M17/4/PHYSI/SPM/ENG/TZ1/XX

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 1

Monday 15 May 2017 (afternoon)

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]**.

Know this.

θ	$\cos\theta$
0°	1
30°	$\sqrt{3}/2$
45°	$\sqrt{2}/2$
60°	1/2
90°	0

16 pages

2217–6510

1. What is the unit of electrical energy in fundamental SI units?

   A. $kg\,m^2\,C^{-1}\,s$

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

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

   D. $kg\,m^2\,s^{-1}\,A$

$KE = \frac{1}{2}mv^2$

$kg\,\frac{m^2}{s^2}$

2. Which of the following is a scalar quantity?

   A. Velocity

   B. Momentum

   C. Kinetic energy

   D. Acceleration

Work, Power, Energy are scalar.
Can be + or − but No direction.

3. An object is released from rest in the gravitational field of the Earth. Air resistance is negligible. How far does the object move during the fourth second of its motion?

   A. 15 m

   B. 25 m

   C. 35 m

   D. 45 m

from 3s to 4s

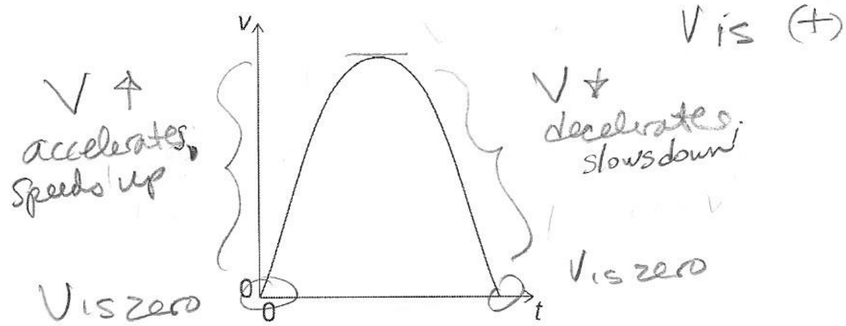
$d = v_i t + \frac{1}{2}at^2$

$t = 3s$ $\quad d = \frac{1}{2}(-10)3^2 = \frac{1}{2}(-90) = -45\,m$

$t = 4s$ $\quad d = \frac{1}{2}(-10)4^2 = \frac{1}{2}(-160) = -80\,m$

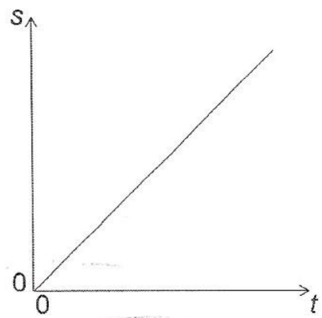
80 − 45 = 35

4. The graph shows the variation of speed v of an object with time t.



Which graph shows how the distance s travelled by the object varies with t?

A.



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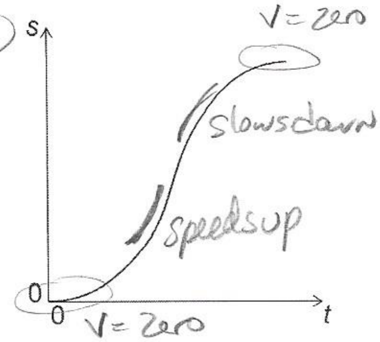
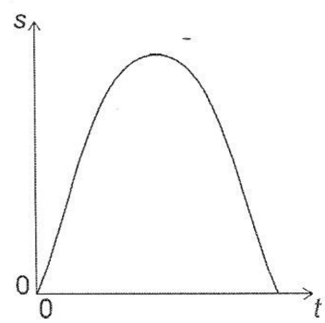
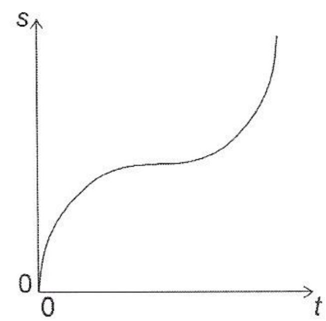


slope of displacement vs t is V

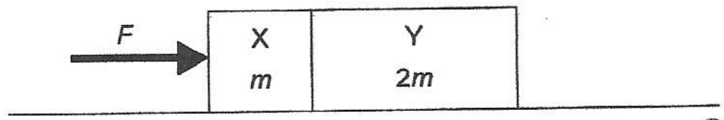
C.



D.



5. Two boxes in contact are pushed along a floor with a force F. The boxes move at a constant speed. Box X has a mass m and box Y has a mass $2m$.



What is the resultant force acting on Y?

$F_{net} = ma$ v = constant so a is zero

F_{net} = zero.

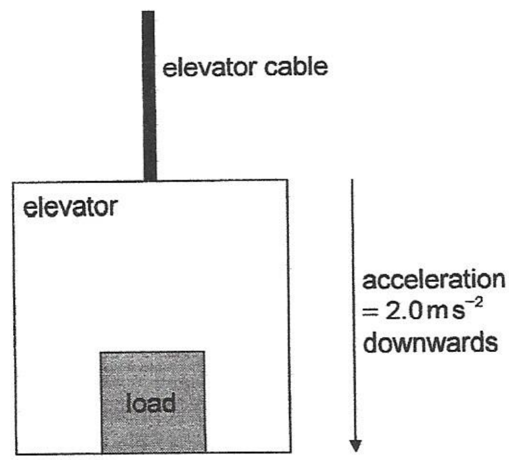
A. 0

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

C. F

D. $2F$

6. An elevator (lift) and its load have a total mass of 750 kg and accelerate vertically downwards at 2.0 m s^{-2}.



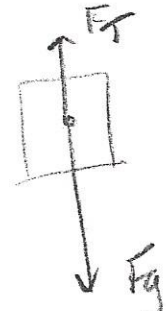
What is the tension in the elevator cable?

A. 1.5 kN

B. 6.0 kN

C. 7.5 kN

D. 9.0 kN



$F_T - F_g = ma$

$F_T - (750\,kg)(10\,\frac{m}{s^2}) = (750\,kg)(-2\,\frac{m}{s^2})$

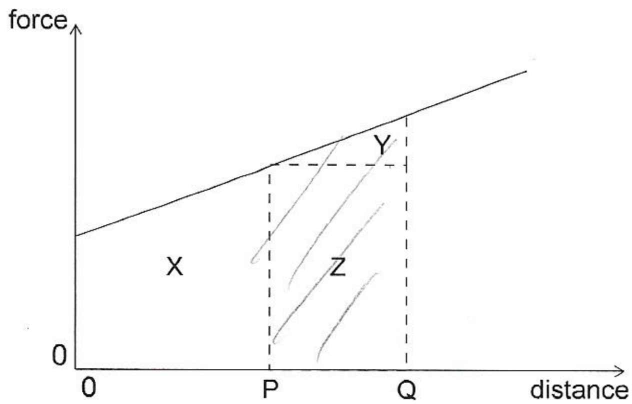
$F_T - 7500 = -1500$

$F_T = +7500 - 1500$

$F_T = 6000\,N$

7. A graph shows the variation of force acting on an object moving in a straight line with distance moved by the object.

Which area represents the work done on the object during its motion from P to Q?



A. X

B. Y

C. Y + Z

D. X + Y + Z

8. A car travelling at a constant velocity covers a distance of 100 m in 5.0 s. The thrust of the engine is 1.5 kN.

What is the power of the car?

A. 0.75 kW

B. 3.0 kW

C. 7.5 kW

D. 30 kW

KE is not conserved

9. An inelastic collision occurs between two bodies in the absence of external forces.

What must be true about the total momentum of the two bodies and the total kinetic energy of the two bodies during this interaction?

A. Only momentum is conserved.

B. Only kinetic energy is conserved.

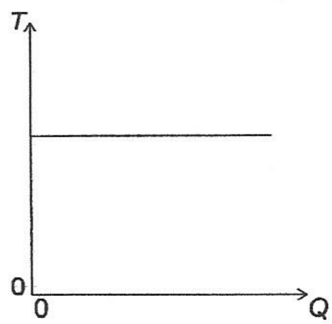
C. Both momentum and kinetic energy are conserved.

D. Neither momentum nor kinetic energy are conserved.

10. A liquid is initially at its freezing point. Energy is removed at a uniform rate from the liquid until it freezes completely.

Which graph shows how the temperature T of the liquid varies with the energy Q removed from the liquid?

A.



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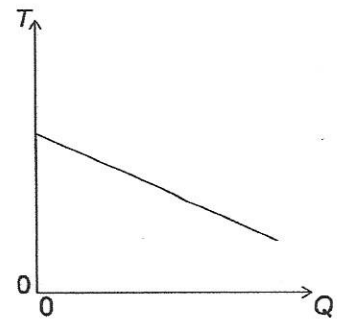
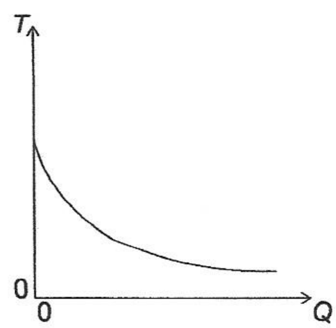


C.



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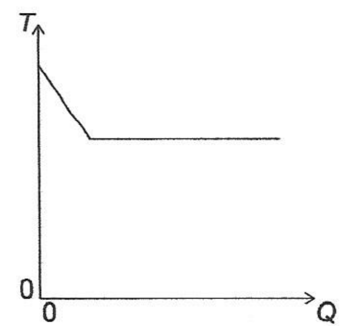
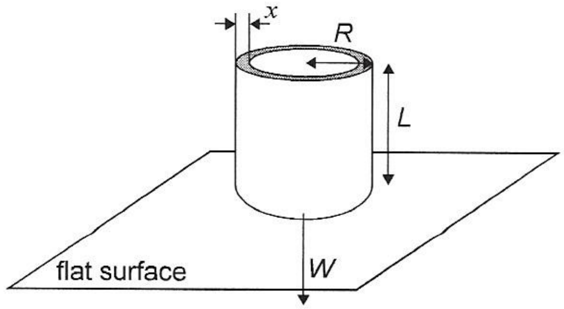


11. A thin-walled cylinder of weight *W*, open at both ends, rests on a flat surface. The cylinder has a height *L*, an average radius *R* and a thickness x where *R* is much greater than x.

Small x



What is the pressure exerted by the cylinder walls on the flat surface?

A. $\frac{W}{2\pi R x}$

B. $\frac{W}{\pi R^2 x}$

C. $\frac{W}{\pi R^2}$

D. $\frac{W}{\pi R^2 L}$

$P = \frac{\text{Force}}{\text{Area}}$

$P = \frac{W}{\pi R^2 - [\pi (R-x)^2]}$

$(R-x)(R-x)$
$R^2 - xR - xR + x^2$
$R^2 + x^2 - 2xR$

$P = \frac{W}{\pi (R^2 - R^2 + x^2 - 2xR)}$ ↑very small

small x, so $x^2 \approx 0$

$P \approx \frac{W}{2\pi x R}$

12. A fixed mass of an ideal gas in a closed container with a movable piston initially occupies a volume *V*. The position of the piston is changed, so that the mean kinetic energy of the particles in the gas is doubled and the pressure remains constant.

What is the new volume of the gas?

A. $\frac{V}{4}$

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

C. 2*V*

D. 4*V*

$\overline{KE} \rightarrow 2\overline{KE}$

P constant

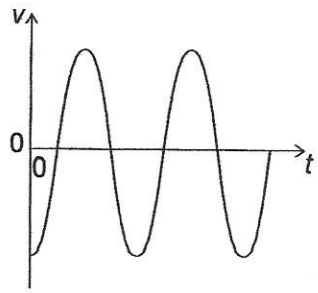
$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

So T Kelvin doubles and V must double

13. A particle undergoes simple harmonic motion (SHM). The graph shows the variation of velocity *v* of the particle with time *t*.

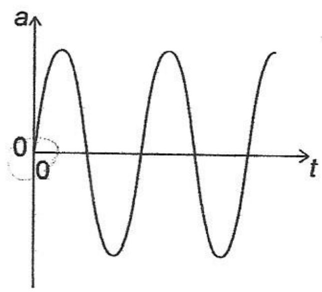
a is zero when speed is max

+a will cause v to ↑ in + direction



What is the variation with time of the acceleration *a* of the particle?

A.



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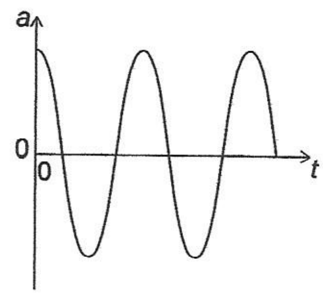

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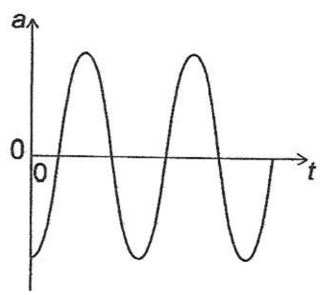

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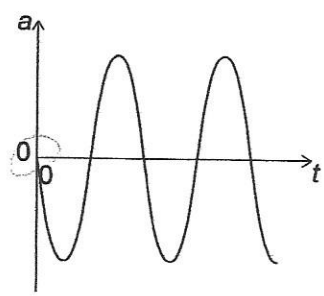


14. What statement about X-rays and ultraviolet radiation is correct?

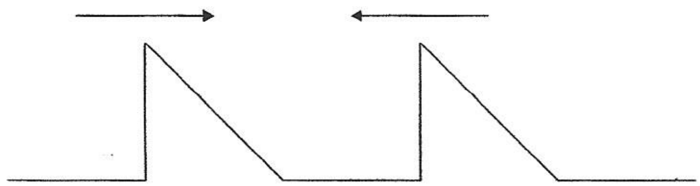
A. X-rays travel faster in a vacuum than ultraviolet waves.

B. X-rays have a higher frequency than ultraviolet waves.

C. X-rays cannot be diffracted unlike ultraviolet waves.

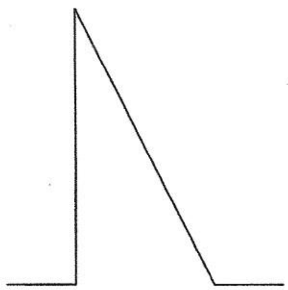
D. Microwaves lie between X-rays and ultraviolet in the electromagnetic spectrum.

15. Two pulses are travelling towards each other.



What is a possible pulse shape when the pulses overlap?

A.



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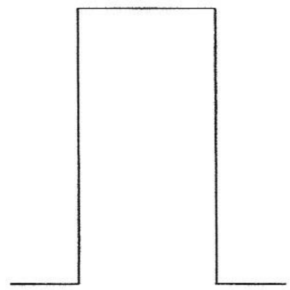
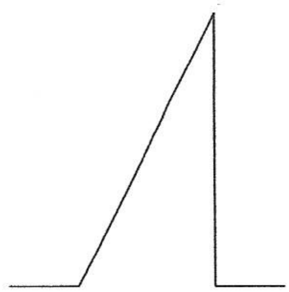


C.

D.

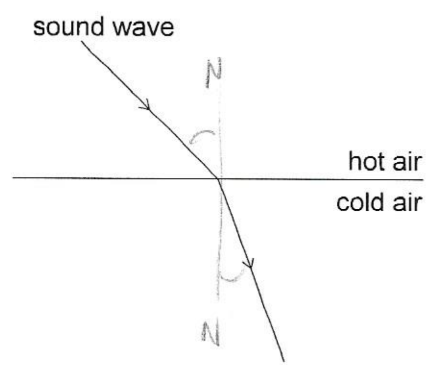


16. Unpolarized light of intensity I_0 is incident on the first of two polarizing sheets. Initially the planes of polarization of the sheets are perpendicular.

Which sheet must be rotated and by what angle so that light of intensity $\frac{I_0}{4}$ can emerge from the second sheet?

	Rotated sheet	Angle of rotation
A.	1 only	$\cos^{-1}\frac{\sqrt{2}}{2}$
B.	2 only	$\cos^{-1}\frac{1}{2}$
C.	1 or 2	$\cos^{-1}\frac{\sqrt{2}}{2}$
D.	1 or 2	$\cos^{-1}\frac{1}{2}$

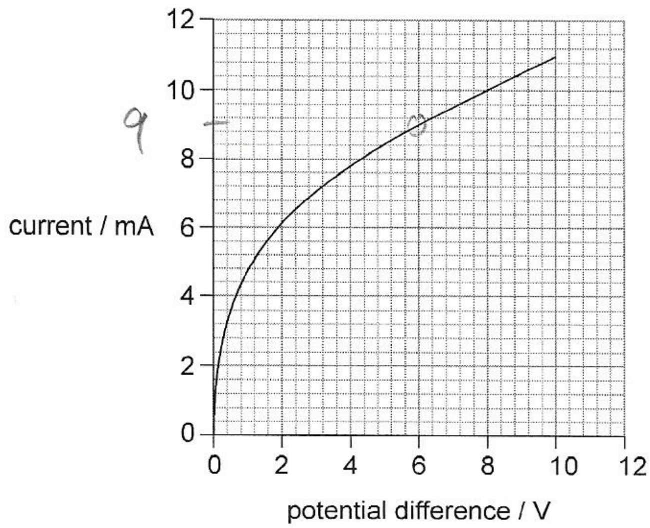
17. When a sound wave travels from a region of hot air to a region of cold air, it refracts as shown.



What changes occur in the frequency and wavelength of the sound as it passes from the hot air to the cold air?

	Frequency	Wavelength
A.	unchanged	increases
B.	unchanged	decreases
C.	increases	increases
D.	decreases	decreases

18. The graph shows the variation of current with potential difference for a filament lamp.



What is the resistance of the filament when the potential difference across it is 6.0 V?

A. 0.5 mΩ

B. 1.5 mΩ

C. 670 Ω

D. 2000 Ω

$R = \frac{V}{I} = \frac{6V}{9\times10^{-3}A}$

$= .67\times10^{+3}\,\Omega$

$= 670\,\Omega$

19. An electron is accelerated through a potential difference of 2.5 MV. What is the change in kinetic energy of the electron?

A. 0.4 μJ

B. 0.4 nJ

C. 0.4 pJ

D. 0.4 fJ

$q = 1.6\times10^{-19}C$

$V = 2.5MV = 2.5\times10^{6}V$

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

$= (2.5\times10^{6}V)(1.6\times10^{-19}C)$

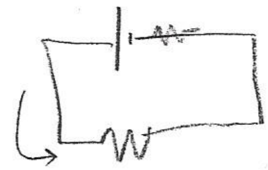
$= 4\times10^{-13}J$

$= .4\times10^{-12}$ pJ

pico is 10^{-12}

20. A cell is connected in series with a resistor and supplies a current of 4.0 A for a time of 500 s. During this time, 1.5 kJ of energy is dissipated in the cell and 2.5 kJ of energy is dissipated in the resistor.

What is the emf of the cell?



A. 0.50 V

B. 0.75 V

C. 1.5 V

D. 2.0 V

21. An electron travelling at speed v perpendicular to a magnetic field of strength B experiences a force F.

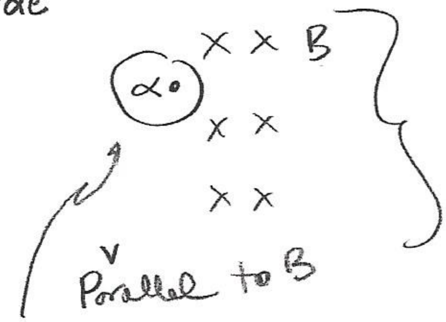
What is the force acting on an alpha particle travelling at $2v$ parallel to a magnetic field of strength $2B$?

A. 0

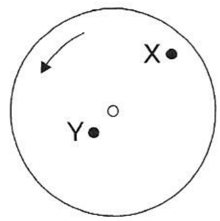
B. $2F$

C. $4F$

D. $8F$



22. A horizontal disc rotates uniformly at a constant angular velocity about a central axis normal to the plane of the disc.



Point X is a distance $2L$ from the centre of the disc. Point Y is a distance L from the centre of the disc. Point Y has a linear speed v and a centripetal acceleration a.

What is the linear speed and centripetal acceleration of point X?

	Linear speed of X	Centripetal acceleration of X
A.	v	a
B.	$2v$	$2a$
C.	v	$2a$
D.	$2v$	$4a$

23. An object of constant mass is tied to the end of a rope of length l and made to move in a horizontal circle. The speed of the object is increased until the rope breaks at speed v. The length of the rope is then changed. At what other combination of rope length and speed will the rope break?

	Rope length	Speed
A.	$4l$	$2v$
B.	$2l$	v
C.	$2l$	$\frac{v}{2}$
D.	$4l$	$\frac{v}{2}$

24. A nucleus of phosphorus (P) decays to a nucleus of silicon (Si) with the emission of particle X and particle Y.

$$^{30}_{15}\text{P} \rightarrow {}^{30}_{14}\text{Si} + \text{X} + \text{Y}$$

What are X and Y?

	X	Y
A.	antineutrino	positron
B.	antineutrino	electron
C.	neutrino	electron
D.	neutrino	positron

25. What is the definition of the unified atomic mass unit?

A. $\frac{1}{12}$ the mass of a neutral atom of carbon-12

B. The mass of a neutral atom of hydrogen-1

C. $\frac{1}{12}$ the mass of a nucleus of carbon-12

D. The mass of a nucleus of hydrogen-1

26. In nuclear fission, a nucleus of element X absorbs a neutron (n) to give a nucleus of element Y and a nucleus of element Z.

$$\text{X} + \text{n} \rightarrow \text{Y} + \text{Z} + 2\text{n}$$

What is $\frac{\text{magnitude of the binding energy per nucleon of Y}}{\text{magnitude of the binding energy per nucleon of X}}$ and $\frac{\text{total binding energy of Y and Z}}{\text{total binding energy of X}}$?

	$\frac{\text{Magnitude of the binding energy per nucleon of Y}}{\text{Magnitude of the binding energy per nucleon of X}}$	$\frac{\text{Total binding energy of Y and Z}}{\text{Total binding energy of X}}$
A.	greater than 1	greater than 1
B.	less than 1	greater than 1
C.	greater than 1	less than 1
D.	less than1	less than 1

27. What is the energy equivalent to the mass of one proton?

A. $9.38 \times (3 \times 10^8)^2 \times 10^6$ J

B. $9.38 \times (3 \times 10^8)^2 \times 1.6 \times 10^{-19}$ J

C. $\frac{9.38 \times 10^8}{1.6 \times 10^{-19}}$ J

D. $9.38 \times 10^8 \times 1.6 \times 10^{-19}$ J

28. The following are energy sources.

I. a battery of rechargeable electric cells

II. crude oil

III. a pumped storage hydroelectric system

Which of these are secondary energy sources?

A. I and II only

B. I and III only

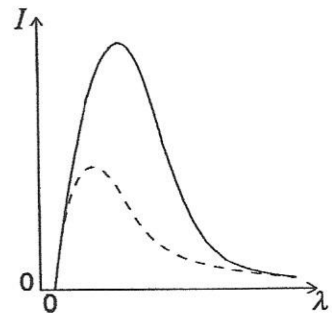
C. II and III only

D. I, II and III

29. Planet X and planet Y both emit radiation as black bodies. Planet X has a surface temperature that is less than the surface temperature of planet Y.

What is the graph of the variation of intensity I with wavelength λ for the radiation emitted by planet Y? The graph for planet X is shown dotted.

X is cooler dotted

A.


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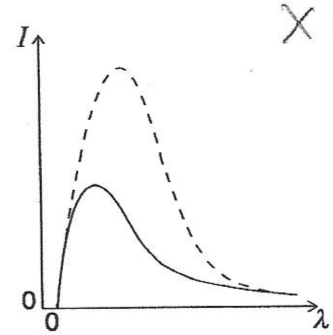

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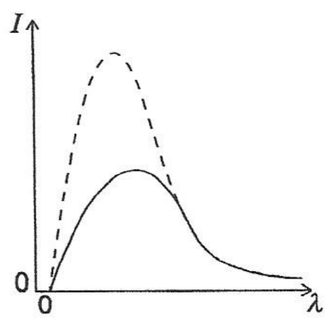

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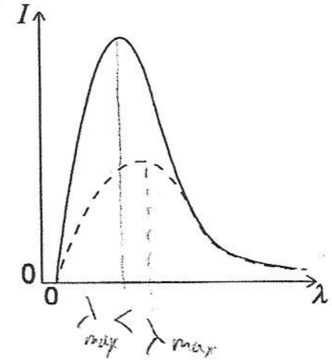

$\varepsilon = hf$

$\varepsilon = \frac{hc}{\lambda}$

30. The average surface temperature of Mars is approximately 200 K and the average surface temperature of Earth is approximately 300 K. Mars has a radius half that of Earth. Assume that both Mars and Earth act as black bodies.

What is $\frac{\text{power radiated by Mars}}{\text{power radiated by Earth}}$?

A. 20

B. 5

C. 0.2

D. 0.05

$P = e\sigma A T^4$ $\quad A_{\text{surface area}} = 4\pi r^2$ $\quad A \propto r^2$

$\frac{P_{Mars}}{P_{Earth}} \propto \frac{(\frac{1}{2})^2 200^4}{(1)^2 300^4}$

$\propto \frac{1}{4}\left(\frac{2}{3}\right)^4$

$\propto \frac{1}{2\cdot 2}\frac{2\cdot 2\cdot 2\cdot 2}{3\cdot 3\cdot 3\cdot 3} = \frac{4}{9\times 9}$

M17/4/PHYSI/SP2/ENG/TZ1/XX

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Monday 15 May 2017 (afternoon)

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.
- Answers must be written within the answer 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]**.

Notes

★ Generally 1 idea for each point for responces to conceptual questions

★ Pace approximately 50 POINTS = 75 min
1.5 MIN/POINT

★ This Paper 2 is "long". Do not get stuck on a single question or section. Keep moving to maximize points with limited time. Topics 1–8 are all represented!

Markscheme 1a i – requires 3 sig Figs before rounding to 2 sig Figs – this does not agree with the 1 sig Fig values read from the graph. IB often ignores the sig. Figs shown on graph axis.

13 pages

2217–6511

16EP01

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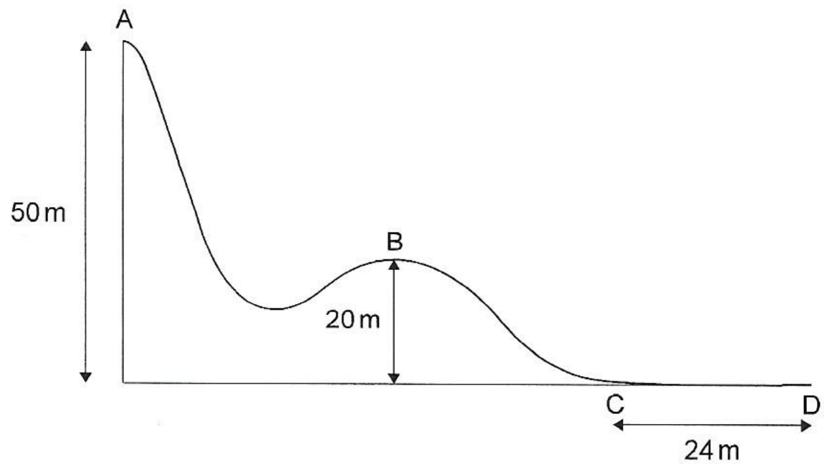
Answer **all** questions. Answers must be written within the answer boxes provided.

1. The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



(a) A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

(i) From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is $12\,m\,s^{-1}$. [2]

$\Delta PE_g = mg\Delta h$

$= (65\,kg)(9.81\,m/s^2)(50-20\,m) = 19{,}130\,J$

$KE = (.24)(19130\,J) = 4591\,J$

$KE = \frac{1}{2}mv^2$

$4591\,J = \frac{1}{2}(65\,kg)(v)^2 = 11.9\,m/s \approx 12\,m/s$

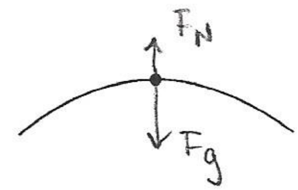
(ii) Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. [2]

- Internal Energy is the total PE+KE of the molecules (in Joules)
- Temp. is a measure of the Avg KE of the molecules (measured in °C or K.)

(This question continues on the following page)

(Question 1 continued)

(b) (i) The dot on the following diagram represents the skier as she passes point B. Draw and label the vertical forces acting on the skier. [2]



$F_g > F_N$

(ii) The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. [3]

Note – alternative solutions are possible – see markscheme

$F_c = ma_c$

$F_g - F_N = \frac{mv^2}{r}$

$F_g = (65\,kg)(9.81\,m/s^2) = 638\,N$

$\frac{mv^2}{r} = \frac{(65\,kg)(12\,m/s)^2}{20\,m} = 468\,N$

$638\,N - F_N = 468\,N$

$-F_N = -170\,N$

$F_N = 170\,N$ ← The skier does not lose contact.

(c) The skier reaches point C with a speed of 8.2 m s⁻¹. She stops after a distance of 24 m at point D.

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected. [3]

$W = \Delta KE$

$F \cdot d = \Delta KE$

$F \cdot (24\,m) = \frac{1}{2}mv_f^2 - \frac{1}{2}(65\,kg)(8.2\,m/s)^2$

$F_f = 91\,N$

$F_f = \mu F_N$

$F_f = \mu mg$

$91\,N = \mu(65\,kg)(9.81\,m/s^2)$

$\mu = 0.14$

(This question continues on the following page)

(Question 1 continued)

(d) At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed $9.6\,m\,s^{-1}$.

(i) Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. [2]

$J = F \cdot t = m\Delta v$

$= (76\,kg)(0 - 9.6\,m/s)$

$= -730\ \frac{kg\,m}{s}$ or N·S

(ii) Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. [2]

- The flexible net increases the time during which the force acts to change the momentum.
- Longer time means a smaller force is required to produce the same change of momentum.

$F = \frac{\Delta p}{\Delta t}$

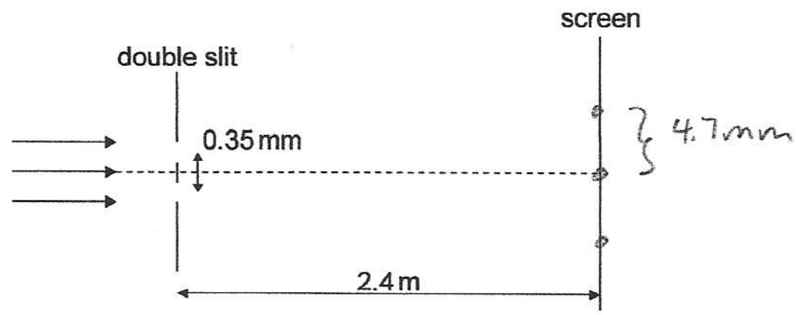
✓

16EP05

2. (a) Outline what is meant by the principle of superposition of waves. [2]

When 2 or more waves meet in the medium the resulting displacement is the sum of the individual displacements.

(b) Red laser light is incident on a double slit with a slit separation of 0.35 mm. A double-slit interference pattern is observed on a screen 2.4 m from the slits. The distance between successive maxima on the screen is 4.7 mm.



(not to scale)

Calculate the wavelength of the light. Give your answer to an appropriate number of significant figures. [3]

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

$4.7 \times 10^{-3} m = \frac{\lambda (2.4 m)}{0.35 \times 10^{-3} m}$

$\lambda = 6.9 \times 10^{-7} m$

note - 1 out of 3 points assigned for correct sig figs on the answer.

(This question continues on the following page)

(Question 2 continued)

(c) Explain the change to the appearance of the interference pattern when the red-light laser is replaced by one that emits green light. [2]

$S = \frac{\lambda D}{d}$ red green

$\lambda_{red} > \lambda_{green}$

Smaller λ will result in smaller s;

smaller distance between maxima.

(d) One of the slits is now covered.

Describe the appearance of the pattern on the screen. [2]

Single slit diffraction pattern

– wide central maxima

– as the angle from the center increases the intensity of the maxima decreases

S7.6
P46

3. Two renewable energy sources are solar and wind.

(a) Describe the difference between photovoltaic cells and solar heating panels. [1]

- photovoltaic cells convert solar energy to electric energy
- solar heating panels use the solar energy to thermal energy of a fluid such as water

$I = \frac{P}{A}$ $\frac{\text{watts}}{m^2}$ area

(b) A solar farm is made up of photovoltaic cells of area 25 000 m^2. The average solar intensity falling on the farm is 240 $W m^{-2}$ and the average power output of the farm is 1.6 MW. Calculate the efficiency of the photovoltaic cells. [2]

Power output

$I = \frac{P}{\text{area}}$ $\quad$ $Eff = \frac{P_{out}}{P_{in}}$

$P = I \cdot \text{area}$

$= (240 \frac{W}{m^2})(25000 m^2)$ $\quad$ $= \frac{1.6 MW}{6 MW}$

$= 6{,}000{,}000$ Watts $= 6 MW$

$= 27\%$

(c) An alternative generation method is the use of wind turbines.

The following data are available:

Length of turbine blade = 17 m
Density of air = 1.3 kg m^{-3}
Average wind speed = 7.5 m s^{-1}

(i) Determine the minimum number of turbines needed to generate the same power as the solar farm. [3]

1 Turbine $P = \frac{1}{2} A \rho v^3$ $\quad$ $Area = \pi r^2$

$P = \frac{1}{2} (\pi)(17m)^2 (1.3 \frac{kg}{m^3})(7.5 \frac{m}{s})^3$

$= 253{,}373$ Watts

For 1.6 MW $= 1.6 \times 10^6$ Watts

$\frac{1.6 \times 10^6 \text{ Watts}}{253373 \text{ Watts/turbine}} = 6.3$ turbines

7 turbines
assumes 100% efficiency

(This question continues on the following page)

(Question 3 continued)

(ii) Explain **two** reasons why the number of turbines required is likely to be greater than your answer to (c)(i). [2]

- The air leaving the turbine is not 0 m/s
- There is some loss of energy due to friction in the movement of the turbine blades.

NOT 100% efficient

for additional posible responces see Markscheme

√

4. A heater in an electric shower has a power of 8.5 kW when connected to a 240 V electrical supply. It is connected to the electrical supply by a copper cable.

The following data are available:

Length of cable	= 10 m
Cross-sectional area of cable	= 6.0 mm^2
Resistivity of copper	= $1.7 \times 10^{-8}\,\Omega$ m

$6\text{ mm}^2\left(\frac{1\text{m}}{1000\text{m}}\right)\left(\frac{1\text{m}}{1000\text{m}}\right)$

$6\times10^{-6}\text{ m}^2$

(a) (i) Calculate the current in the copper cable. [1]

$P = IV$ $I = 35$ Amps

8.5×10^3 Watts $= I(240\text{V})$

(ii) Calculate the resistance of the cable. [2]

$R = \frac{\rho L}{A} = \frac{(1.7\times10^{-8}\,\Omega\text{m})(10\text{m})}{6\times10^{-6}\text{m}^2} = 2.83\times10^{-2}\,\Omega$

$= 0.028\,\Omega$

(b) Explain, in terms of electrons, what happens to the resistance of the cable as the temperature of the cable increases. [3]

- As temp. ↑ the atoms of the Cu wire move faster.
- Faster moving atoms increase the resistivity of the Cu
- Higher resistivity means higher resistance – more difficult for the electrons to move.

(This question continues on the following page)

(Question 4 continued)

(c) The heater changes the temperature of the water by 35 K. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

Determine the rate at which water flows through the shower. State an appropriate unit for your answer. [4]

Note: $\Delta T = \Delta$ Temp. t = time

$Q = mc\Delta T$

$P = \frac{W}{t} = \frac{mc\Delta T}{t} =$

$\frac{8.5 \times 10^3 \text{ Watts}}{(4200 \frac{J}{kgK})(35K)} = \frac{m}{t}$

$0.058 \frac{kg}{sec}$

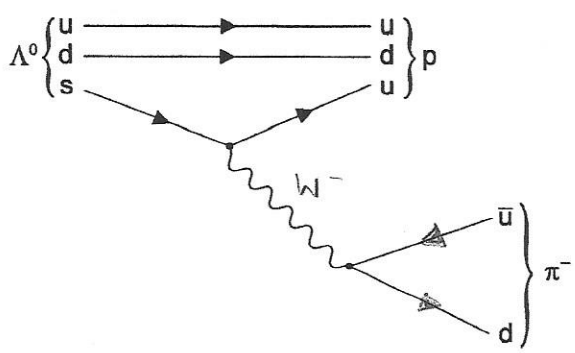
✓

5. (a) State the quark structures of a meson and a baryon. [2]

Meson: QUART + ANTI QUARK

Baryon: 3 QUARKS (or 3 ANTIQUARKS)

(b) A possible decay of a lambda particle (Λ^0) is shown by the Feynman diagram.



(i) Explain which interaction is responsible for this decay. [2]

– Strange quark becomes an up quark

– Exchanges between quarks is a weak interaction

(ii) Draw arrow heads on the lines representing $\bar{u}$ and d in the π^-. [1]

(This question continues on the following page)

(Question 5 continued)

(iii) Identify the exchange particle in this decay. [1]

W^-

(c) Outline **one** benefit of international cooperation in the construction or use of high-energy particle accelerators. [1]

The cost of construction is very high – cooperation reduces the cost for each participant.

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 3

Tuesday 16 May 2017 (morning)

1 hour

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.
- Answers must be written within the answer 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]**.

Section A	Questions
Answer all questions.	1 – 2

Applies your knowledge of topic 1; (measurement & uncertainty) Lab analysis skills.

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Relativity	3 – 4
Option B — Engineering physics	5 – 6
Option C — Imaging	7 – 8
Option D — Astrophysics	9 – 10

Complete only this section.

25 pages

2217–6512

International Baccalaureate
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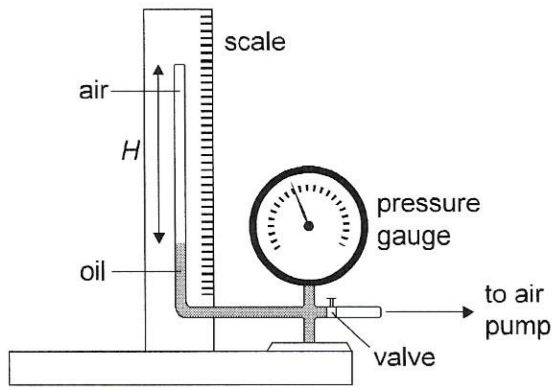
Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure p of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

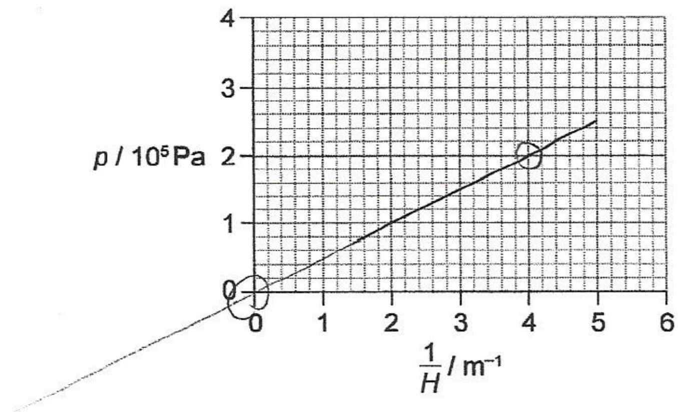
(a) The student measured the height H of the air column and the corresponding air pressure p. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. [1]

– Because it takes time for the system to reach thermal equilibrium.

(This question continues on the following page)

(Question 1 continued)

(b) The following graph of p versus $\frac{1}{H}$ was obtained. Error bars were negligibly small.



$y = \text{slope} \times x + \text{intercept}$

$p = b\left(\frac{1}{H}\right) + a$

The equation of the line of best fit is $p = a + \frac{b}{H}$.

Determine the value of b including an appropriate unit. [3]

b is the slope

$b = \frac{\Delta y}{\Delta x} = \frac{2 \times 10^5 \text{ Pa} - 0 \text{ Pa}}{4 \left(\frac{1}{m}\right) - 0 \frac{1}{m}} = 5 \times 10^4 \frac{\text{Pa}}{m}$

Note acceptable b values $4.7 \times 10^4 < b < 5.3 \times 10^4$

(c) Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. [2]

- H = height is proportional to volume
- Ideal gas will have zero volume at zero pressure
- graph shows zero H (zero volume) at zero pressure with a linear relationship.

(This question continues on the following page)

(Question 1 continued)

(d) The cross-sectional area of the tube is $1.3 \times 10^{-3}\,m^2$ and the temperature of air is 300 K. Estimate the number of moles of air in the tube. [2]

$PV = nRT$

$\frac{1}{H} = \frac{4}{m}$

$H = \frac{1}{4\frac{1}{m}} = .25\,m$

$(2 \times 10^5\,Pa)(1.3 \times 10^{-3}\,m^2)(.25\,m) = n\left(8.31\frac{J}{mol\,K}\right)(300\,K)$

$n = 0.026$ moles ≈ 0.03 moles

Note 1–2 Sig Figs acceptable

(e) The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. [2]

– large $\frac{1}{H}$ → small H which is small V, large Pressure

– at very small V molecules are close together and the Force between molecules will not be zero – (Required assumption of the Ideal Gas model.)

✓

2. (a) In a simple pendulum experiment, a student measures the period T of the pendulum many times and obtains an average value $T = (2.540 \pm 0.005)$ s. The length L of the pendulum is measured to be $L = (1.60 \pm 0.01)$ m.

Calculate, using $g = \frac{4\pi^2 L}{T^2}$, the value of the acceleration of free fall, including its uncertainty. State the value of the uncertainty to one significant figure. [3]

$g = \frac{4\pi^2(1.60\text{ m})}{(2.540\text{ s})^2} = 9.78 \frac{\text{m}}{\text{s}^2}$

$\frac{\Delta g}{g} = \frac{\Delta L}{L} + \frac{\Delta T}{T} + \frac{\Delta T}{T}$

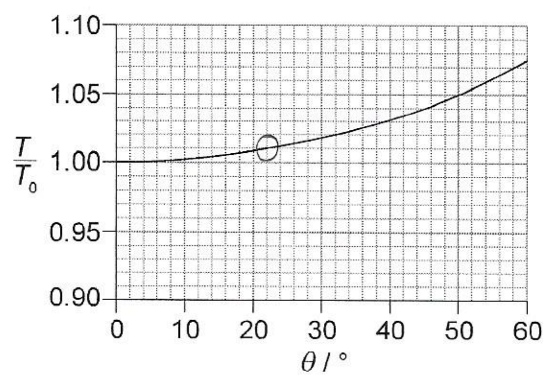
$\frac{\Delta g}{9.78 \frac{\text{m}}{\text{s}^2}} = \frac{.01\text{m}}{1.60\text{m}} + 2\left(\frac{0.005\text{ s}}{2.540\text{ s}}\right)$

$\frac{\Delta g}{9.78} = .00625 + 2(0.00197)$

$\Delta g = 0.0996 \cong 0.1$

$9.8 \pm .1 \text{ m/s}^2$

(b) In a different experiment a student investigates the dependence of the period T of a simple pendulum on the amplitude of oscillations θ. The graph shows the variation of $\frac{T}{T_0}$ with θ, where T_0 is the period for small amplitude oscillations.



The period may be considered to be independent of the amplitude θ as long as $\frac{T - T_0}{T_0} < 0.01$. Determine the maximum value of θ for which the period is independent of the amplitude. [2]

$\frac{T - T_0}{T_0} < .01$ $\frac{T}{T_0} < 1.01$ from graph $\theta = 22°$

$\frac{T}{T_0} - 1 < .01$

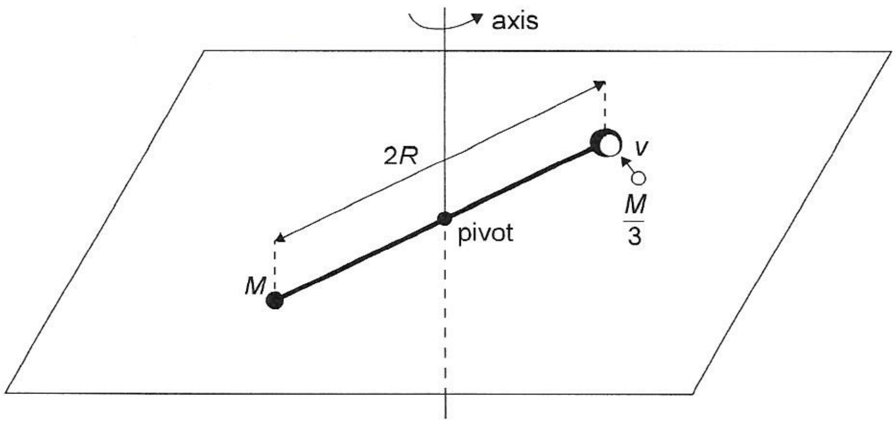
Note acceptable values $20° < \theta < 24°$

Option B — Engineering physics

5. A horizontal rigid bar of length $2R$ is pivoted at its centre. The bar is free to rotate in a horizontal plane about a vertical axis through the pivot. A point particle of mass M is attached to one end of the bar and a container is attached to the other end of the bar.

A point particle of mass $\frac{M}{3}$ moving with speed v at right angles to the rod collides with the container and gets stuck in the container. The system then starts to rotate about the vertical axis.

The mass of the rod and the container can be neglected.



(a) (i) Write down an expression, in terms of M, v and R, for the angular momentum of the system about the vertical axis just before the collision. [1]

$L = mvr$

$L = \left(\frac{M}{3}\right) vR$

(ii) Just after the collision the system begins to rotate about the vertical axis with angular velocity ω. Show that the angular momentum of the system is equal to $\frac{4}{3}MR^2\omega$. [1]

$\omega = \frac{v}{r}$ $\quad L = \Sigma mvr = M(\omega R)R + \frac{M}{3}(\omega R)R$

$v = \omega r$ $\quad = M\omega R^2 + \frac{M}{3}\omega R^2 = \left(M + \frac{M}{3}\right)\omega R^2$

$L = \frac{4}{3}MR^2\omega$

(Option B continues on the following page)

(Option B, question 5 continued)

(iii) Hence, show that $\omega = \frac{v}{4R}$. [1]

Conservation of momentum = $L_i = L_f$ $\quad \frac{M}{3}VR = \frac{4}{3}MR^2\omega$

$L_i = \frac{M}{3}VR$ $\quad V = 4R\omega$

$L_f = \frac{4}{3}MR^2\omega$ $\quad \omega = \frac{V}{4R}$

(iv) Determine in terms of *M* and *v* the energy lost during the collision. [3]

KE lost ?

$KE = \frac{1}{2}\Sigma mr^2\omega$

$KE_i = \frac{1}{2}\left(\frac{M}{3}\right)V^2$

$KE_i = \frac{M}{6}V^2$

$KE_f = \frac{1}{2}M\omega^2R^2 + \frac{1}{2}\left(\frac{M}{3}\right)\omega^2R^2$

$= \frac{1}{2}\left(\frac{4}{3}M\right)R^2\omega^2$

$= \frac{4}{6}MR^2\frac{V^2}{16R^2}$

$= \frac{1}{6}\frac{1}{4}MV^2$

$KE_f = \frac{1}{24}MV^2$

$\omega = \frac{V}{4R}$

$\omega^2 = \frac{V^2}{16R^2}$

$\Delta KE = KE_f - KE_i$

$= \frac{1}{24}Mv^2 - \frac{1}{6}Mv^2$

$= Mv^2\left(\frac{1}{24} - \frac{4}{24}\right)$

$\Delta KE = \frac{1}{8}MV^2$

τ $\quad V_f = 0\,m/s$

(b) A torque of 0.010 N m brings the system to rest after a number of revolutions. For this case $R = 0.50$ m, $M = 0.70$ kg and $v = 2.1$ m s^{-1}. $\omega_f = 0\,\frac{rad}{s}$?

F=ma

(i) Show that the angular deceleration of the system is 0.043 rad s^{-2}. [1]

$\tau = I\alpha \quad \alpha = \frac{\tau}{I} = \frac{0.010\,Nm}{\left(\frac{4}{3}\right)(0.70\,kg)(0.50\,m)^2}$

$L = I\omega$

$L = (4/3)MR^2\omega$ (I)

$\alpha = 0.043\,rad/s^2$

(ii) Calculate the number of revolutions made by the system before it comes to rest. [3]

First determine circular distance $\Theta = ?$

$\omega_f^2 = \omega_i^2 + 2\alpha\Theta$

$\left(0\,\frac{rad}{s}\right)^2 = \left(1.05\,\frac{rad}{s}\right)^2 + 2\left(0.043\,\frac{rad}{s^2}\right)\Theta$

$\Theta = 12.8\,rad$

1 rotation = 2π radians

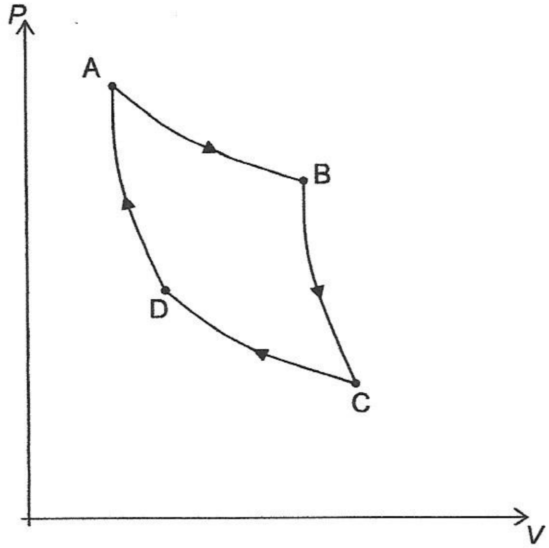
$12.8\,rad \times \frac{1\,rotation}{2\pi\,radians}$

= 2 rotations

(Option B continues on the following page)

(Option B continued)

6. The *P*–*V* diagram of the Carnot cycle for a monatomic ideal gas is shown.



(a) State what is meant by an adiabatic process. [1]

adiabatic process Q = zero Not heat is exchanged, the process is isolated from the surroundings

(b) Identify the two isothermal processes. [1]

A-B and C-D are isothermal

(c) The system consists of 0.150 mol of a gas initially at A. The pressure at A is 512 kPa and the volume is $1.20 \times 10^{-3}\,m^3$.

n P V need Pa

(i) Determine the temperature of the gas at A. [2]

$PV = nRT$

$(512\times10^3\ Pa)(1.20\times10^{-3}\ m^3) = (0.150\ moles)(8.31\ \frac{J}{mol\,K})T$

$T = 492.9\ K = 493\ K$

(Option B continues on the following page)

✓

(Option B, question 6 continued)

(ii) The volume at B is $2.30 \times 10^{-3}\,m^3$. Determine the pressure at B. [2]

A–B is isothermal

$\left(\frac{PV}{T}\right)_A = \left(\frac{PV}{T}\right)_B$

$(512\ kPa)(1.2 \times 10^{-3}\ m^3) = (P_B)(2.3 \times 10^{-3}\ m^3)$

$P_B = 267\ kPa$

(d) At C the volume is V_C and the temperature is T_C.

(i) Show that $P_B V_B^{\frac{5}{3}} = nRT_C V_C^{\frac{2}{3}}$. [1]

adiabatic (monatomic) $PV^{5/3}$ = Constant } $P_B V_B^{5/3} = P_C V_C^{5/3}$

ideal gas $P_C V_C = nRT_C$; $P_C = \frac{nRT_C}{V_C}$

$P_B V_B^{5/3} = \left(\frac{nRT_C}{V_C}\right) V_C^{5/3}$

$\frac{V_C^{5/3}}{V_C} = V_C^{2/3}$

$P_B V_B^{5/3} = nRT_C V_C^{2/3}$

(ii) The volume at C is $2.90 \times 10^{-3}\,m^3$. Calculate the temperature at C. [2]

Note need P in Pa

use $P_B V_B^{5/3} = nRT_C V_C^{2/3}$

$T_C = \frac{P_B V_B^{5/3}}{nRV_C^{2/3}} = \frac{(267 \times 10^3\ Pa)(2.30 \times 10^{-3}\ m^3)^{5/3}}{(0.15\ mol)(8.31\ \frac{J}{mol\,K})(2.90 \times 10^{-3}\ m^3)^{2/3}}$

$T_C = 422\ K$

(e) State a reason why a Carnot cycle is of little use for a practical heat engine. [1]

– The isothermal steps need to be conducted very slowly – not practical

End of Option B