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|---------------------|--|-------------|------------------|
| Surname             |  | Other Names |                  |
| Centre Number       |  |             | Candidate Number |
| Candidate Signature |  |             |                  |

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General Certificate of Education  
 January 2006  
 Advanced Subsidiary Examination



**PHYSICS (SPECIFICATION A)**  
**Unit 2 Mechanics and Molecular Kinetic Theory**

**PA02**

Thursday 12 January 2006 9.00 am to 10.00 am

|  |
|--|
| <p><b>For this paper you must have:</b></p> <ul style="list-style-type: none"> <li>• a calculator</li> <li>• a pencil and a ruler</li> </ul> |
|--|

Time allowed: 1 hour

**Instructions**

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- All working must be shown and clearly labelled; otherwise marks for method may be lost.
- Make and state any necessary assumptions.
- Do all rough work in this book. Cross through any work you do not want marked.

**Information**

- The maximum mark for this paper is 50. This includes up to 2 marks for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are reminded of the need for good English and clear presentation in your answers. Questions 2(a) and 3(d) should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

| For Examiner's Use               |      |        |      |
|----------------------------------|------|--------|------|
| Number                           | Mark | Number | Mark |
| 1                                |      |        |      |
| 2                                |      |        |      |
| 3                                |      |        |      |
| 4                                |      |        |      |
| 5                                |      |        |      |
| 6                                |      |        |      |
|                                  |      |        |      |
|                                  |      |        |      |
| Total (Column 1)                 |      | →      |      |
| Total (Column 2)                 |      | →      |      |
| Quality of Written Communication |      |        |      |
| TOTAL                            |      |        |      |
| Examiner's Initials              |      |        |      |

**Data Sheet**

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

**Fundamental constants and values**

| Quantity                               | Symbol       | Value                   | Units                             |
|--|--------------|-------------------------|-----------------------------------|
| speed of light in vacuo                | $c$          | $3.00 \times 10^8$      | $\text{m s}^{-1}$                 |
| permeability of free space             | $\mu_0$      | $4\pi \times 10^{-7}$   | $\text{H m}^{-1}$                 |
| permittivity of free space             | $\epsilon_0$ | $8.85 \times 10^{-12}$  | $\text{F m}^{-1}$                 |
| charge of electron                     | $e$          | $1.60 \times 10^{-19}$  | C                                 |
| the Planck constant                    | $h$          | $6.63 \times 10^{-34}$  | J s                               |
| gravitational constant                 | $G$          | $6.67 \times 10^{-11}$  | $\text{N m}^2 \text{kg}^{-2}$     |
| the Avogadro constant                  | $N_A$        | $6.02 \times 10^{23}$   | $\text{mol}^{-1}$                 |
| molar gas constant                     | $R$          | 8.31                    | $\text{J K}^{-1} \text{mol}^{-1}$ |
| the Boltzmann constant                 | $k$          | $1.38 \times 10^{-23}$  | $\text{J K}^{-1}$                 |
| the Stefan constant                    | $\sigma$     | $5.67 \times 10^{-8}$   | $\text{W m}^{-2} \text{K}^{-4}$   |
| the Wien constant                      | $a$          | $2.90 \times 10^{-3}$   | m K                               |
| electron rest mass                     | $m_e$        | $9.11 \times 10^{-31}$  | kg                                |
| (equivalent to $5.5 \times 10^{-4}u$ ) |              |                         |                                   |
| electron charge/mass ratio             | $e/m_e$      | $1.76 \times 10^{11}$   | $\text{C kg}^{-1}$                |
| proton rest mass                       | $m_p$        | $1.67 \times 10^{-27}$  | kg                                |
| (equivalent to 1.00728u)               |              |                         |                                   |
| proton charge/mass ratio               | $e/m_p$      | $9.58 \times 10^7$      | $\text{C kg}^{-1}$                |
| neutron rest mass                      | $m_n$        | $1.67 \times 10^{-27}$  | kg                                |
| (equivalent to 1.00867u)               |              |                         |                                   |
| gravitational field strength           | $g$          | 9.81                    | $\text{N kg}^{-1}$                |
| acceleration due to gravity            | $g$          | 9.81                    | $\text{m s}^{-2}$                 |
| atomic mass unit                       | $u$          | $1.661 \times 10^{-27}$ | kg                                |
| (1u is equivalent to 931.3 MeV)        |              |                         |                                   |

**Fundamental particles**

| Class   | Name     | Symbol    | Rest energy /MeV |
|---------|----------|-----------|------------------|
| photon  | photon   | $\gamma$  | 0                |
| lepton  | neutrino | $\nu_e$   | 0                |
|         |          | $\nu_\mu$ | 0                |
|         | electron | $e^\pm$   | 0.510999         |
|         | muon     | $\mu^\pm$ | 105.659          |
| mesons  | pion     | $\pi^\pm$ | 139.576          |
|         |          | $\pi^0$   | 134.972          |
|         | kaon     | $K^\pm$   | 493.821          |
|         |          | $K^0$     | 497.762          |
| baryons | proton   | p         | 938.257          |
|         | neutron  | n         | 939.551          |

**Properties of quarks**

| Type | Charge         | Baryon number  | Strangeness |
|------|----------------|----------------|-------------|
| u    | $+\frac{2}{3}$ | $+\frac{1}{3}$ | 0           |
| d    | $-\frac{1}{3}$ | $+\frac{1}{3}$ | 0           |
| s    | $-\frac{1}{3}$ | $+\frac{1}{3}$ | -1          |

**Geometrical equations**

- arc length =  $r\theta$
- circumference of circle =  $2\pi r$
- area of circle =  $\pi r^2$
- area of cylinder =  $2\pi rh$
- volume of cylinder =  $\pi r^2 h$
- area of sphere =  $4\pi r^2$
- volume of sphere =  $\frac{4}{3}\pi r^3$

**Mechanics and Applied Physics**

- $v = u + at$
- $s = \left(\frac{u+v}{2}\right)t$
- $s = ut + \frac{at^2}{2}$
- $v^2 = u^2 + 2as$
- $F = \frac{\Delta(mv)}{\Delta t}$
- $P = Fv$
- efficiency =  $\frac{\text{power output}}{\text{power input}}$
- $\omega = \frac{v}{r} = 2\pi f$
- $a = \frac{v^2}{r} = r\omega^2$
- $I = \sum mr^2$
- $E_k = \frac{1}{2}I\omega^2$
- $\omega_2 = \omega_1 + at$
- $\theta = \omega_1 t + \frac{1}{2}at^2$
- $\omega_2^2 = \omega_1^2 + 2a\theta$
- $\theta = \frac{1}{2}(\omega_1 + \omega_2)t$
- $T = I\alpha$
- angular momentum =  $I\omega$
- $W = T\theta$
- $P = T\omega$
- angular impulse = change of angular momentum =  $Tt$
- $\Delta Q = \Delta U + \Delta W$
- $\Delta W = p\Delta V$
- $pV^\gamma = \text{constant}$

- work done per cycle = area of loop
- input power = calorific value  $\times$  fuel flow rate
- indicated power as (area of p - V loop)  $\times$  (no. of cycles/s)  $\times$  (no. of cylinders)
- friction power = indicated power - brake power
- efficiency =  $\frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$
- maximum possible efficiency =  $\frac{T_H - T_C}{T_H}$

**Fields, Waves, Quantum Phenomena**

- $g = \frac{F}{m}$
- $g = -\frac{GM}{r^2}$
- $g = -\frac{\Delta V}{\Delta x}$
- $V = -\frac{GM}{r}$
- $a = -(2\pi f)^2 x$
- $v = \pm 2\pi f \sqrt{A^2 - x^2}$
- $x = A \cos 2\pi ft$
- $T = 2\pi \sqrt{\frac{m}{k}}$
- $T = 2\pi \sqrt{\frac{l}{g}}$
- $\lambda = \frac{\omega s}{D}$
- $d \sin \theta = n\lambda$
- $\theta \approx \frac{\lambda}{D}$
- $n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$
- $n_2 = \frac{n_2}{n_1}$
- $\sin \theta_c = \frac{1}{n}$
- $E = hf$
- $hf = \phi + E_k$
- $hf = E_1 - E_2$
- $\lambda = \frac{h}{p} = \frac{h}{mv}$
- $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

**Electricity**

- $\epsilon = \frac{E}{Q}$
- $\epsilon = I(R + r)$
- $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
- $R_T = R_1 + R_2 + R_3 + \dots$
- $P = I^2 R$
- $E = \frac{F}{Q} = \frac{V}{d}$
- $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
- $E = \frac{1}{2} QV$
- $F = BI l$
- $F = BQv$
- $Q = Q_0 e^{-t/RC}$
- $\Phi = BA$

$$\text{magnitude of induced e.m.f.} = N \frac{\Delta\Phi}{\Delta t}$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

### Mechanical and Thermal Properties

$$\text{the Young modulus} = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F l}{A e}$$

$$\text{energy stored} = \frac{1}{2} Fe$$

$$\Delta Q = mc \Delta\theta$$

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

### Nuclear Physics and Turning Points in Physics

$$\text{force} = \frac{eV_p}{d}$$

$$\text{force} = Bev$$

$$\text{radius of curvature} = \frac{mv}{Be}$$

$$\frac{eV}{d} = mg$$

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

$$I = k \frac{I_0}{x^2}$$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$N = N_0 e^{-\lambda t}$$

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

$$R = r_0 A^{\frac{1}{3}}$$

$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

$$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

### Astrophysics and Medical Physics

| Body  | Mass/kg               | Mean radius/m      |
|-------|-----------------------|--------------------|
| Sun   | $2.00 \times 10^{30}$ | $7.00 \times 10^8$ |
| Earth | $6.00 \times 10^{24}$ | $6.40 \times 10^6$ |

$$1 \text{ astronomical unit} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ parsec} = 206265 \text{ AU} = 3.08 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

$$1 \text{ light year} = 9.45 \times 10^{15} \text{ m}$$

$$\text{Hubble constant } (H) = 65 \text{ kms}^{-1} \text{ Mpc}^{-1}$$

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$M = \frac{f_o}{f_e}$$

$$m - M = 5 \log \frac{d}{10}$$

$$\lambda_{\text{max}} T = \text{constant} = 0.0029 \text{ m K}$$

$$v = Hd$$

$$P = \sigma AT^4$$

$$\frac{\Delta f}{f} = \frac{v}{c}$$

$$\frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$$

$$R_s \approx \frac{2GM}{c^2}$$

### Medical Physics

$$\text{power} = \frac{1}{f}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \text{ and } m = \frac{v}{u}$$

$$\text{intensity level} = 10 \log \frac{I}{I_0}$$

$$I = I_0 e^{-\mu x}$$

$$\mu_m = \frac{\mu}{\rho}$$

### Electronics

Resistors

Preferred values for resistors (E24)  
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2  
2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2  
6.8 7.5 8.2 9.1 ohms  
and multiples that are ten times greater

$$Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

$$C_T = C_1 + C_2 + C_3 + \dots$$

$$X_C = \frac{1}{2\pi fC}$$

### Alternating Currents

$$f = \frac{1}{T}$$

### Operational amplifier

$$G = \frac{V_{\text{out}}}{V_{\text{in}}} \quad \text{voltage gain}$$

$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

$$G = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

$$V_{\text{out}} = -R_f \left( \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \quad \text{summing}$$

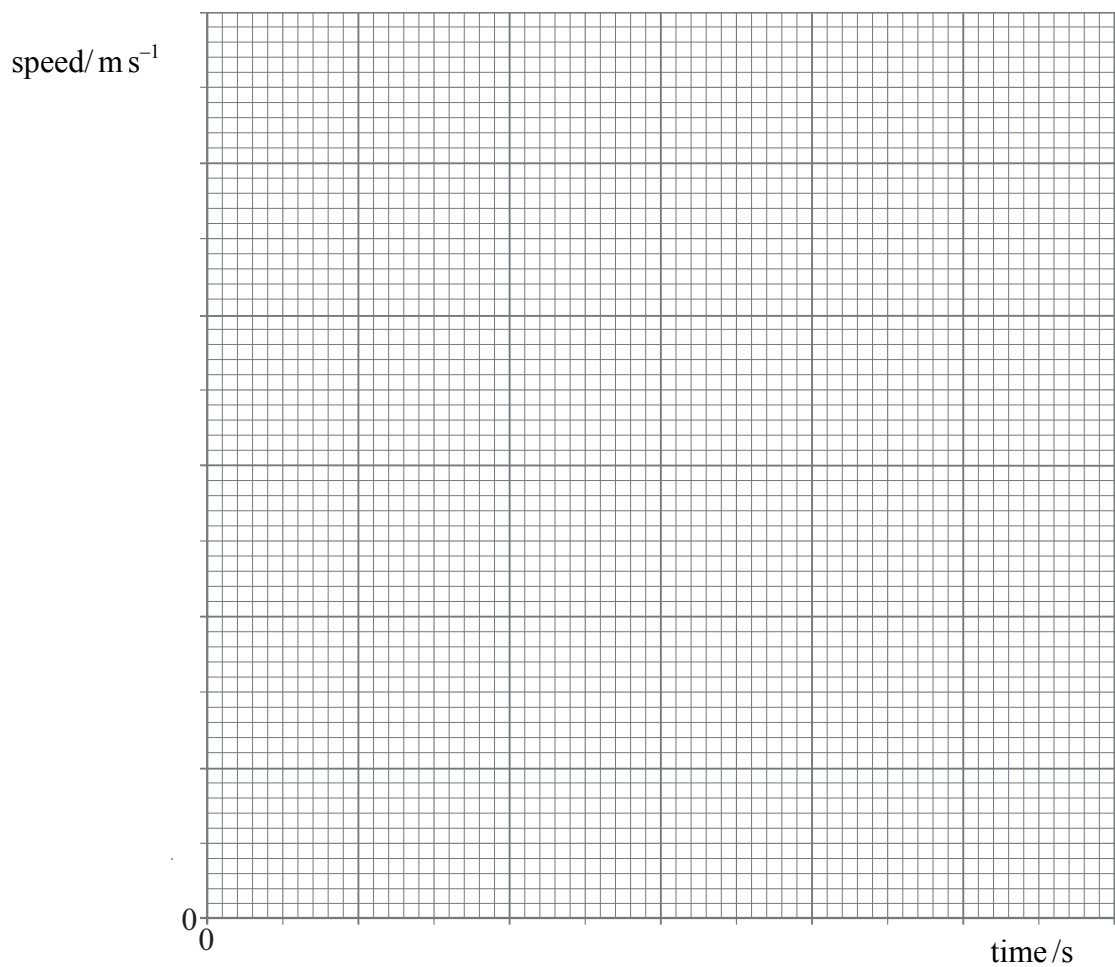
**Turn over for the first question**

Answer **all** questions.

- 1 A car accelerates from rest to a speed of  $26 \text{ m s}^{-1}$ . The table shows how the speed of the car varies over the first 30 seconds of motion.

|  |   |      |      |      |      |      |      |
|--|---|------|------|------|------|------|------|
| <b>time/s</b>                              | 0 | 5.0  | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 |
| <b>speed/ <math>\text{m s}^{-1}</math></b> | 0 | 16.5 | 22.5 | 24.5 | 25.5 | 26.0 | 26.0 |

- (a) Draw a graph of speed against time on the grid provided.



(3 marks)

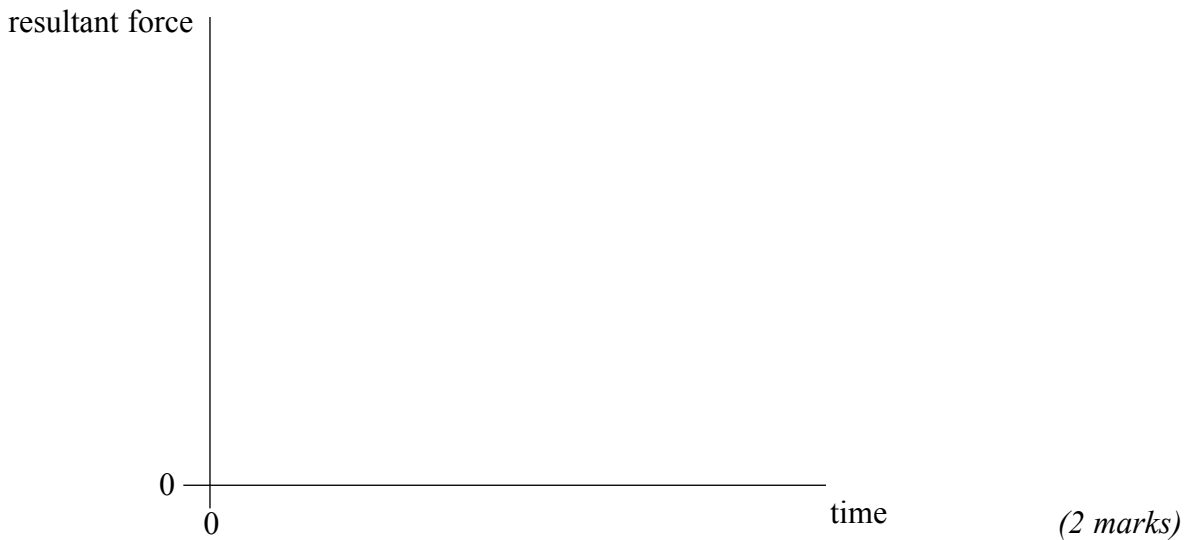
(b) Calculate the average acceleration of the car over the first 25 s.

.....  
.....  
*(2 marks)*

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

.....  
.....  
.....  
.....  
*(2 marks)*

(d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.

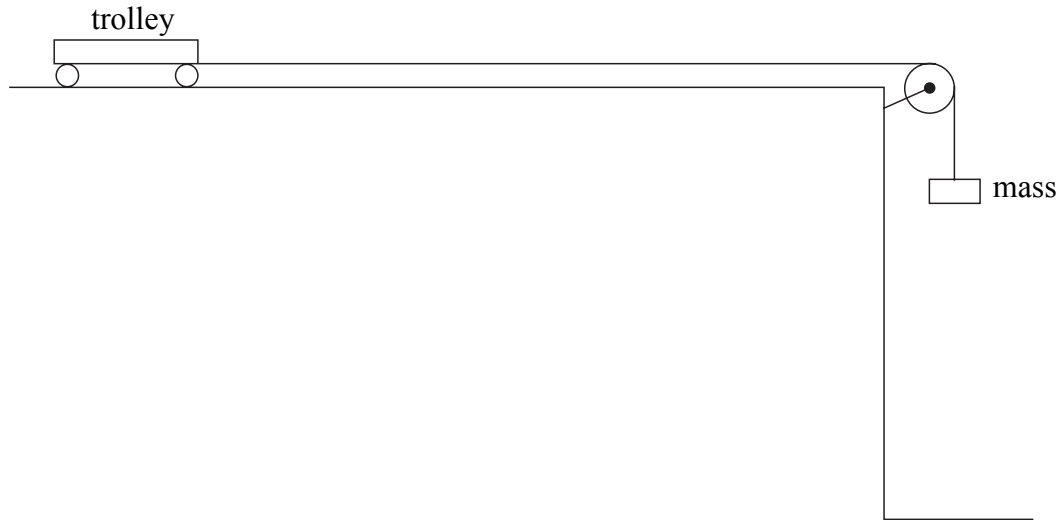


(e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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.....  
.....  
.....  
*(2 marks)*

2 **Figure 1** shows apparatus that can be used to investigate energy changes.

**Figure 1**



The trolley and the mass are joined by an inextensible string. In an experiment to investigate energy changes, the trolley is initially held at rest, and is then released so that the mass falls vertically to the ground.

You may be awarded marks for the quality of written communication in your answer.

(a) (i) State the energy changes of the falling mass.

.....

.....

(ii) Describe the energy changes that take place in this system.

.....

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(4 marks)



(b) State what measurements would need to be made to investigate the *conservation of energy*.

.....  
.....  
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(2 marks)

(c) Describe how the measurements in part (b) would be used to investigate the conservation of energy.

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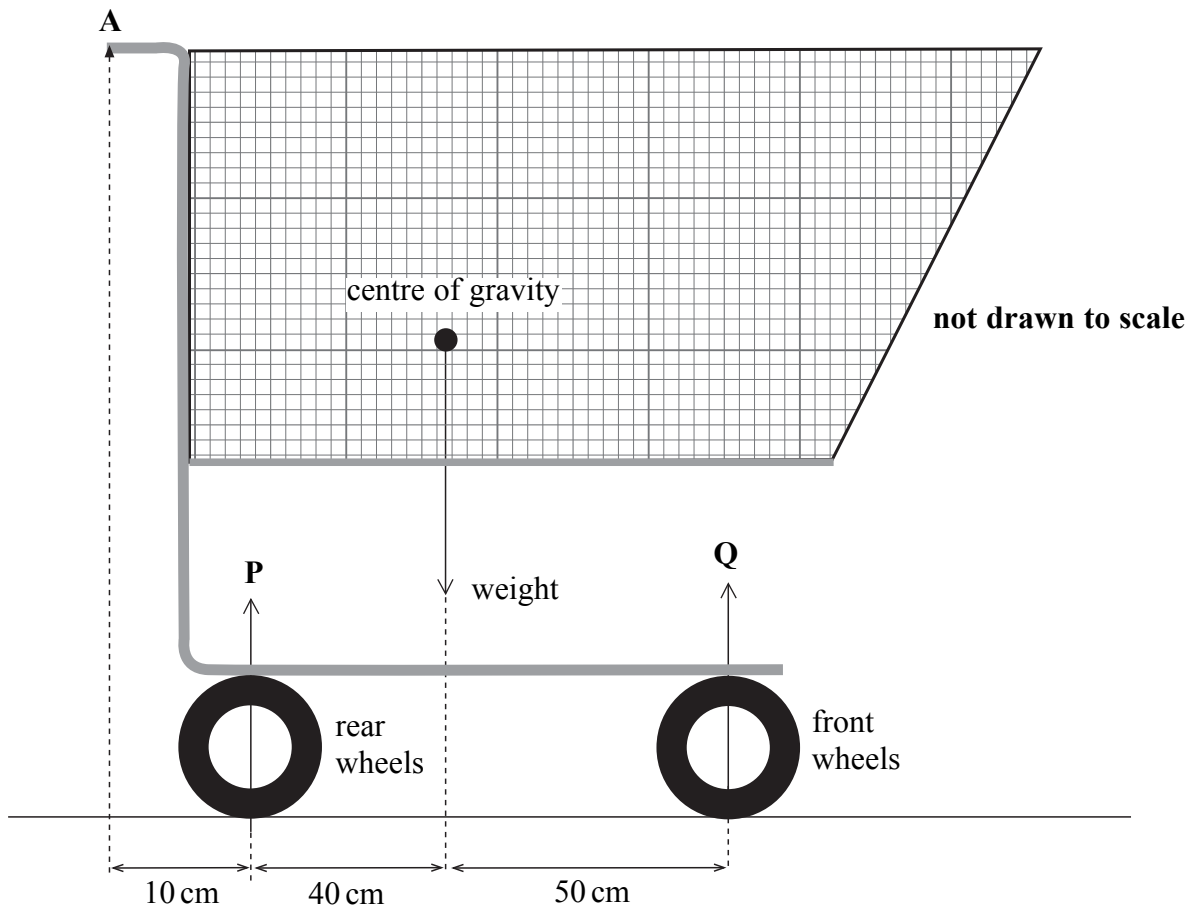
(4 marks)

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**Turn over for the next question**

3 Figure 2 shows a supermarket trolley.

Figure 2



The weight of the trolley and its contents is 160 N.

(a) Explain what is meant by centre of gravity.

.....

.....

(2 marks)

(b) **P** and **Q** are the resultant forces that the ground exerts on the rear wheels and front wheels respectively. Calculate the magnitude of

(i) force **P**,

.....  
.....  
.....

(ii) force **Q**.

.....  
.....

*(3 marks)*

(c) Calculate the minimum force that needs to be applied vertically at **A** to lift the front wheels off the ground.

.....  
.....  
.....

*(2 marks)*

(d) State and explain, without calculation, how the minimum force that needs to be applied vertically at **A** to lift the rear wheels off the ground compares to the force you calculated in part (c).

You may be awarded marks for the quality of written communication in your answer.

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.....  
.....

*(3 marks)*

- 4 In an experiment to measure the temperature of the flame of a Bunsen burner, a lump of copper of mass 0.12 kg is heated in the flame for several minutes. The copper is then transferred quickly to a beaker, of negligible heat capacity, containing 0.45 kg of water, and the temperature rise of the water measured.

$$\text{specific heat capacity of water} = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$\text{specific heat capacity of copper} = 390 \text{ J kg}^{-1} \text{ K}^{-1}$$

- (a) If the temperature of the water rises from 15 °C to 35 °C, calculate the thermal energy gained by the water.

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(2 marks)

- (b) (i) State the thermal energy lost by the copper, assuming no heat is lost during its transfer.

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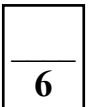
- (ii) Calculate the fall in temperature of the copper.

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.....  
.....

- (iii) Hence calculate the temperature reached by the copper while in the flame.

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(4 marks)



- 5 The number of molecules in one cubic metre of air decreases as altitude increases. The table shows how the pressure and temperature of air compare at sea-level and at an altitude of 10 000 m.

| altitude  | pressure/Pa       | temperature/K |
|-----------|-------------------|---------------|
| sea-level | $1.0 \times 10^5$ | 300           |
| 10 000 m  | $2.2 \times 10^4$ | 270           |

- (a) Calculate the number of moles of air in a cubic metre of air at

- (i) sea-level,

.....

.....

- (ii) 10 000 m.

.....

.....

(3 marks)

- (b) In air, 23% of the molecules are oxygen molecules. Calculate the number of extra oxygen molecules there are per cubic metre at sea-level compared with a cubic metre of air at an altitude of 10 000 m.

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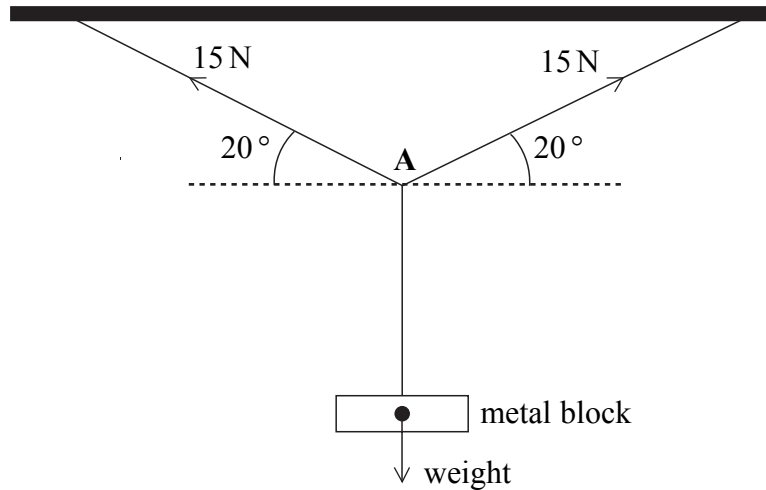
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(2 marks)

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- 6 **Figure 3** shows a stationary metal block hanging from the middle of a stretched wire which is suspended from a horizontal beam. The tension in each half of the wire is 15 N.

**Figure 3**



- (a) Calculate for the wire at **A**,
- (i) the resultant horizontal component of the tension forces,

.....

.....

- (ii) the resultant vertical component of the tension forces.

.....

.....

(3 marks)

(b) (i) State the weight of the metal block.

.....

(ii) Explain how you arrived at your answer, with reference to an appropriate law of motion.

.....

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.....

*(3 marks)*

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| 6 |

**Quality of Written Communication** *(2 marks)*

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| 2 |

**END OF QUESTIONS**

**There are no questions printed on this page**