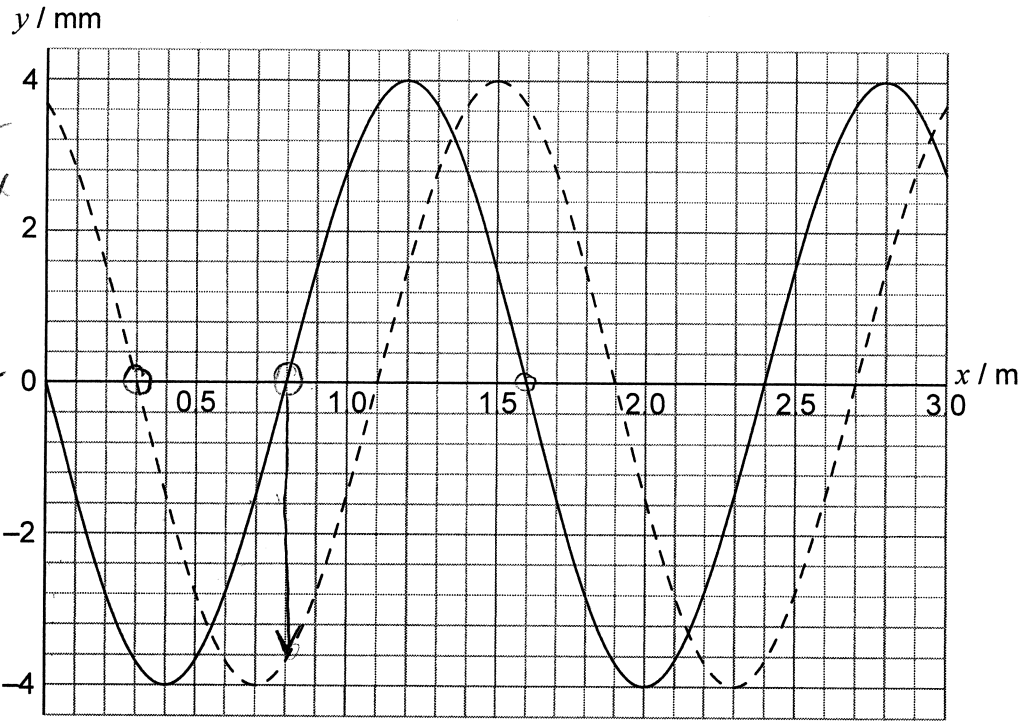
Time to reach the final temperature will be less because energy will be transferred faster; crushed ice has more surface area.

Please **do not** write on this page.

Answers written on this page
will not be marked.

4. A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance x of the displacement y of the particles in the medium. The solid line and the dotted line show the displacement at $t = 0$ and $t = 0.882\,\text{ms}$, respectively.

a Graph of displacement y vs distance x Not what a longitudinal wave looks like



wave →
↔ particles

The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

(a) State what is meant by a longitudinal travelling wave. [1]

The particles of the wave oscillate parallel to the direction of the wave (energy)

(b) Calculate, for this wave,

(i) the speed. [2]

see graph

$V = \frac{d}{t} = \frac{0.3\,\text{m}}{0.883 \times 10^{-3}\,\text{s}} = 340\,\text{m/s}$

(This question continues on the following page)

(Question 4 continued)

(ii) the frequency. [2]

from graph $\lambda = 1.6\,m$

$v = f\lambda$

$340\,\frac{m}{s} = f(1.6\,m)$ $f = 210\,Hz$

(c) The equilibrium position of a particle in the medium is at $x = 0.80\,m$. For this particle at $t = 0$, state and explain

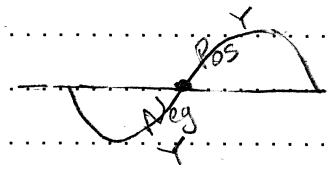
(i) the direction of motion. [2]

at t_0 $y_0 = 0mm$

at $t = .882ms$ $y = -3.6mm$ } The particle is moving in the Negative direction

(note it does not move down vertically)

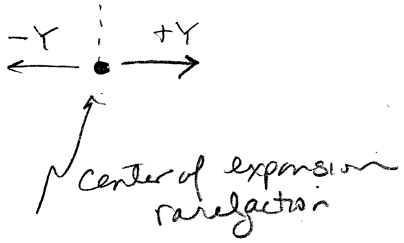
(ii) whether the particle is at the centre of a compression or a rarefaction. [2]



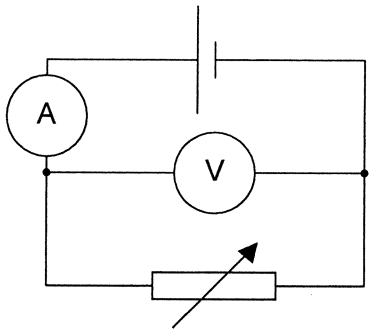
• Particles are at the center of a rarefaction.

• molecules to the left of the point have moved left (Neg)
molecules to the right have moved right (Pos.)

Y is displacement // to the wave



5. In an experiment a student constructs the circuit shown in the diagram. The ammeter and the voltmeter are assumed to be ideal.



(a) State what is meant by an ideal voltmeter. [1]

An ideal voltmeter has infinite resistance

(b) The student adjusts the variable resistor and takes readings from the ammeter and voltmeter. The graph shows the variation of the voltmeter reading V with the ammeter reading I.

$\mathcal{E} = I(R+r)$

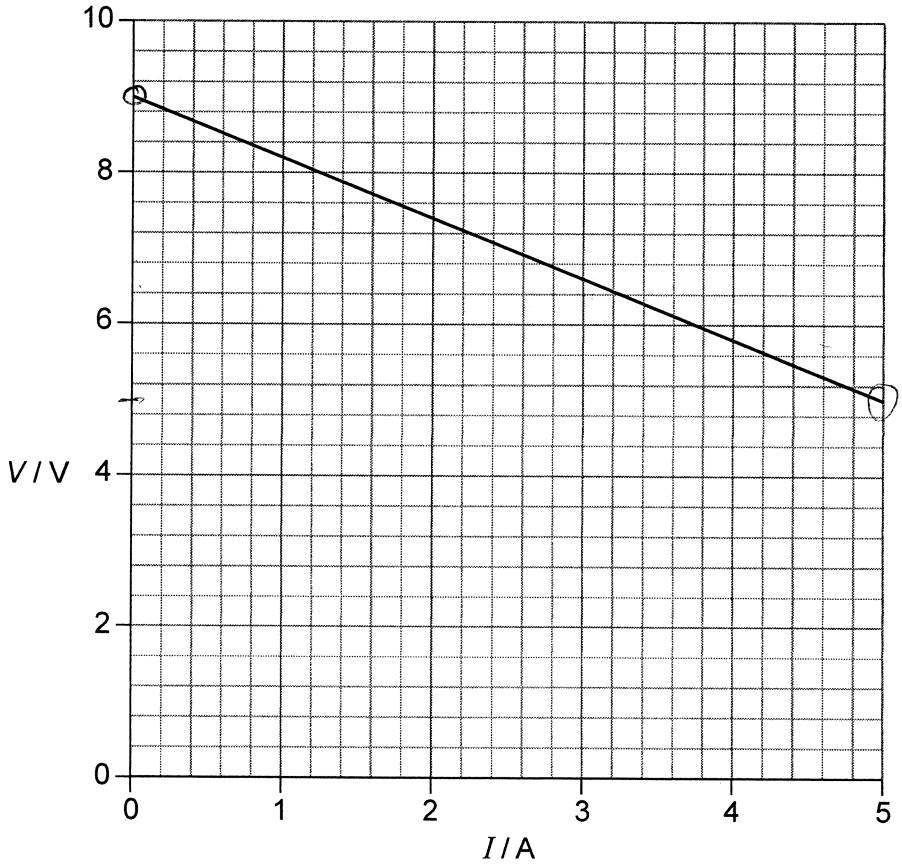
$\mathcal{E} = IR + rI$

$IR + rI = \mathcal{E}$

$IR = -rI + \mathcal{E}$

$V = -rI + \mathcal{E}$

$y = \text{slope}\, x + \mathcal{E}$



(This question continues on the following page)

(Question 5 continued)

Use the graph to determine

(i) the electromotive force (emf) of the cell. [1]

Emf = 9.0V (the y intercept)

(ii) the internal resistance of the cell. [2]

Slope = $-r$

Slope = $\frac{5-9V}{5-0A} = -\frac{4}{5} = -.8\,\Omega$

$r = 0.8\,\Omega$

(c) A connecting wire in the circuit has a radius of 1.2 mm and the current in it is 3.5A. The number of electrons per unit volume of the wire is $2.4\times10^{28}\,m^{-3}$. Show that the drift speed of the electrons in the wire is $2.0\times10^{-4}\,m\,s^{-1}$. [1]

$r = 1.2\times10^{-3}\,m$ I

$I = nAvq$

$3.5A = \left(2.4\times10^{28}\,\frac{e}{m^3}\right)(3.14)(1.2\times10^{-3}\,m)^2\,v\left(1.6\times10^{-19}\,\frac{C}{e}\right)$

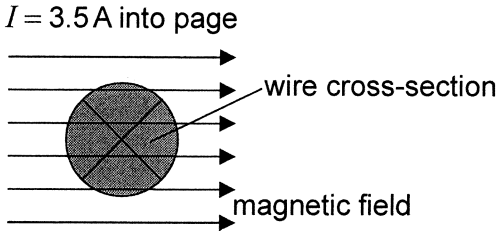
$v = 2.0\times10^{-4}\,m/s$

(This question continues on the following page)

$A = \pi r^2$

(Question 5 continued)

(d) The diagram shows a cross-sectional view of the connecting wire in (c).



$F = BIL\sin\theta$

No L

$F = Bqv\sin\theta$

The wire which carries a current of 3.5A into the page, is placed in a region of uniform magnetic field of flux density 0.25T. The field is directed at right angles to the wire.

Determine the magnitude **and** direction of the magnetic force on one of the charge carriers in the wire. [2]

$F = Bqv$ F ↓ toward the bottom of the page

$F = (0.25\text{T})(1.6\times10^{-19}\text{C})(2\times10^{4}\text{m/s})$

$F = 8.0\times10^{-24}\text{N}$

6. (a) A nucleus of phosphorus-32 $\left({}^{32}_{15}\mathrm{P}\right)$ decays by beta minus (β^-) decay into a nucleus of sulfur-32 $\left({}^{32}_{16}\mathrm{S}\right)$. The binding energy per nucleon of ${}^{32}_{15}\mathrm{P}$ is 8.398 MeV and for ${}^{32}_{16}\mathrm{S}$ it is 8.450 MeV.

Determine the energy released in this decay. [2]

${}^{32}_{15}\mathrm{P} \rightarrow {}^{32}_{16}\mathrm{S} + {}^{0}_{-1}e + \bar{\nu} + \mathcal{E}$

$\mathcal{E} = 1.664$ MeV

8.398 MeV / nucleon → 8.450 MeV / nucleon

× 32 × 32 nucleons

268.736 MeV → 270.400 MeV + $\mathcal{E}$

(This question continues on the following page)

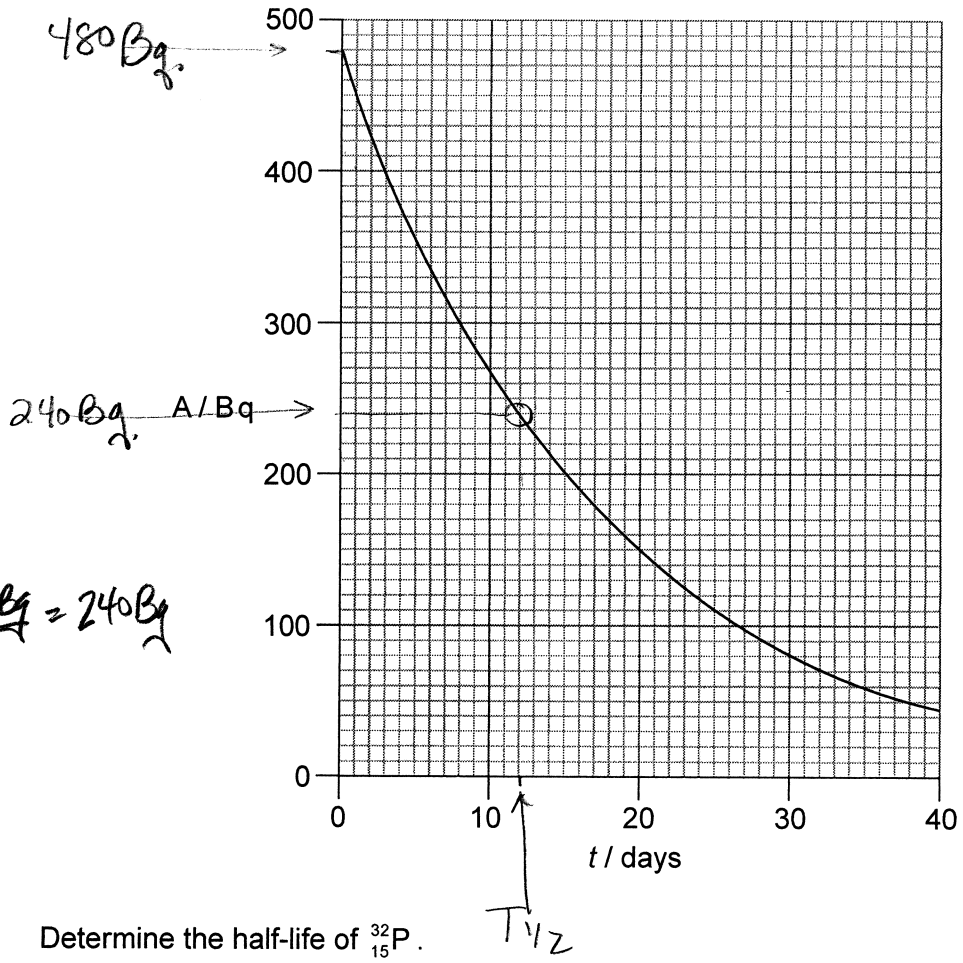
${}^{32}_{16}\mathrm{S}$ has more BE / nucleon

" is more stable

forming " from ${}^{32}_{15}\mathrm{P}$ $\mathcal{E} = 1.664$ MeV released.

(Question 6 continued)

(b) The graph shows the variation with time t of the activity A of a sample containing phosphorus-32 $\left({}^{32}_{15}\mathrm{P}\right)$.



at $T_{1/2}$ $A = \frac{480\text{Bq}}{2} = 240\text{Bq}$

Determine the half-life of $^{32}_{15}\mathrm{P}$. [1]

12 days

(c) Quarks were hypothesized long before their existence was experimentally verified. Discuss the reasons why physicists developed a theory that involved quarks. [3]

- A baryon can be changed into a different baryon (p → n or n → p)
- Baryons must be composed of smaller fundamental particles, (conservation rule applied.)
- Fundamental particles called quarks. Quark theory explains observations.

7. The Sun has a radius of 7.0×10^8 m and is a distance 1.5×10^{11} m from Earth. The surface temperature of the Sun is 5800 K.

(a) Show that the intensity of the solar radiation incident on the upper atmosphere of the Earth is approximately 1400 Wm^{-2}. [2]

See sketch below

$I = \frac{P}{A}$ $\quad P = \varepsilon \sigma A T^4$

$A_{surface\ of\ asphere} = 4\pi r^2$ $\quad = 1$ assume a Perfect Black Body

$I = \frac{\sigma 4\pi r_{sun}^2 T^4}{4\pi (r_{S-E})^2}$

$= \frac{(5.67 \times 10^{-8} \frac{W}{m^2 K^4})(7.0 \times 10^8 m)^2 (5800K)^4}{(1.5 \times 10^{11} m)^2}$

$I = 1397 \cong 1400\ W/m^2$ ☺

(b) The albedo of the atmosphere is 0.30. Deduce that the average intensity over the entire surface of the Earth is 245 Wm^{-2}. [2]

albedo = fraction reflected = .30

I reaching the surface = .70

$1400 \frac{W}{m^2} \times .70 = 980 \frac{W}{m^2}$ reaching Earth's surface

only 1/2 side receives light at one time

$I_{avg} = \frac{\pi r_e^2}{4\pi r_e^2} 980 \frac{W}{m^2} = 245 \frac{W}{m^2}$

$\frac{\text{Surface area circle}}{\text{Surface area of asphere}}$

☺

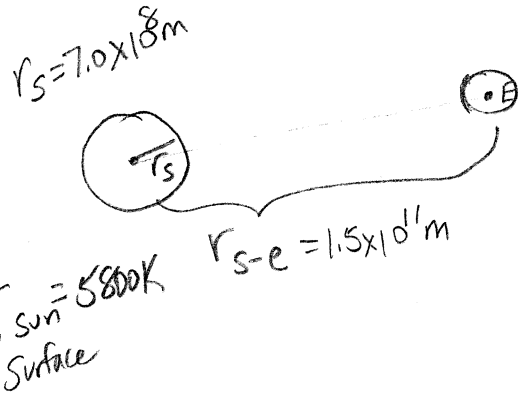
(c) Estimate the average surface temperature of the Earth. [2]

$I = \frac{P}{A} = \frac{\varepsilon \sigma A T^4}{A}$ assume Perfect Black Body $\varepsilon = 1$

$245 \frac{W}{m^2} = (1)(5.67 \times 10^{-8} \frac{W}{m^2 K^4}) T^4$

$4.32 \times 10^9 = T^4$

$T = 256 K$



Please **do not** write on this page.

Answers written on this page
will not be marked.

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 3

Monday 9 May 2016 (morning)

Candidate session number

1 hour

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[35 marks]**.

Answer ALL Section A

Option	Questions
Option A — Relativity	3 – 6
Option B — Engineering physics	7 – 8
Option C — Imaging	9 – 11
Option D — Astrophysics	12 – 14

section B Answer all of Option B

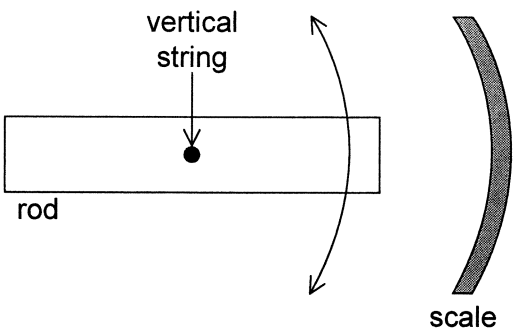
Note - IB markscheme Paper 3 1b is not correct Our Solution is correct.

2216–6506

Section A

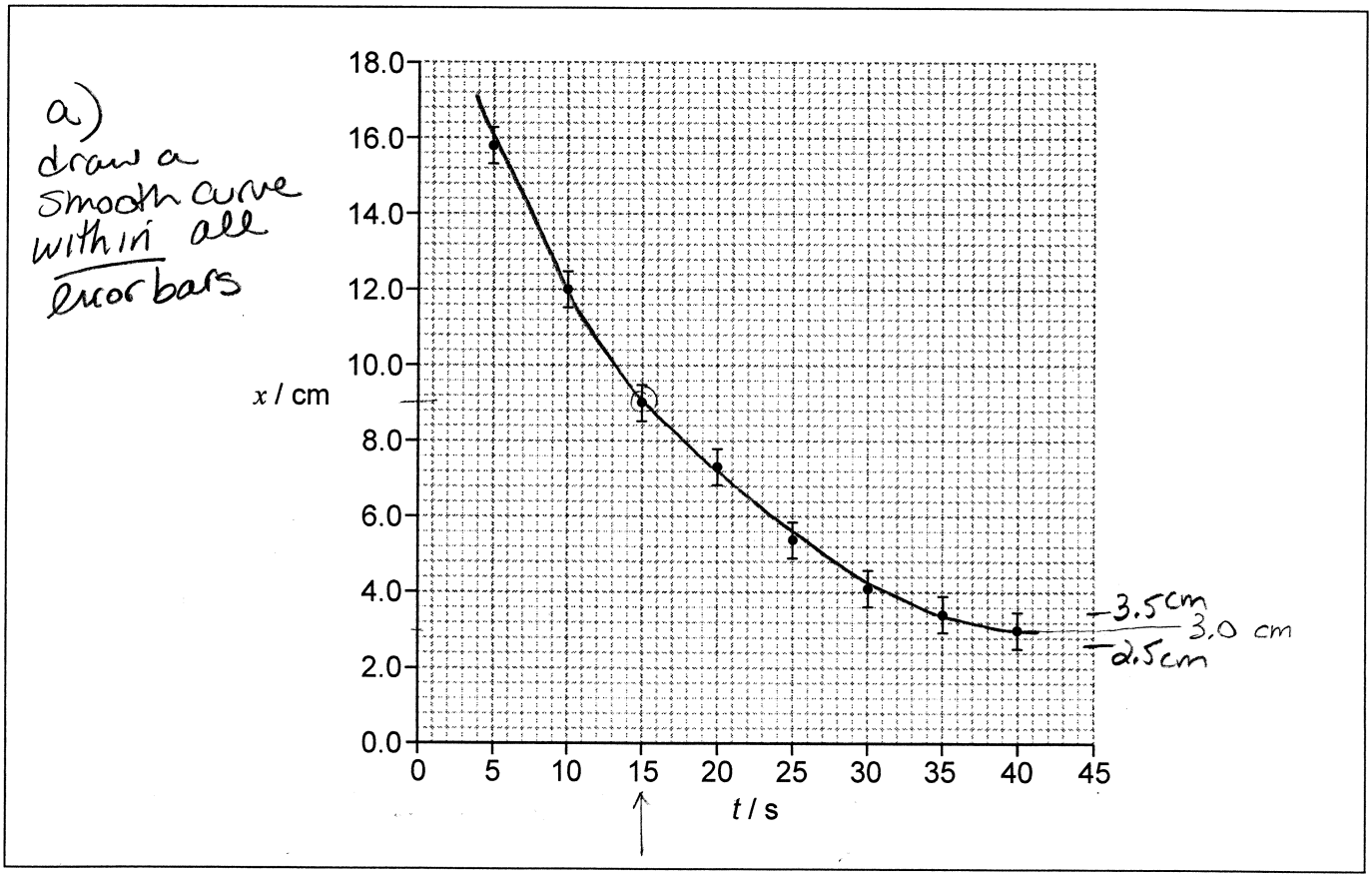
Answer **all** questions. Write your answers in the boxes provided.

1. A student investigates the oscillation of a horizontal rod hanging at the end of a vertical string. The diagram shows the view from above.



The student starts the rod oscillating and measures the largest displacement for each cycle of the oscillation on the scale and the time at which it occurs. The student begins to take measurements a few seconds after releasing the rod.

The graph shows the variation of displacement x with time t since the release of the rod. The uncertainty for t is negligible.



(a) On the graph above, draw the line of best fit for the data. [1]

(This question continues on the following page)

(Question 1 continued)

(b) Calculate the percentage uncertainty for the displacement when $t = 40\,s$. [2]

at 40s point center 3.0cm (max 3.5cm, min 2.5cm)

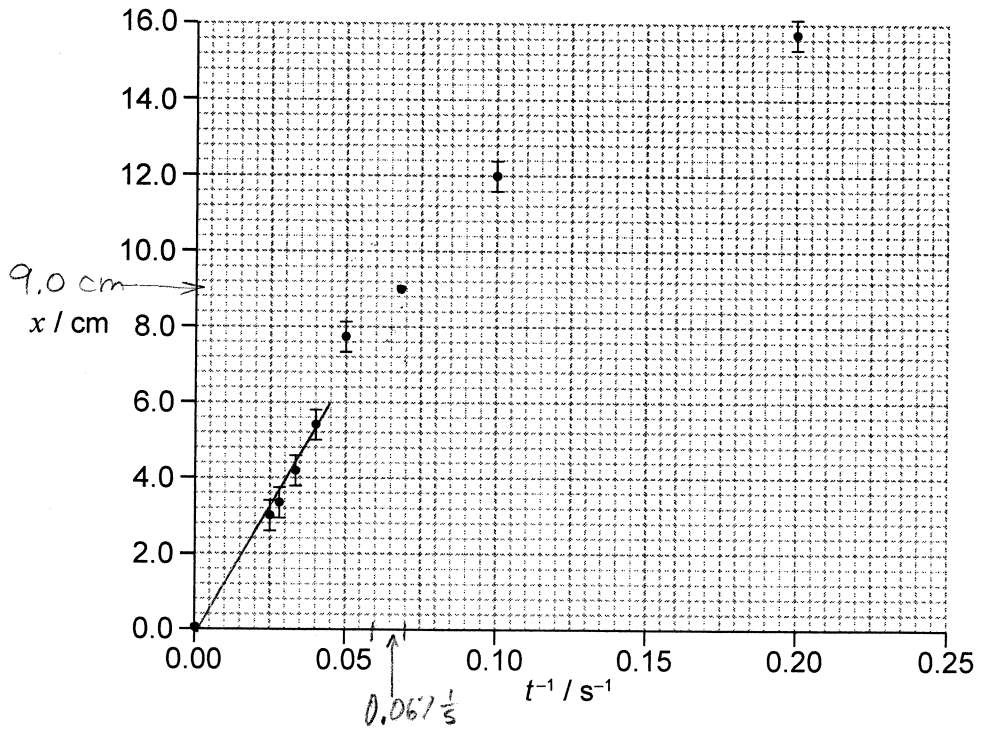
Value is $3.0 \pm 0.5\,cm$

% uncertainty $= \frac{\pm 0.5\,cm}{3.0\,cm} \times 100\% = 17\%$

Note error in markscheme

(c) The student hypothesizes that the relationship between x and t is $x = \frac{a}{t}$ where a is a constant.

To test the hypothesis x is plotted against $\frac{1}{t}$ as shown in the graph.



note error bar is not required.

(i) The data point corresponding to $t = 15\,s$ has not been plotted. Plot this point on the graph above. at t=15s from graph x = 9.0cm 1/t = 1/15s = 0.067 1/sec [1]

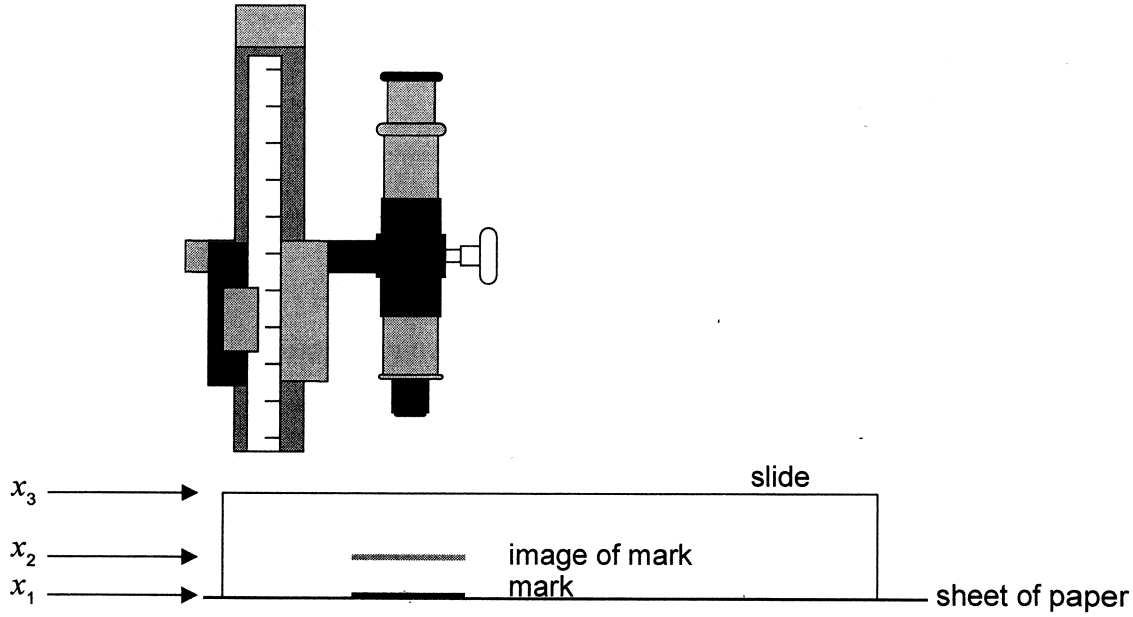
(ii) Suggest the range of values of t for which the hypothesis may be assumed to be correct. [2]

From $\frac{1}{t} = .025\,1/sec$ to $\frac{1}{t} 0.04\,1/sec$ the graph is linear and goes through 0,0. → Answer t 25-40 sec.

(Alternative answer – The graph does not support the hypothesis.)

2. A student measures the refractive index of the glass of a microscope slide.

He uses a travelling microscope to determine the position x_1 of a mark on a sheet of paper. He then places the slide over the mark and finds the position x_2 of the image of the mark when viewed through the slide. Finally, he uses the microscope to determine the position x_3 of the top of the slide.



The table shows the average results of a large number of repeated measurements.

	Average position of mark / mm
x_1	0.20 ±0.02
x_2	0.59 ±0.02
x_3	1.35 ±0.02

(a) The refractive index of the glass from which the slide is made is given by

$$n = \frac{x_3 - x_1}{x_3 - x_2}.$$

Determine

(i) the refractive index of the glass to the correct number of significant figures, ignoring any uncertainty. [1]

$n = \frac{x_3 - x_1}{x_3 - x_2} = \frac{1.35 - 0.20\,\text{mm}}{1.35 - 0.59\,\text{mm}} = 1.51316 = 1.5$

$= \frac{1.15\,\text{mm}}{0.76\,\text{mm}} = 1.5$

correct sig fig in calculator same precision rule

When × or ÷ round to the least # of sig.digits = 2 digits here

(This question continues on the following page)

(Question 2 continued)

(ii) the uncertainty of the value calculated in (a)(i). [3]

apply addition rule

$\pm X_3 - X_1 = (\pm .02\text{mm}) + (\pm .02\text{mm}) = \pm .04\text{mm}$

$\pm X_3 - X_2 = (\pm .02\text{mm}) + (\pm .02\text{mm}) = \pm .04\text{mm}$

apply division rule

$$\frac{\pm n}{n} = \frac{\pm (X_3 - X_1)}{X_3 - X_1} + \frac{\pm (X_3 - X_2)}{X_3 - X_2}$$

$$\frac{\pm n}{1.5} = \frac{\pm .04\text{mm}}{1.15\text{mm}} + \frac{\pm .04\text{mm}}{0.76\text{mm}}$$

$\pm n = [(.03478) + (0.05263)]\,1.5 = \pm 0.1$

So $n = 1.5 \pm .1$

(b) After the experiment, the student finds that the travelling microscope is badly adjusted so that the measurement of each position is too large by 0.05 mm.

(i) State the name of this type of error. [1]

Systematic error

(ii) Outline the effect that the error in (b)(i) will have on the calculated value of the refractive index of the glass. [2]

No effect because X_1, X_2 and X_3 would all be 0.05 mm too large but $X_3 - X_1$ and $X_3 - X_2$ will not change – So $n = \frac{X_3 - X_1}{X_3 - X_2}$ will be unchanged

(This question continues on the following page)

(Question 2 continued)

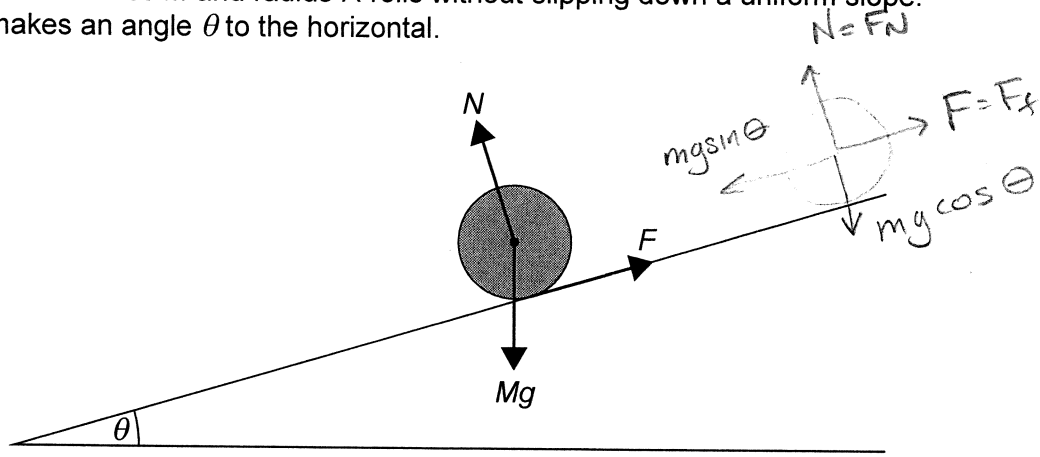
(c) After correcting the adjustment of the travelling microscope, the student repeats the experiment using a glass block 10 times thicker than the original microscope slide. Explain the change, if any, to the calculated result for the refractive index and its uncertainty. [2]

– No change in value for n because both the numerator and the denominator will be 10 times larger.

– Uncertainty for n will be smaller: In the calculation $\frac{\pm n}{n} = \frac{\pm (x_3 - x_1)}{x_3 - x_1} + \frac{\pm (x_3 - x_2)}{x_3 - x_2}$ each numerator will not change but each denominator will be larger

Option B — Engineering physics

7. A solid cylinder of mass M and radius R rolls without slipping down a uniform slope. The slope makes an angle θ to the horizontal.



The diagram shows the three forces acting on the cylinder. N is the normal reaction force and F is the frictional force between the cylinder and the slope.

(a) State why F is the only force providing a torque about the axis of the cylinder. [1]

$\tau = rF\sin\theta$

F is the only force that does not act at the center of mass ($r \neq$ zero for F)

GIVEN!

(b) (i) The moment of inertia of a cylinder about its axis is $I = \frac{1}{2}MR^2$. Show that, by applying Newton's laws of motion, the linear acceleration of the cylinder is $a = \frac{2}{3}g\sin\theta$. [4]

$F = ma$ for rotation

$F_{net} = ma$

$F_{g\,//} - F_f = ma$

$Mg\sin\theta - F = Ma$ 1pt

$\tau = rF\sin\theta$

F is tangent so $\sin\theta = 1$

$\tau = I\alpha$

$+F = I\alpha$

$F = \frac{I\alpha}{r}$

$Mg\sin\theta - \frac{I\alpha}{r} = Ma$

$v = \omega r$ TOPIC 6

$a = \alpha r$

so $\alpha = \frac{a}{r}$

$Mg\sin\theta - \frac{\frac{1}{2}MR^2}{r}\frac{a}{r} = Ma$

$g\sin\theta - \frac{1}{2}a = a$

$g\sin\theta = \frac{3}{2}a$

$a = \frac{2}{3}g\sin\theta$

Outside the box goes not get seen.

Note - I would need to write more of my work in an

(Option B continues on the following page)

(Option B, question 7 continued)

(ii) Calculate, for $\theta = 30°$, the time it takes for the solid cylinder to travel 1.5 m along the slope. The cylinder starts from rest. [2]

$d = v_i t + \frac{1}{2} a t^2$

$1.5\,m = \frac{1}{2}\left(\frac{2}{3} g \sin 30°\right) t^2$

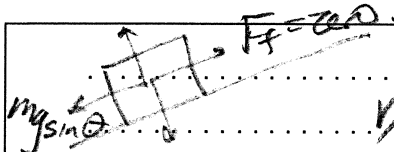
$\frac{4.5}{g \sin 30°} = t^2$

$0.917 = t^2$

$t = 0.96\,sec$

(c) A block of ice is placed on the slope beside the solid cylinder and both are released at the same time. The block of ice is the same mass as the solid cylinder and slides without friction. [1]

At any given point on the slope, the speed of the block of ice is greater than the speed of the solid cylinder. Outline why, using the answer to (b)(i).



For ICE: $F_{net} = ma$; $mg\sin\theta = ma$; $a = g\sin\theta$

Ice: $a = g\sin\theta$

Cylinder: $a = \frac{2}{3} g\sin\theta$

So the ice has a larger acceleration and speeds up faster.

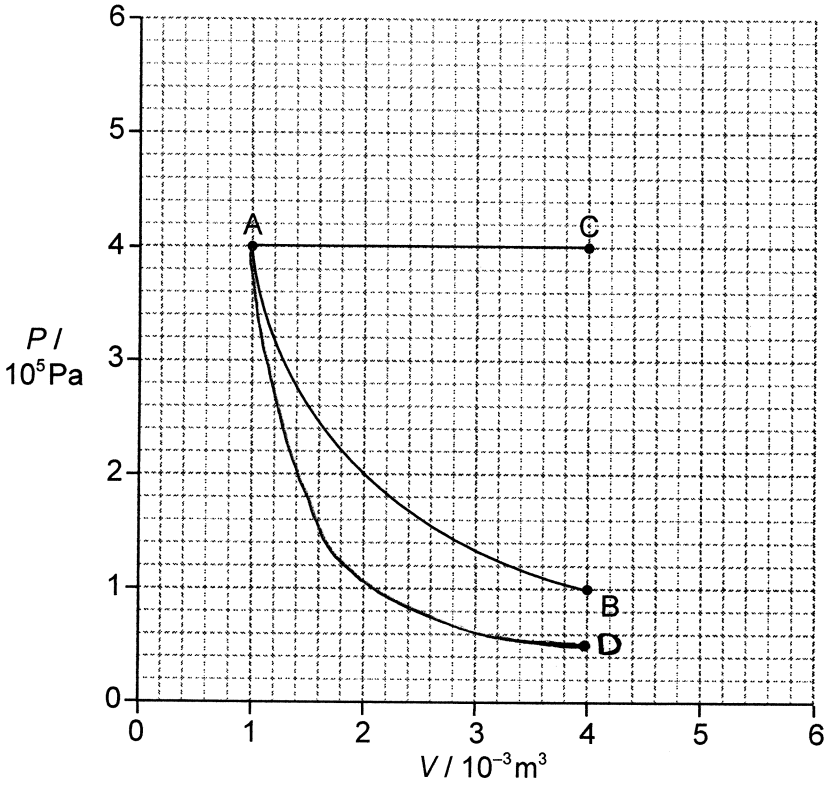
(d) The solid cylinder is replaced by a hollow cylinder of the same mass and radius. Suggest how this change will affect, if at all, the acceleration in (b)(i). [2]

- Hollow cylinder with the same mass and radius has a larger I.
- So acceleration will be smaller

(Option B continues on the following page)

(Option B continued)

8. A fixed mass of an ideal monatomic gas undergoes an isothermal change from A to B as shown.



The temperature at A is 350 K. An identical mass of the same ideal monatomic gas undergoes an isobaric change from A to C.

(a) (i) Calculate the temperature at C. [1]

$\frac{P_A V_A}{T_A} = \frac{P_C V_C}{T_C}$ $\quad \frac{(4\times10^5\,Pa)(1\times10^{-3}\,m^3)}{350\,K} = \frac{(4\times10^5\,Pa)(4\times10^{-3}\,m^3)}{T_C}$

$T_C = 1400\,K$

(ii) Calculate the change in internal energy for AC. [2]

$\Delta U = ?$ $\quad \Delta U = \frac{3}{2} nR(\Delta T)$ $\quad PV = nRT$ $\quad \Delta U = 1800\,J$

n is not known $\quad$ OR $\quad P_A V = nR\Delta T$

Note can use $PV = nRT$ at A or C because you know P, V, T

So, $\Delta U = \frac{3}{2}(P_A V)$

$= \frac{3}{2}(4\times10^5\,Pa)(4\times10^{-3}\,m^3 - 1\times10^{-3}\,m^3)$

(Option B continues on the following page)

(Option B, question 8 continued)

(iii) Determine the energy supplied to the gas during the change AC. [2]

$Q = ?$ $Q = \Delta U + W$ $W = P\Delta V$

$Q = 1800\,J + (4\times10^{5}\,Pa)(3\times10^{-3}\,m^3)$

$Q = 3000\,J$

(iv) On the graph, draw a line to represent an adiabatic expansion from A to a state of volume $4.0\times10^{-3}\,m^3$ (point D). A–B is an isotherm – [1]
The adiabatic line A-D starting at A will be steeper than A-B

(b) (i) State the change in entropy of a gas for the adiabatic expansion from A to D. [1]

Adiabatic means $Q = zero$

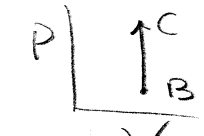
$\Delta S = \frac{\Delta Q}{T}$ so $\Delta S = zero$

(ii) Explain, with reference to the concept of disorder, why the entropy of the gas is greater at C than B. [3]

$S_C > S_B$

- Entropy is a measure of the disorder (V is the same)
- C is higher temp than B ; higher Temp is more disorder
- more entropy (more disorder) at C than B

or



ΔQ is +

$\Delta S = \frac{\Delta Q}{T}$ so ΔS is +

End of Option B

ΔS is related to disorder.