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2003 TJC Prelim P1

19/30

1 The relationship between four physical quantities X, p, q and t is given by

$$X = p + qt$$

where t is the time is seconds. If p has the units m s^{-1}, then q must have the units

A m s^{-1} B m s^{-2} C m s D m

B

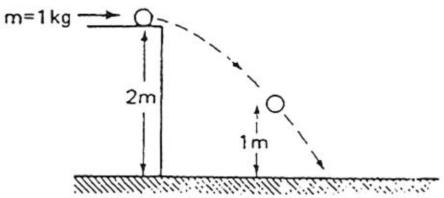
2 Four students each made a series of measurements of the acceleration of free fall g. The table shows the results obtained.

Which student obtained a set of results that could be described as accurate but not precise?

Student	results, g / m s^{-2}			
A	9.81	9.80	9.82	9.82
B	9.21	10.32	10.13	9.58
C	9.45	9.21	8.99	8.76
D	8.45	8.46	8.50	8.41

B

3

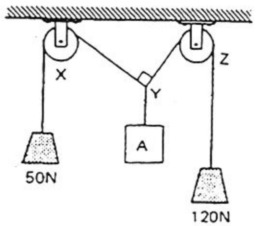


A particle of mass m = 1 kg is given a push so that it leaves the table with a velocity of 2 m s^{-1} as shown. Assuming g = 10 m s^{-2}, the mechanical energy of the particle possessed at a point 1 m above the ground is

A 2 J B 10 J C 12 J D 22 J

D

4

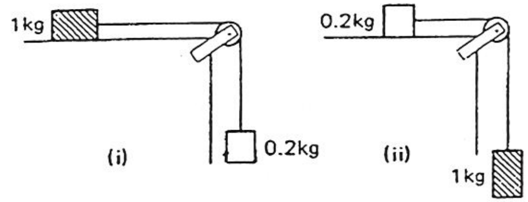


The diagram shows a body **A** supported by strings passing over two pulleys with the weights attached, the system is in equilibrium with angle XYZ = 90°. The weight of **A** in N is

A 85 B 70 C 130 D 170

D ×C

5

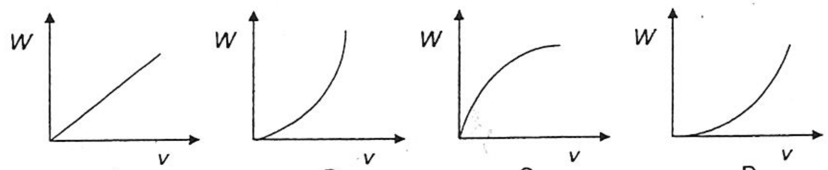


A 0.2 kg and a 1 kg masses are arranged as in (i). The table top and the pulley are frictionless and the string is inelastic. Then they are arranged as in (ii). The acceleration of the system in (i) and (ii)

A are the same
B are in the ratio of 1: 4
C are in the ratio of 1: 5
D are in the ratio of 4: 5

C

6 A particle, initially at rest on a frictionless horizontal surface, is acted upon by a horizontal force which is constant in size and direction. A graph is plotted of the work done on the particle, W, against the speed of the particle, v. If there are no other horizontal forces acting on the particle, the graph would look like



A B C D

A ×D

$a = r\omega^2 = r\left(\frac{2\pi}{T}\right) = 2.0\left(\frac{2\pi}{3.0}\right)$

7 An object moves at constant speed round a circle of radius 2.0 m in 3.0 s. The magnitude of its acceleration is

A 0.46 m s^{-2} B 0.95 m s^{-2} C 4.2 m s^{-2} D 8.8 m s^{-2}

C ×D

$F \propto \frac{1}{r^2}$

$45 = \frac{k}{R^2}$ —(1)

$5 = \frac{k}{(R+h)^2}$ —(2)

$\frac{(1)}{(2)}: 3 = \frac{R+h}{R}$

$3R = R + h$

$h = 2R$

8 On the ground, the gravitational force acting on an object is 45 N. When the object is at the height h, the gravitational force on it is 5 N. If R is the radius of the Earth, the approximate value for h is

A 2R B 3R C 4R D 9R

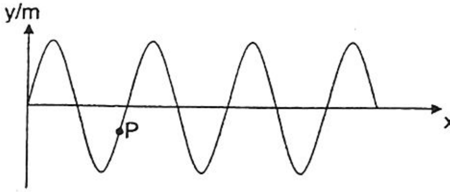
A

9 When a mechanical system is in resonance,

A the driven system is in phase with the driver system.
B the driver frequency is the same as the natural frequency of the system.
C the energy transferred from the driver system to the resonant system is a minimum.
D damping forces are at their minimum.

B

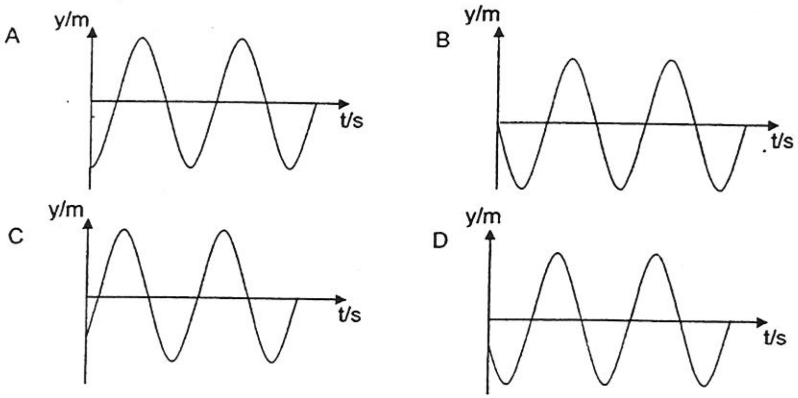
10 The diagram below represents part of a transverse wave travelling along a string in the positive x-direction at a particular instant of time.



$x =$

$v = \frac{dx}{dt}$

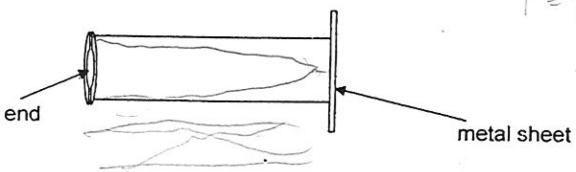
Which one of the following graphs represents the subsequent displacement (y) – time (t) relation for particle P ?



D

11 A piece of glass tubing with both ends open is closed at one end by covering it with a sheet of metal as shown in the diagram below. The fundamental frequency is found to be 280 Hz.

$f = \frac{n\lambda}{D}$ $\quad f \propto \frac{1}{\lambda}$



$280 = \frac{\lambda}{D}$

$\lambda \propto f$

If the metal sheet is now removed, what is the new fundamental frequency of the resulting open tubing?

A 140 Hz
B 280 Hz
C 420 Hz
D 560 Hz

A

× D

12 A stationary wave is formed by superimposing two longitudinal waves of frequency 20 MHz. The adjacent nodes in the stationary waves are 25 μm apart. What is the speed of the progressive waves?

A 330 m s^{-1}
B 500 m s^{-1}
C 1000 m s^{-1}
D 2000 m s^{-1}

$v = f\lambda$

$= 20\times10^{6}\times50\times10^{-6}$

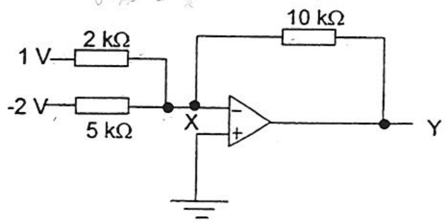
C

13 Which one of the following summarises the change in wave characteristics when going from infra-red to X-rays in the electromagnetic spectrum?

	Frequency	wavelength (in vacuum)	speed (in vacuum)
A	increases	decreases	remains constant
B	decreases	increases	decreases
C	increases	increases	increases
D	decreases	increases	remains constant

D

14



× A

What is the current flowing through the 10 kΩ resistor?

A 0.1 mA from **X** to **Y**
B 0.5 mA from **X** to **Y**
C 0.9 mA from **X** to **Y**
D 0.1 mA from **Y** to **X**

D

× A

15 A constant potential difference is maintained between the ends of a length of copper wire. If the temperature is raised from 20°C to 50°C, there is a negligible change in the

A number of free electrons in the conductor.
B kinetic energy of the lattice ions.
C amplitude of vibration of the lattice ions.
D frequency of collisions between the electrons and the lattice ions.

A

16 A digital voltmeter connected across the terminals of a certain battery gives a reading of 6.05 V. When a 10 Ω resistor is also connected across the battery terminals, the meter reading falls to 5.85 V. The internal resistance of the battery, in ohms, must be

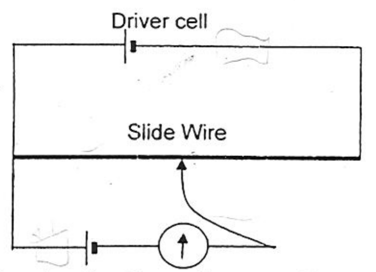
A 0.34 B 0.60 C 5.34 D 9.67

A

$E = V + Ir$

$6.05 = 5.85 + \left(\frac{5.85}{10}\right) r$

17 For the potentiometer circuit below, it is noticed that the balance length is too small. The balance length can be increased by



A changing the driver cell to one with a larger emf.
B connecting a protective resistor in series with the galvanometer.
C adding a resistor in series with the driver cell.
D replacing the slide wire with one that has a higher resistance.

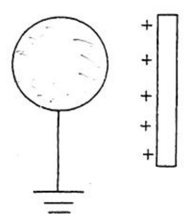
18 A sinusoidal current of peak value I_o is passed through a resistor R with a diode connected in series with it. The average rate of heat dissipated in R is

A $0.25\,I_o^2R$ B $0.50\,I_o^2R$ C $0.71\,I_o^2R$ D $1.41\,I_o^2R$

$I_o = \sqrt{2}\,I_{rms}$

$P = I^2R = \left(\frac{I_o}{\sqrt{2}}\right)^2 R = \frac{I_o^2}{2}R$

19 What is the potential and nature of the charge on the metallic sphere, which is placed closely to a positively charged conducting plate as shown in the diagram below.

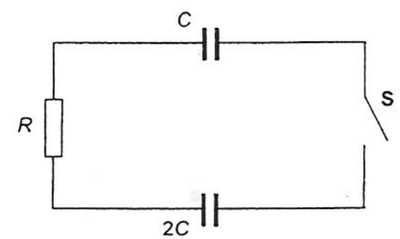


	Potential	Charge
A	positive	positive
B	negative	negative
C	zero	negative
D	zero	positive

20 From a supply of identical capacitors rated 8 μF and 250 V, the minimum number to form a composite 16 μF and 1000 V capacitor is

A 4 B 8 C 16 D 32

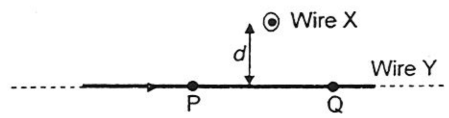
21 A charged capacitor of capacitance C is connected to a resistor R, an uncharged capacitor of capacitance $2C$ and a switch **S** as shown in the diagram.



When the switch is closed, which one of the following statements is *correct*?

A The total energy stored in the capacitors remains the same.
B The final charge on each capacitor is different.
C The final potential differences across the capacitors are different.
D The final potential difference across the resistor is not zero.

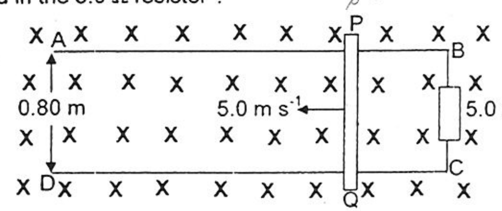
22 Two long straight wires, X and Y, are placed perpendicular to each other at a distance d apart. A current flows out of page in wire X. The same current flows from left to right in wire Y.



What are the directions of the forces acting on wire Y at points P and Q due to the magnetic field produced by wire X?

	Force at P	Force at Q
A	out of page	into page
B	into page	out of page
C	towards X	away from X
D	away from X	towards X

23 A conducting rod PQ is made to slide on smooth metal rails AB and CD in a uniform magnetic field of flux density 2.0 T by an applied force. The speed of PQ is 5.0 m s^{-1}. The only resistance in the circuit PBCQ is 5.0 Ω in the arm BC. At what rate is heat being generated in the 5.0 Ω resistor ?



A 3.2 W B 5.0 W C 8.0 W D 12.8 W

24 A thermocouple thermometer has one of its junctions dipped into steam at 100 °C while the other junction dipped into ice at 0 °C. An emf of –1.6 V is produced. When the junction in ice is removed and placed into an unknown liquid, the thermocouple thermometer produces an emf of 0.9 V. What is the temperature of the unknown liquid?

A -230 °C
B -110 °C
C 44 °C
D 160 °C

~~C~~ D

25 A solid **X** is in thermal equilibrium with a solid **Y**, which is at the same temperature as a third solid **Z**. The three bodies are of different materials and masses. Which one of the following statements is certainly correct?

A **X** and **Y** have the same heat capacity
B **X** and **Y** have the same internal energy
C There is no net transfer of energy if **X** is placed in thermal contact with **Z**
D **Y** need not be in thermal equilibrium with **Z**

C

26 An inexpansible vessel initially contains 2.0 kg of gas at 300 K. What is the mass of gas that has escaped from the vessel if it is heated from 300 K to 400 K under constant pressure?

A 0.50 kg
B 0.75 kg
C 1.2 kg
D 1.5 kg

$pV = nRT$
$n \propto \frac{1}{T}$
$n_1 = \frac{k}{T}$
$2.0 = \frac{k}{300}$ — (1)
$\frac{2.0}{m_2} = \frac{400}{300}$
$m_2 = \frac{3}{4} \times 2$

~~A~~

$pV = nRT$
$n = \frac{pV}{RT}$
$mass = \frac{pV}{RT \cdot M_r}$
$2.0 = \frac{pV}{8.31}$
$mass \propto \frac{1}{T}$
$2.0 = \frac{k}{300}$
$k = 600$
$mass = \frac{600}{400}$
$= 1.5$
$2 - 1.5 = 0.5$

27 Ions of several isotopes are accelerated through the same potential difference *V* in an 'ion accelerator'. Then they are directed in a beam into a uniform magnetic field. The initial direction of the beam is at right angles to the field so the ions move in circular paths in the magnetic field. Which ion has the least curved path?

A $^{16}_{8}O^{+}$ B $^{14}_{7}N^{2+}$ C $^{6}_{3}Li^{+}$ D $^{12}_{6}C^{+}$

A

$E = \frac{1}{2}mv^2$ $v^2 = \frac{2E}{m}$ $v = \sqrt{\frac{2E}{m}}$

28 The de Broglie wavelength of an electron accelerated from rest by a p.d. of 1000 V is λ_1. The de Broglie wavelength of another electron accelerated from rest by a p.d. of 2000 V is λ_2. The ratio $\frac{\lambda_1}{\lambda_2}$ is

A $\frac{1}{2}$ B $\frac{1}{\sqrt{2}}$ C $\sqrt{2}$ D 2

C

1000 J C⁻¹
2000 J C⁻¹
$qV = E$
$\lambda = \frac{h}{p}$
$\frac{\lambda_1}{\lambda_2} = \frac{p_2}{p_1} = \frac{v_2}{v_1} = \frac{\sqrt{\frac{2q(2000)}{m}}}{\sqrt{\frac{2q(1000)}{m}}}$ $\frac{\sqrt{2000}}{\sqrt{1000}}$

29 A nucleon is

A a nucleus. B a neutron or a proton. C a nuclide. D a radioactive isotope.

B

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

30 The initial count-rate of a radioactive source is 220 s⁻¹. In the absence of the source, the count-rate is 20 s⁻¹. If the half-life of the source is 30 minutes, what is the count-rate 1 hour later?

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

A 50 s⁻¹ B 55 s⁻¹ C 70 s⁻¹ D 120 s⁻¹

C

Physics 2003 Prelim

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1ai) 1. Total momentum and kinetic energy conserved.
2. Total momentum conserved.

1aii)

$$u_1 - u_2 = v_2 - v_1 \quad \text{—— (1)}$$

$$m_1 u_1^2 + m_2 u_2^2 = m_1 v_1^2 + m_2 v_2^2 \quad \text{—— (2)}$$

1aiii) 1. Relative speed after collision $= v_2 - v_1$ $\qquad v_2 - v_1 = u_1 - u_2$

$= u_1 - u_2$ $\qquad u_2 = v_1 + v_1 - v_2$

$= 5.0 - 2.0$ $\qquad u_1 + v_1 = u_2 + v_2$

$= 3.0\ ms^{-1}$

2. $u_1 = 5.0\ ms^{-1}$

$u_2 = 2.0\ ms^{-1}$

From 1.: $v_2 = v_1 + 3.0$ —— (3)

Subt $u_1 = 5.0$ & $u_2 = 2.0$ into (2): $25.0m_1 + 4.0m_2 = m_1 v_1^2 + m_2(v_1 + 3.0)^2$

$54.0m_2 = 2m_2 v_1^2 + m_2(v_1^2 + 2v_1 + 9.0)$

$54.0m_2 = 2m_2 v_1^2 + m_2 v_1^2 + 2m_2 v_1 + 9.0m_2$

$54.0 = 2v_1^2 + v_1^2 + 2v_1 + 9.0$

$3v_1^2 + 2v_1 - 45.0 = 0$

$v_1 = \frac{-2 \pm \sqrt{4 - 4(3)(-45.0)}}{2(3)}$

$= \frac{-2 \pm \sqrt{544}}{6}$

$\therefore v_1 = \frac{-2 + \sqrt{544}}{6}$ or $v_1 = \frac{-2 - \sqrt{544}}{6}$ (N.A)

$\therefore v_1 = 3.55\ ms^{-1}$ (3 s.f)

Subt $v_1 = 3.554$ into (3): $\therefore v_2 = 3.554 + 3.0$

$= 6.55\ ms^{-1}$ (3 s.f)

1bi) 1. $|Force_{C\to B}| = |Force_{A\to B}|$

$= F$

2. By Newton's 3rd law, $Force_{C\to B} = -Force_{A\to B}$

$\therefore$ force is to the left

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2. The maximum displacements of spheres A and C decrease with time.

1(b)(ii) The spheres will simultaneously move back to height h. A exerts a force on C through B, causing C to move to height h. At the same time A receives a force from C through B which is of equal magnitude but opposite direction to the force it exerts, thus it is pushed to height h.

1(c)(i)

$$F = \frac{dp}{dt}$$
$$= Nmv \quad \text{—— (1)}$$

Assumption: Sand particles striking the plate have their speeds v only in horizontal plane.

1(c)(ii)

$$F = kx \quad \text{—— (2)}$$

Subst (1) into (2): $Nmv = kx$

$$v \propto x$$

1(c)(iii)

$$F = 10000 \times 0.020 \times 5.0$$
$$= 1000 N \ (3 s.f)$$
$$x = \frac{1000}{50}$$
$$= 200 \ m \ (3 s.f)$$

1(d) Sand particles undergo inelastic collision with surfaces while gas molecules undergo elastic collisions with surfaces.

2(a)(i) The satellite has a negative gravitational potential energy, thus its orbit is stable. It moves in a circular orbit as it is constantly accelerating towards the Earth's centre

$gR_e^2 = GM \quad -\frac{GMm}{r} \quad \frac{GMm}{2r} \quad -\frac{GMm}{2r} \quad -\frac{GMm}{2r}$

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2aii)

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$

$$v^2 = \frac{GM}{r}$$

$$v = \sqrt{\frac{GM}{r}} \quad \text{---} (1)$$

$$gR_E^2 = GM$$

$$R_E = \sqrt{\frac{GM}{g}} \quad \text{---} (2)$$

subst (2) into (1): $v = \sqrt{GM \div \left(\sqrt{\frac{GM}{g}} + 300000\right)}$

$$= \sqrt{6.67\times10^{-11} \times 6.0\times10^{24} \div \left(\left(\frac{6.67\times10^{-11}\times6.0\times10^{24}}{9.81}\right)^{\frac{1}{2}} + 300000\right)}$$

$$= 7740\,ms^{-1} \text{ (3 s.f)}$$

2aiii)

$$E_{total} = -\frac{GMm}{2r}$$

$$= -\frac{6.67\times10^{-11}\times6.0\times10^{24}\times500}{2\left((6.67\times10^{-11}\times6.0\times10^{24}\div9.81)^{\frac{1}{2}} + 300000\right)}$$

$$= -1.50\times10^{10}\,J \text{ (3 s.f)}$$

2aiv)

$$\text{Energy absorbed} = -\frac{GMm}{2r_i} - \left(-\frac{GMm}{2r_f}\right)$$

$$= -\frac{GMm}{2}\left(\frac{1}{r_i} + \frac{1}{r_f}\right)$$

$$= -\frac{6.67\times10^{-11}\times6.0\times10^{24}\times500}{2}\left(\frac{1}{6.687\times10^6} - \frac{1}{6.387\times10^6}\right)$$

$$= 7.03\times10^{8}\,J \text{ (3 s.f)}$$

2av)

$$F = \frac{mv^2}{r} = ma$$

As the satellite slows down and v decreases, the centripetal force must remain the same in order for the acceleration of the satellite to stay constant. Thus, r must decrease as well and the satellite gradually spirals in towards the Earth's surface.

2bi) This enables the orbits to be stable and prevents the satellites from escaping from the moon's gravitational field.

2bii) As distance from centre of moon increases, gravitational potential energy decreases,

$$GPE \propto -\frac{1}{r}$$

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$$GPE = \frac{k}{r}$$

When $GPE = -2.92 \times 10^9 J$, $r = 0.740 \times 10^6 + 1.76 \times 10^6$

$$-2.92 \times 10^9 = \frac{k}{(0.740+1.76)10^6}$$

$$k = -7.300 \times 10^{15}$$

When $GPE = -2.44 \times 10^9 J$, $-2.44 \times 10^9 = \frac{-7.300 \times 10^{15}}{r}$

$$r = 2.992 \times 10^6$$

Distance from centre of moon $= (2.992 - 1.76)10^6$

$= 1.24 \times 10^6 m$ (3s.f)

When $GPE = -2.06 \times 10^9 J$, $-2.06 \times 10^9 = \frac{-7.300 \times 10^{15}}{r}$

$$r = 3.544 \times 10^6 m$$

Distance from centre of moon $= (3.544 - 1.76)10^6$

$= 1.79 \times 10^6 m$ (3s.f)

since values are consistent with equation of form $GPE = \frac{k}{r}$, $\therefore GPE \propto \frac{1}{r}$

2(biii)

$$GPE = -\frac{GMm}{r}$$

When $m = 1.500 \times 10^6 g$, $GPE = -2.92 \times 10^9 J$

$$-2.92 \times 10^9 = -\frac{6.67 \times 10^{-11} \times M \times 1.500 \times 10^6}{(0.740+1.76)10^6}$$

$$Mass_{moon} = 7.30 \times 10^{20} kg \text{ (3s.f)}$$

2biv) The value of GPE used to calculate M would have been lower, the mass calculated would be higher.

3a)

$$\Delta u = q + w$$

q will increase as electrical energy supplied to the tungsten filament will be converted to heat.

w increases slightly as the bulb expands and the gas molecules in the bulb does work against the atmosphere.

Δu will increase as sum of q and w is positive.

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3bi) No change in internal energy. All heat energy supplied is used to do work against the system.

3bii) It is the work done by the system.

3biii)

$$p_C V_C = nRT_C \quad \text{—— (1)}$$

$$p_B V_B = nRT_B \quad \text{—— (2)}$$

$\frac{(1)}{(2)}$:

$$\frac{T_C}{T_B} = \frac{p_C}{p_B} \cdot \frac{V_C}{V_B}$$

$$= \frac{1.0\times10^5}{3.75\times10^5}\left(\frac{0.65}{0.15}\right)$$

$$= 0.7536$$

$$T_C = 0.7536\, T_B$$

$$< T_B \text{ shown}$$

3biv) 1.

$$pV = nRT$$

$$(1.0\times10^5)(0.15) = n(8.31)(293)$$

$$n = 6.16 \text{ mol (3s.f.)}$$

2.

$$\Delta U = q + w$$

$$= 2.0\times10^5 + (6.161)(8.31)(293)\ln\left(\frac{0.65}{0.15}\right)$$

$$= 2.22\times10^5 \text{ J (3s.f.)}$$

3. Net work done $= nRT\ln\left(\frac{V_f}{V_i}\right)$

$$= (6.161)(8.31)(293)\ln\left(\frac{0.65}{0.15}\right)$$

$$= 2.20\times10^4 \text{ J (3s.f.)}$$

4. Power $= 2.200\times10^4 \times 180 \div 60$

$$= 6.60\times10^4 \text{ W (3s.f.)}$$

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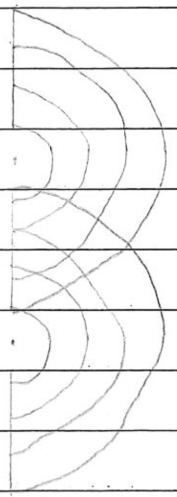
5. Efficiency $= \frac{2.20 \times 10^{4}}{2.22 \times 10^{5}} \times 100\%$
$= 9.91\%$ (3 s.f)

4ai) They can be diffracted about a slit like an electromagnetic wave.

4aii) The oscillations of the helium atoms are in phase at some positions and out of phase at other positions. Their path differences cause constructive or destructive interference at different locations and the resultant intensity varies.

4aiii)



The helium atoms diffract about the slits. Where the diffraction wavefronts cross, the path differences of the helium atoms are π and resultant amplitude is 0. Where midpt of diffraction wavefronts meet, constructive interference takes place and resultant amplitude is twice of that of one wave. At other locations, various degrees of destructive interference occur, giving rise to sinusoidal pattern of intensity against detector position.

4aiv)

$d \sin\theta = n\lambda$

$\sin\theta = \frac{\lambda}{D}$

$\lambda = 8.0 \times 10^{-6} \times 0.75 \div (10 \times 10^{-6})$

$=$