Killara HIGH SCHOOL
MATHEMATICS DEPARTMENT

Student Name

2022 **YEAR 12**

Mathematics Extension 1

Task 2

Q	Marks
1	/12
2	/10
3	/14
Total	**/36**

8th March, 2022

General Instructions:

- Reading time – 5 minutes
- Working time – 55 minutes
- Write using blue or black pen
- NESA approved calculators may be used
- Show relevant mathematical reasoning and/or calculations
- No white-out may be used

This question paper must not be removed from the examination room.

This validation test constitutes 60% of the assessment task.

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Question 1 (12 marks) Answer each question in a NEW booklet.

(a) Find vector $\underset{\sim}{b} = \begin{pmatrix} p \\ q \end{pmatrix}$, such that **2**

$$proj_{\underset{\sim}{b}}\underset{\sim}{a} = \frac{87}{117}\underset{\sim}{b}$$

$$proj_{\underset{\sim}{b}}\underset{\sim}{c} = \frac{60}{117}\underset{\sim}{b}$$

given $\underset{\sim}{a} = \begin{pmatrix} 4 \\ 7 \end{pmatrix}$, and $\underset{\sim}{c} = \begin{pmatrix} -2 \\ 8 \end{pmatrix}$.

(b) Consider the vector $\underset{\sim}{a} = \underset{\sim}{i} + \sqrt{3}\underset{\sim}{j}$.

(i) Find the unit vector in the direction of $\underset{\sim}{a}$. **1**

(ii) Find the acute angle that $\underset{\sim}{a}$ makes with the positive direction of the x-axis. **1**

(iii) Given that vector $\underset{\sim}{b} = m\underset{\sim}{i} - 2\underset{\sim}{j}$ is perpendicular to $\underset{\sim}{a}$, find the value of m. **1**

(c) A ship needs to travel on a bearing of $240°$. The ship is sailing at a constant 60 km/h. However, there is a current from the north with a constant speed of 9 km/h. **2**

On what constant bearing, to the nearest degree, is the ship sailing?

Examination continues on next page

(d) A crate of mass 25.0 kg is pulled across the floor with a force of 168 N. The force makes an angle of 15.0° with the horizontal. Assume there is no friction between the crate and the floor and that the crate does not lift. You may assume that $g = 10\text{m}s^{-2}$.

Find the:

(i) Resultant force acting on the crate, correct to the nearest Newton. **2**

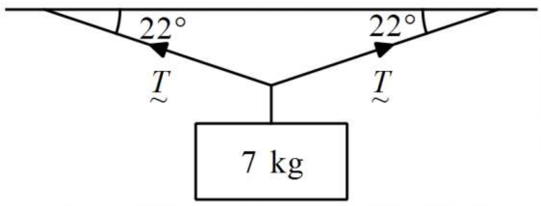
(ii) The acceleration of the crate, correct one decimal place. **1**

(iii) The magnitude of the normal force, correct to the nearest Newton. **2**

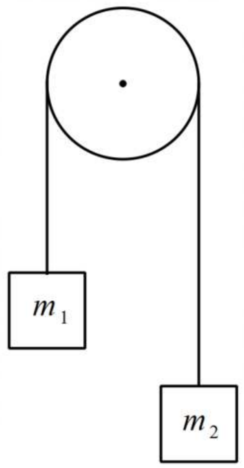
Do NOT write in this area.

Question 2 (10 marks) Answer each question in a NEW booklet.

(a) A mass of 7 kg is suspended from a horizontal ceiling by two inextensible light strings of equal length. Each string is at 22° to the ceiling. Find the tension $\underset{\sim}{T}$ in each string, correct to the nearest Newton. You may assume $g = 10 \text{ ms}^{-2}$. **2**



(b) Two masses are connected by a light inextensible string over a smooth pulley.

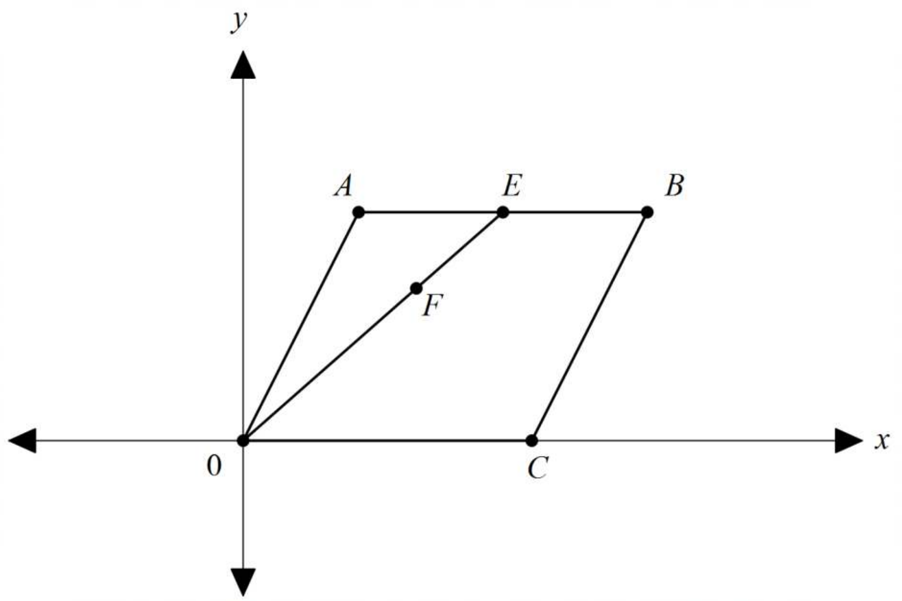


(i) Write equations for the tension in the string, assuming $m_1 < m_2$. **2**

(ii) The second mass has an acceleration of $0.25g$. Find the ratio $m_2 : m_1$. **2**

Examination continues on next page

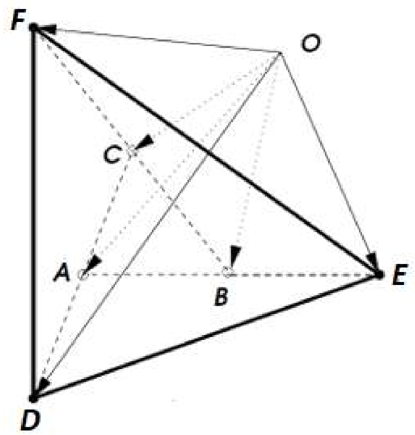
(c) $OABC$ is a parallelogram. $\overline{O}A = \underset{\sim}{a}$, $\overline{A}B = \underset{\sim}{b}$, E is the midpoint of AB. F lies on OE such that $OE = 3FE$. **4**



Prove that A, F and C are collinear.

Question 3 (14 marks) Answer each question in a NEW booklet.

(a) Given a ΔABC, line CA is extended to D, so that $CA = AD$, line AB is extended to E so that $AB = BE$ and line BC is extended to F so that $BC = CF$. The new ΔDEF is formed. Let the position vectors $\overline{OA} = \underset{\sim}{a}$, $\overline{OB} = \underset{\sim}{b}$, $\overline{OC} = \underset{\sim}{c}$, $\overline{OD} = \underset{\sim}{d}$, $\overline{OE} = \underset{\sim}{e}$ and $\overline{OF} = \underset{\sim}{f}$.



(i) Find $\underset{\sim}{a}$ in terms of $\underset{\sim}{c}$ and $\underset{\sim}{d}$. **2**

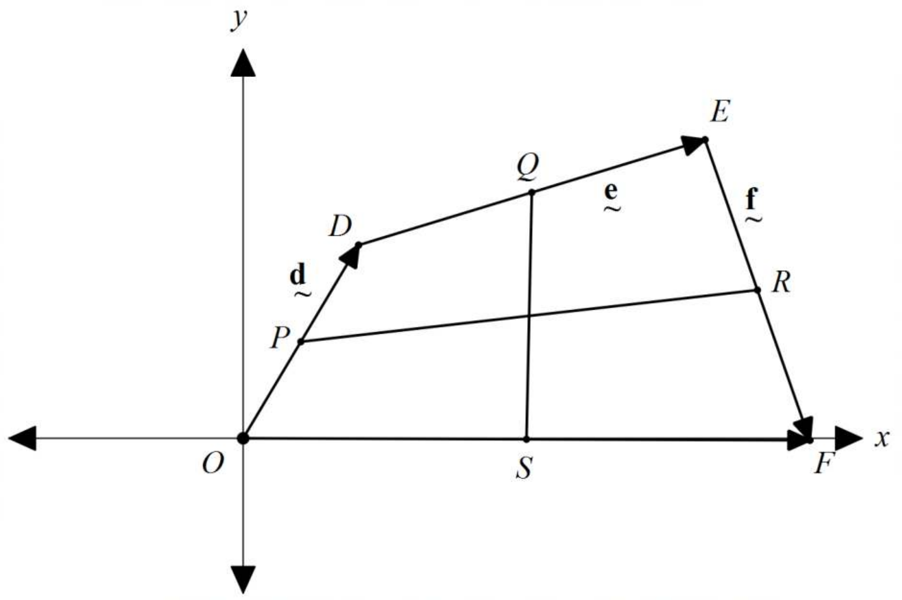
(ii) Find $\underset{\sim}{b}$ in terms of $\underset{\sim}{a}$ and $\underset{\sim}{e}$. **1**

(iii) Find $\underset{\sim}{c}$ in terms of $\underset{\sim}{b}$ and $\underset{\sim}{f}$. **1**

(iv) Then find $\underset{\sim}{b}$ in terms of $\underset{\sim}{d}$, $\underset{\sim}{e}$ and $\underset{\sim}{f}$. **2**

Examination continues on next page

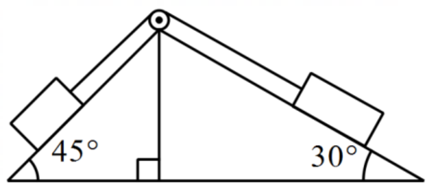
(b) $ODEF$ is a quadrilateral. $\overline{O}D = \underset{\sim}{d}, \overline{D}E = \underset{\sim}{e}, \overline{E}F = \underset{\sim}{f}$. **4**



P, Q, R, S are the midpoints of OD, DE, EF and FO, respectively.

Show that the intervals joining the midpoints of opposite sides of a quadrilateral bisect one another.

(c) Masses of 30 kg and 50 kg on adjacent smooth inclined planes are connected by a light inextensible string over a frictionless pulley, as shown in the diagram below. The 50 kg mass is on a plane inclined at 30° to the horizontal and the 30 kg mass is on a plane at 45° to the horizontal.



(i) Write an expression in terms of g involving the tension in the string for each mass. **2**

(ii) Find the magnitude of the acceleration of the masses in terms of g and state which is descending. **2**

End of Examination

2022 Ext Validation task Solutions

Friday, 10 March 2023 12:07 AM

Killara HIGH SCHOOL
MATHEMATICS DEPARTMENT

Student Name

2022 **YEAR 12**

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$$proj_{\underset{\sim}{b}}\underset{\sim}{a} = \frac{87}{117}\underset{\sim}{b}$$

$$proj_{\underset{\sim}{b}}\underset{\sim}{c} = \frac{60}{117}\underset{\sim}{b}$$

given $\underset{\sim}{a} = \begin{pmatrix} 4 \\ 7 \end{pmatrix}$, and $\underset{\sim}{c} = \begin{pmatrix} -2 \\ 8 \end{pmatrix}$.

a) $\operatorname{proj}_{\underset{\sim}{b}} \underset{\sim}{a} = \dfrac{\underset{\sim}{a} \cdot \underset{\sim}{b}}{\underset{\sim}{b} \cdot \underset{\sim}{b}} \cdot \underset{\sim}{b} = \dfrac{87}{117} \underset{\sim}{b}$. $\operatorname{proj}_{\underset{\sim}{b}} \underset{\sim}{c} = \dfrac{\underset{\sim}{c} \cdot \underset{\sim}{b}}{\underset{\sim}{b} \cdot \underset{\sim}{b}} \cdot \underset{\sim}{b} = \dfrac{60}{117} \underset{\sim}{b}$.

$$\frac{\begin{pmatrix}4\\7\end{pmatrix} \cdot \begin{pmatrix}p\\q\end{pmatrix}}{\begin{pmatrix}p\\q\end{pmatrix} \cdot \begin{pmatrix}p\\q\end{pmatrix}} = \frac{87}{117}. \qquad \frac{\begin{pmatrix}-2\\8\end{pmatrix} \cdot \begin{pmatrix}p\\q\end{pmatrix}}{\begin{pmatrix}p\\q\end{pmatrix}\begin{pmatrix}p\\q\end{pmatrix}} = \frac{60}{117}.$$

$$\frac{4p+7q}{(p^2+q^2)} = \frac{87}{117} \quad ① \qquad \frac{-2p+8q}{p^2+q^2} = \frac{60}{117}. \quad ②$$

① ÷ ②

$$\frac{4p+7q}{-2p+8q} = \frac{87}{60}.$$

$240p + 420q = -174p + 696q$.

$414p = 276q$.

$\frac{3}{2} p = q$.

$p^2+q^2 = 117$.

$p^2 + \frac{9}{4}p^2 = 117$.

$\frac{13}{4}p^2 = 117$

$p^2 = 36$.

$p = \pm 6$

$q = 9$ or -9.

$\begin{cases} p = 6 \\ q = 9 \end{cases} \quad \begin{cases} p = -6 \\ q = -9 \end{cases}$.

$\because 4p+7q = 87$.

$\therefore p \cdot q$ positive

$\therefore \underset{\sim}{b} = \begin{pmatrix}6\\9\end{pmatrix}$.

(b) Consider the vector $\underset{\sim}{a} = \underset{\sim}{i} + \sqrt{3}\underset{\sim}{j}$.

(i) Find the unit vector in the direction of $\underset{\sim}{a}$. **1**

(ii) Find the acute angle that $\underset{\sim}{a}$ makes with the positive direction of the x-axis. **1**

(iii) Given that vector $\underset{\sim}{b} = m\underset{\sim}{i} - 2\underset{\sim}{j}$ is perpendicular to $\underset{\sim}{a}$, find the value of m. **1**

b) . $\sqrt{1+(\sqrt{3})^2} = \sqrt{1+3} = \sqrt{4} = 2$.

(i) $\frac{\underset{\sim}{a}}{|\underset{\sim}{a}|} = \begin{pmatrix} \frac{1}{2} \\ \frac{\sqrt{3}}{2} \end{pmatrix} = \frac{1}{2}\underset{\sim}{i} + \frac{\sqrt{3}}{2}\underset{\sim}{j}$.

(ii) 

$\tan\theta = \frac{\sqrt{3}}{1}$

$\theta = 60°$.

(iii) $\underset{\sim}{b} \perp \underset{\sim}{a}$

$\therefore \underset{\sim}{b} \cdot \underset{\sim}{a} = 0$

$\begin{pmatrix} m \\ -2 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix} = 0$

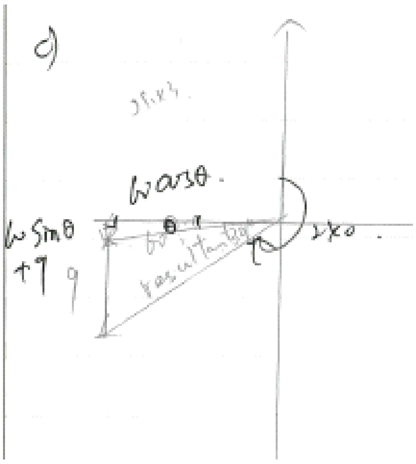
$m - 2\sqrt{3} = 0$

$m = 2\sqrt{3}$.

(c) A ship needs to travel on a bearing of 240°. The ship is sailing at a constant 60 km/h. However, there is a current from the north with a constant speed of 9 km/h. **2**

On what constant bearing, to the nearest degree, is the ship sailing?

c)



2/60/√3 . $V_{sail} = V_{resultant} - V_{wind}$

=

$V_{sail} + V_{wind} = V_{resultant}$

$\frac{1}{\tan 30°} = \frac{60\cos\theta}{60\sin\theta + 9}$.

$60\sqrt{3}\sin\theta + 9\sqrt{3} = 60\cos\theta.$

$9\sqrt{3} = 60\cos\theta - 60\sqrt{3}\sin\theta$

$\frac{3\cancel{9}\sqrt{3}}{\cancel{120}40} = \frac{1}{2}\cos\theta - \frac{\sqrt{3}}{2}\sin\theta$

$\frac{3}{40}\sqrt{3}. = \cos(60° + \theta)$

$60° + \theta = \cos^{-1}\left(\frac{3}{40}\sqrt{3}\right)$

$\theta = \cos^{-1}\left(\frac{3}{40}\sqrt{3}\right) - 60°.$

$= 22.536°.$

Bearing $= 270° - \theta$

$= 247.46°.$

$= 247° T$

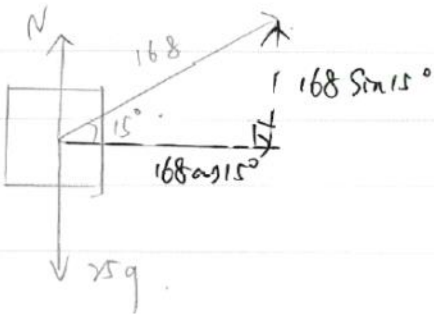
(d) A crate of mass 25.0 kg is pulled across the floor with a force of 168 N. The force makes an angle of 15.0° with the horizontal. Assume there is no friction between the crate and the floor and that the crate does not lift. You may assume that $g = 10\text{m}s^{-2}$.

Find the:

(i) Resultant force acting on the crate, correct to the nearest Newton. **2**

(ii) The acceleration of the crate, correct one decimal place. **1**

(iii) The magnitude of the normal force, correct to the nearest Newton. **2** d).



i) $F_{resultant} = 168\cos 15°$

$= 162.28\ N$

$= 162\ N$

Towards right.
Along horizontal.

ii) $F = ma$

$a = \frac{F}{m} = \frac{168\cos 15°}{25} = 6.49$

$= 6.5\ m/s^2$ (1 d.p.)

iii). As there is no vertical acceleration,

$\Sigma F_{vertical} = 0$.

$\therefore N + 168\sin 15° = 25g$.

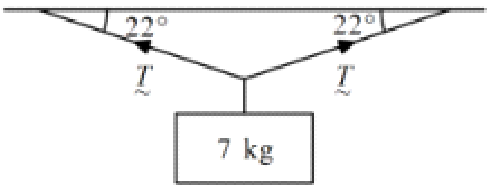
$N = 25g - 168\sin 15°$

$= 206.52\ N$

$= 207\ N$

Question 2 (10 marks) Answer each question in a NEW booklet.

(a) A mass of 7 kg is suspended from a horizontal ceiling by two inextensible light strings of equal length. Each string is at 22° to the ceiling. Find the tension $\underset{\sim}{T}$ in each string, correct to the nearest Newton. You may assume $g = 10\text{ ms}^{-2}$. **2**



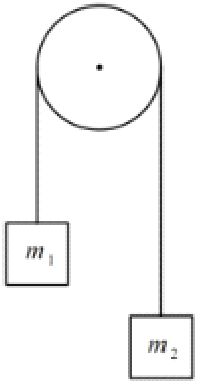
a) ② $2 \times \sin 22° |\underset{\sim}{T}| = 7g$. ∵ equilibrium

$|\underset{\sim}{T}| = \dfrac{7 \times 10}{2 \times \sin 22°}$. $\therefore \Sigma F = 0$.

$= 93.43N$ @ $\cos 22° \underset{\sim}{T_1} = \cos 22° \underset{\sim}{T_2}$.

$= 93N$ $\therefore \underset{\sim}{T_1} = \underset{\sim}{T_2}$.

(b) Two masses are connected by a light inextensible string over a smooth pulley.



(i) Write equations for the tension in the string, assuming $m_1 < m_2$. **2**

(ii) The second mass has an acceleration of $0.25g$. Find the ratio $m_2 : m_1$. **2**

b).

i) For m_2.

$m_2 a = m_2 g - T$.

$T = m_2(g - a)$.

For m_1

$\cancel{T + m_1 a = m_1 g}$.

$\cancel{T = m_1(g-a)}$.

$m_1 a = T - m_1 g$.

$T = m_1(a + g)$

ii). $a = 0.25g \downarrow$.

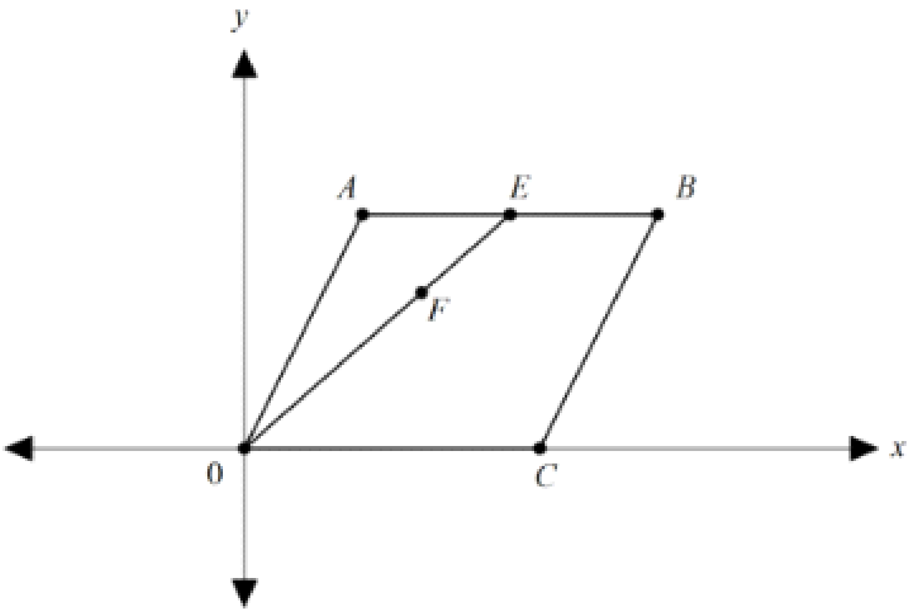
$m_2(g - 0.25g) = m_1(0.25g + g)$

$0.75 m_2 = 1.25 m_1$

$\frac{3}{4} m_2 = \frac{5}{4} m_1$.

$m_2 : m_1 = 5 : 3$.

(c) $OABC$ is a parallelogram. $\overrightarrow{OA} = \underset{\sim}{a}$, $\overrightarrow{AB} = \underset{\sim}{b}$, E is the midpoint of AB. F lies on OE such that $OE = 3FE$. **4**



Prove that A, F and C are collinear.

c). As OABC is parallelogram

$\therefore \overrightarrow{AB} = \overrightarrow{OC} = \underset{\sim}{b}$.

$\overrightarrow{AC} = \overrightarrow{OC} - \overrightarrow{OA} = \underset{\sim}{b} - \underset{\sim}{a}$.

$\overrightarrow{OF} = \frac{2}{3}\overrightarrow{OE} = \frac{2}{3}(\overrightarrow{OA} + \frac{1}{2}\overrightarrow{AB})$

$= \frac{2}{3} \times (\underset{\sim}{a} + \frac{1}{2}\underset{\sim}{b})$

$= \frac{2}{3}\underset{\sim}{a} + \frac{1}{3}\underset{\sim}{b}$.

$\overrightarrow{AF} = \overrightarrow{OF} - \overrightarrow{OA} = \frac{2}{3}\underset{\sim}{a} + \frac{1}{3}\underset{\sim}{b} - \underset{\sim}{a}$.

$= \frac{1}{3}\underset{\sim}{b} - \frac{1}{3}\underset{\sim}{a}$

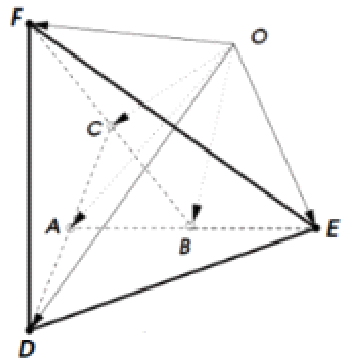
$= \frac{1}{3}(\underset{\sim}{b} - \underset{\sim}{a})$

$\because \overrightarrow{AF} = \frac{1}{3}\overrightarrow{AC}$.

$\therefore$ A. F. C are collinear.

Question 3 (14 marks) Answer each question in a NEW booklet.

(a) Given a ΔABC, line CA is extended to D, so that $CA = AD$, line AB is extended to E so that $AB = BE$ and line BC is extended to F so that $BC = CF$. The new ΔDEF is formed. Let the position vectors $\overrightarrow{OA} = \underset{\sim}{a}$, $\overrightarrow{OB} = \underset{\sim}{b}$, $\overrightarrow{OC} = \underset{\sim}{c}$, $\overrightarrow{OD} = \underset{\sim}{d}$, $\overrightarrow{OE} = \underset{\sim}{e}$ and $\overrightarrow{OF} = \underset{\sim}{f}$.



(i) Find $\underset{\sim}{a}$ in terms of $\underset{\sim}{c}$ and $\underset{\sim}{d}$. **2**

(ii) Find $\underset{\sim}{b}$ in terms of $\underset{\sim}{a}$ and $\underset{\sim}{e}$. **1**

(iii) Find $\underset{\sim}{c}$ in terms of $\underset{\sim}{b}$ and $\underset{\sim}{f}$. **1**

(iv) Then find $\underset{\sim}{b}$ in terms of $\underset{\sim}{d}$, $\underset{\sim}{e}$ and $\underset{\sim}{f}$. **2**

a) i) $\overrightarrow{CD} = \overrightarrow{OD} - \overrightarrow{OC}$

$= \underset{\sim}{d} - \underset{\sim}{c}$.

$\overrightarrow{CA} = \frac{1}{2}\overrightarrow{CD} = \frac{1}{2}(\underset{\sim}{d} - \underset{\sim}{c})$

$\underset{\sim}{a} = \overrightarrow{OA} = \overrightarrow{OC} + \overrightarrow{CA}$

$= \underset{\sim}{c} + \frac{1}{2}\underset{\sim}{d} - \frac{1}{2}\underset{\sim}{c}$

$= \frac{1}{2}(\underset{\sim}{d} + \underset{\sim}{c})$.

ii) $\overrightarrow{AE} = \overrightarrow{OE} - \overrightarrow{OA}$

$= \underset{\sim}{e} - \underset{\sim}{a}$.

$\overrightarrow{AB} = \frac{1}{2}\overrightarrow{AE} = \frac{1}{2}(\underset{\sim}{e} - \underset{\sim}{a})$.

$\underset{\sim}{b} = \overrightarrow{OB} = \overrightarrow{OA} + \overrightarrow{AB}$

$= \frac{1}{2}\underset{\sim}{e} - \frac{1}{2}\underset{\sim}{a} + \underset{\sim}{a}$.

$= \frac{1}{2}(\underset{\sim}{a} + \underset{\sim}{e})$.

iii) $\overrightarrow{BF} = \underset{\sim}{f} - \underset{\sim}{b}$.

$\overrightarrow{BC} = \frac{1}{2}\overrightarrow{BF} = \frac{1}{2}\underset{\sim}{f} - \frac{1}{2}\underset{\sim}{b}$

$\underset{\sim}{c} = \overrightarrow{OC} = \overrightarrow{OB} + \overrightarrow{BC} = \frac{1}{2}(\underset{\sim}{b} + \underset{\sim}{f})$.

iv). $\underset{\sim}{b} = \frac{1}{2}(\underset{\sim}{a} + \underset{\sim}{e})$ (from ii)

$= \frac{1}{2} \times \frac{1}{2}(\underset{\sim}{d} + \underset{\sim}{c}) + \frac{1}{2}\underset{\sim}{e}$ (from i)

$= \frac{1}{4}\underset{\sim}{d} + \frac{1}{2}\underset{\sim}{e} + \frac{1}{4}\underset{\sim}{c}$.

$= \frac{1}{4}\underset{\sim}{d} + \frac{1}{2}\underset{\sim}{e} + \frac{1}{4} \times \frac{1}{2}(\underset{\sim}{b} + \underset{\sim}{f})$ (from iii)

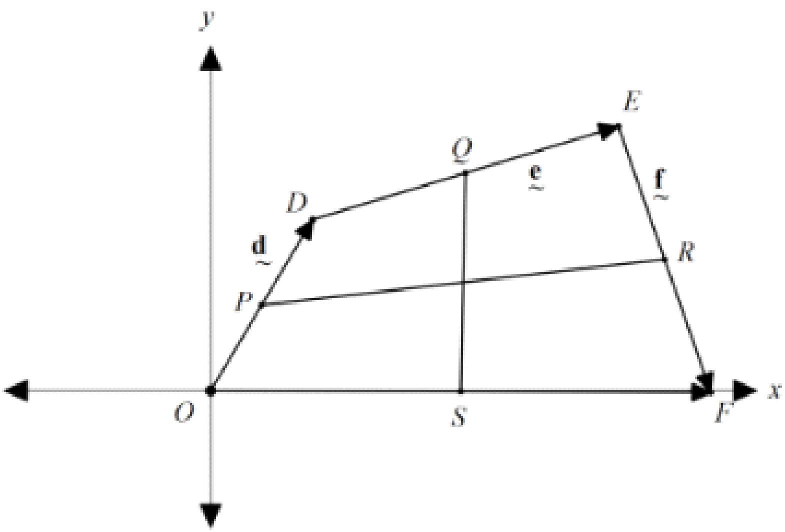
$= \frac{1}{4}\underset{\sim}{d} + \frac{1}{2}\underset{\sim}{e} + \frac{1}{8}\underset{\sim}{b} + \frac{1}{8}\underset{\sim}{f}$.

$\frac{7}{8}\underset{\sim}{b} = \frac{1}{4}\underset{\sim}{d} + \frac{1}{2}\underset{\sim}{e} + \frac{1}{8}\underset{\sim}{f}$.

$\underset{\sim}{b} = \frac{2}{7}\underset{\sim}{d} + \frac{4}{7}\underset{\sim}{e} + \frac{1}{7}\underset{\sim}{f}$.

$= \frac{1}{7}(2\underset{\sim}{d} + 4\underset{\sim}{e} + \underset{\sim}{f})$.

(b) $ODEF$ is a quadrilateral. $\overrightarrow{OD} = \underset{\sim}{d}, \overrightarrow{DE} = \underset{\sim}{e}, \overrightarrow{EF} = \underset{\sim}{f}$. **4**



P, Q, R, S are the midpoints of OD, DE, EF and FO, respectively.

Show that the intervals joining the midpoints of opposite sides of a quadrilateral bisect one another.

b). $\vec{OP} = \frac{1}{2}d$.

$\vec{OR} = d + e + \frac{1}{2}f$

$\vec{PR} = \vec{OR} - \vec{OP}$

$= d + e + \frac{1}{2}f - \frac{1}{2}d$

$= \frac{1}{2}d + \frac{1}{2}f + e$.

$\vec{OP} = d + e + f$.

$\vec{OS} = \frac{1}{2}\vec{OP} = \frac{1}{2}d + \frac{1}{2}e + \frac{1}{2}f$.

$\vec{OQ} = d + \frac{1}{2}e$.

$\vec{QS} = \vec{OS} - \vec{OQ}$

$= \frac{1}{2}d + \cancel{\frac{1}{2}e} + \frac{1}{2}f - d - \cancel{\frac{1}{2}e}$.

$= \frac{1}{2}(f - d)$.

Let the intersect point of PR, QS be A.

$\vec{PA} = \lambda \vec{PR}$. $\vec{QA} = \cancel{\lambda}\,\mu \vec{QS}$. $\vec{PQ} = \vec{OQ} - \vec{OP}$

$\cancel{\lambda(\frac{1}{2}d + \frac{1}{2}f}$. $= d + \frac{1}{2}e - \frac{1}{2}d$

$\vec{PA} + \vec{AQ} = \vec{PQ}$. $= \frac{1}{2}e + \frac{1}{2}d$.

$\lambda(\frac{1}{2}d + \frac{1}{2}f + e) + \mu(\frac{1}{2}d - \frac{1}{2}f) = \frac{1}{2}e + \frac{1}{2}d$.

$\frac{1}{2}\lambda + \frac{1}{2}\mu = \frac{1}{2}$. $\frac{1}{2}\lambda - \frac{1}{2}\mu = 0$.

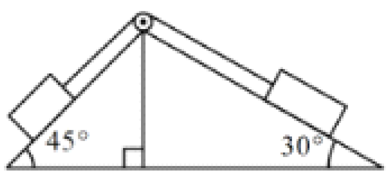
$\lambda + \mu = 1$ $\lambda = \mu$.

$\therefore \lambda = \mu = \frac{1}{2}$.

$\therefore \vec{PA} = \frac{1}{2}\vec{PR}$. $\vec{QA} = \frac{1}{2}\vec{QS}$.

$\therefore$ $\vec{PR}$ ~~bisect~~, $\vec{QS}$ bisect each other

(c) Masses of 30 kg and 50 kg on adjacent smooth inclined planes are connected by a light inextensible string over a frictionless pulley, as shown in the diagram below. The 50 kg mass is on a plane inclined at 30° to the horizontal and the 30 kg mass is on a plane at 45° to the horizontal.



(i) Write an expression in terms of g involving the tension in the string for each mass. **2**

(ii) Find the magnitude of the acceleration of the masses in terms of g and state which is descending. **2**

c) i) Assume $\boxed{50kg}$ is sliding down. $\boxed{30kg}$ is sliding upward.

$30a = T - 30g\sin 45°$. ① $50a = 50g\sin 30° - T$. ②

①×5. $150a = 5T - 150g\sin 45°$ ②×3. $150a = 150g\sin 30° - 3T$.

$$5T - 150g\sin 45° = 150g\sin 30° - 3T.$$
$$8T = 150g(\sin 30° + \sin 45°)$$
$$T = \frac{150}{8}g(\sin 30° + \sin 45°).$$
$$= \frac{\sqrt{2}+1}{2} \times \frac{150}{8}g$$
$$= \frac{75(\sqrt{2}+1)}{8}g.$$

---

ii) from ① $30a = T - 30g\sin 45°$.

$$30a = \frac{75\sqrt{2}+75}{8}g - 30\sin 45° g$$
$$= \left(\frac{75\sqrt{2}+75}{8} - 15\sqrt{2}\right)g$$
$$= \frac{75 - 45\sqrt{2}}{8}g.$$
$$a = \frac{5-3\sqrt{2}}{16}g.$$

As this a is positive. $5-3\sqrt{2} > 0$.

Therefore Assumption is true.

$\boxed{50kg}$ is descending (sliding down).