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PERTH MODERN SCHOOL
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Independent Public School

Year 12 Specialist
TEST 3
2018
TIME: 45 minutes working Classpads **allowed!**
3~~8~~9 Marks 7 Questions

Name: Marking Key

Teacher: ______________________

Note: All part questions worth more than 2 marks require working to obtain full marks.

Q1 (2 & 2 = 4 marks)

Consider a line with parametric equations $\begin{aligned} x &= 3 - 5\lambda \\ y &= -7 + 2\lambda \end{aligned}$

i) Determine a vector equation

$$\underset{\sim}{r} = \begin{pmatrix} 3 \\ -7 \end{pmatrix} + \lambda \begin{pmatrix} -5 \\ 2 \end{pmatrix}$$

✓ uses $\underset{\sim}{r} + \lambda$
✓ obtains vector eqn

ii) Determine a cartesian equation.

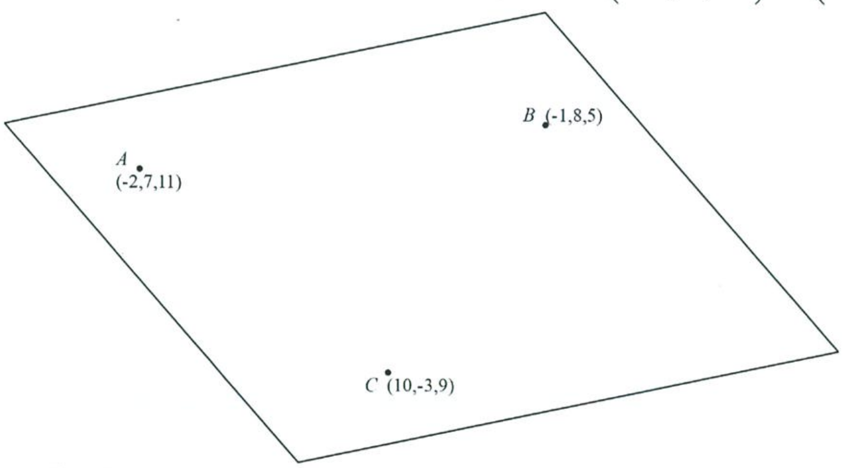
$$\lambda = \frac{x-3}{-5} \qquad y = -7 + \frac{2(x-3)}{-5}$$

$$y = \frac{-2x}{5} - \frac{29}{5}$$

✓ Expresses λ in terms of one variable
✓ obtains cartesian eqn

Q2 (3 & 2 = 5 marks)

Consider a plane containing the three points A$(-2,7,11)$, B$(-1,8,5)$ & C$(10,-3,9)$.



i) Determine the vector equation of the plane.

$$\overrightarrow{AB} = \begin{pmatrix} 1 \\ 1 \\ -6 \end{pmatrix} \qquad \overrightarrow{AC} = \begin{pmatrix} 12 \\ -10 \\ -2 \end{pmatrix} \qquad \overrightarrow{AB} \times \overrightarrow{AC} = \begin{pmatrix} -62 \\ -70 \\ -22 \end{pmatrix} = -2\begin{pmatrix} 31 \\ 35 \\ 11 \end{pmatrix}$$

$$\underset{\sim}{r} \cdot \begin{pmatrix} 31 \\ 35 \\ 11 \end{pmatrix} = \begin{pmatrix} -2 \\ 7 \\ 11 \end{pmatrix} \cdot \begin{pmatrix} 31 \\ 35 \\ 11 \end{pmatrix} = 304$$

✓ obtains two vectors in plane
✓ uses cross product to find normal
✓ finds vector eqn of plane

OR $\underset{\sim}{r} = \begin{pmatrix} -2 \\ 7 \\ 11 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 1 \\ -6 \end{pmatrix} + \mu \begin{pmatrix} 12 \\ -10 \\ -2 \end{pmatrix}$

Continued-

ii) Determine the cartesian equation of the plane. (simplified)

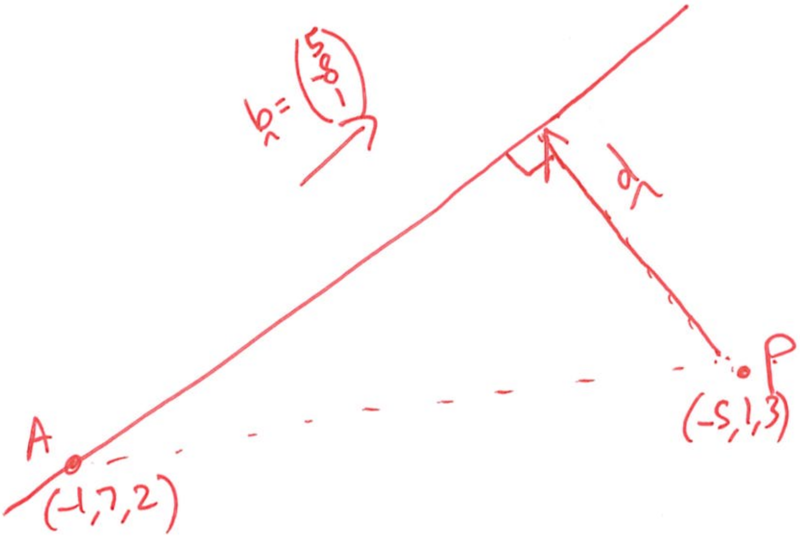
$$31x + 35y + 11z = 304$$

✓ uses dot product with $\begin{pmatrix} x \\ y \\ z \end{pmatrix}$

✓ simplified co-efficients

Q3 (4 marks)

Determine the distance of point P $(-5,1,3)$ from the line $\underset{\sim}{r} = \begin{pmatrix} -1 \\ 7 \\ 2 \end{pmatrix} + \lambda \begin{pmatrix} 5 \\ -8 \\ 1 \end{pmatrix}$



$$\underset{\wedge}{d} = \overrightarrow{PA} + \lambda \underset{\wedge}{b}$$

$$= \begin{pmatrix} -1 \\ 7 \\ 2 \end{pmatrix} - \begin{pmatrix} -5 \\ 1 \\ 3 \end{pmatrix} + \lambda \begin{pmatrix} 5 \\ -8 \\ 1 \end{pmatrix}$$

$$= \begin{pmatrix} 4 + 5\lambda \\ 6 - 8\lambda \\ -1 + \lambda \end{pmatrix}$$

$$\underset{\wedge}{d} \cdot \begin{pmatrix} 5 \\ -8 \\ 1 \end{pmatrix} = 0$$

$$\begin{pmatrix} 4+5\lambda \\ 6-8\lambda \\ -1+\lambda \end{pmatrix} \cdot \begin{pmatrix} 5 \\ -8 \\ 1 \end{pmatrix} = 5(4+5\lambda) - 8(6-8\lambda) - 1 + \lambda = 0$$

$$\lambda = \frac{29}{90}$$

$$|\underset{\wedge}{d}| = \frac{\sqrt{39290}}{30} \text{ or } \approx 6.607$$

using classpad.

VECTORS

✓ sets up a displacement vector $\underset{\wedge}{d}$

✓ uses dot product equated to zero

✓ solves for parameter λ

✓ determines $|\underset{\wedge}{d}|$

CALCULUS

OR ✓ determines $\underset{\wedge}{r} - \overrightarrow{OP}$

✓ obtain expression for magnitude

✓ minimises distance using calculus

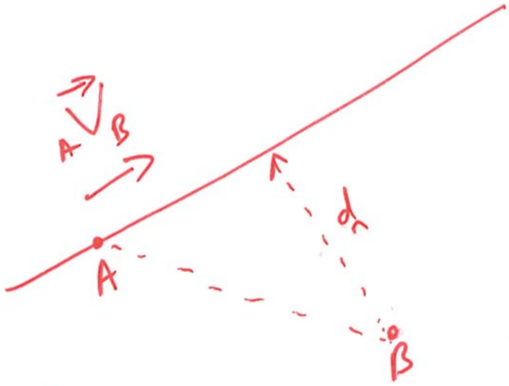
✓ determines distance.

Q4 (4 marks)

Consider two particles A and B whose position at $t = 0$ is recorded as below moving with constant velocities v_A & v_B . Determine the distance of closest approach and the time that this occurs.

$$r_A = \begin{pmatrix} 2 \\ -5 \\ 9 \end{pmatrix} \qquad v_A = \begin{pmatrix} 11 \\ -5 \\ 7 \end{pmatrix}$$

$$r_B = \begin{pmatrix} 1 \\ -1 \\ 9 \end{pmatrix} \qquad v_B = \begin{pmatrix} 12 \\ -10 \\ 2 \end{pmatrix}$$



$$_A\vec{V}_B = \begin{pmatrix} 11 \\ -5 \\ 7 \end{pmatrix} - \begin{pmatrix} 12 \\ -10 \\ 2 \end{pmatrix} = \begin{pmatrix} -1 \\ 5 \\ 5 \end{pmatrix}$$

$$\underset{\sim}{d} = \vec{BA} + t\begin{pmatrix} -1 \\ 5 \\ 5 \end{pmatrix} = \begin{pmatrix} 2 \\ -5 \\ 9 \end{pmatrix} - \begin{pmatrix} 1 \\ -1 \\ 9 \end{pmatrix} + t\begin{pmatrix} -1 \\ 5 \\ 5 \end{pmatrix}$$

$$\underset{\sim}{d} = \begin{pmatrix} 1 \\ -4 \\ 0 \end{pmatrix} + t\begin{pmatrix} -1 \\ 5 \\ 5 \end{pmatrix} = \begin{pmatrix} 1-t \\ -4+5t \\ 5t \end{pmatrix}$$

$$\underset{\sim}{d} \cdot {}_A\vec{V}_B = 0 \qquad \begin{pmatrix} 1-t \\ -4+5t \\ 5t \end{pmatrix} \cdot \begin{pmatrix} -1 \\ 5 \\ 5 \end{pmatrix} = 0$$

$$-(1-t) + 5(-4+5t) + 25t = 0$$

$$t = \frac{7}{17}$$

VECTOR

✓ uses relative velocity

✓ obtains expression for separation vector $\underset{\sim}{d}$

✓ uses dot product and solves for t

✓ obtains distance.

$|\underset{\sim}{d}|$ when $t = \frac{7}{17}$ hr

is $\frac{\sqrt{2414}}{17}$ OR ≈ 2.890 Km

CALCULUS ✓ sets up vector eqn for displacement $\hat{}$ each

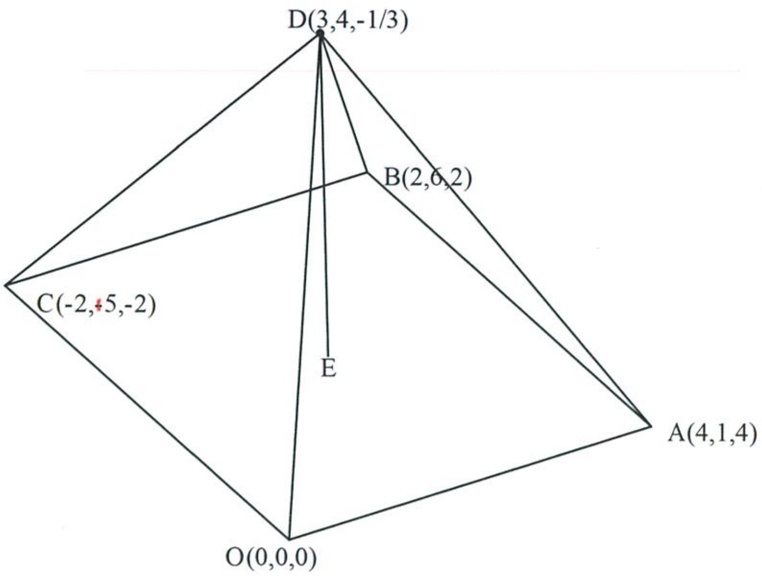
✓ subtracts to find separation & finds distance

✓ minimises distance expression & solves for time

✓ obtains distance (minimum)

(2, 4+3=9)

Q5 (~~2, 3 & 3 = 8~~ marks)
OABCD is a pyramid. The height of the pyramid is the length of DE, where E is the point on the base OABC such that DE is perpendicular to the base.



i) Show that the base OABC is a rhombus. $\overrightarrow{OC} = \overrightarrow{AB}$

$LHS = \begin{pmatrix}-2\\+5\\-2\end{pmatrix} - \begin{pmatrix}0\\0\\0\end{pmatrix}$ ✓ $RHS = \begin{pmatrix}2\\6\\2\end{pmatrix} - \begin{pmatrix}4\\1\\4\end{pmatrix} = \begin{pmatrix}-2\\5\\-2\end{pmatrix}$ ✓

$|CB| = |OC|$ ✓

The unit vector $p\underset{\sim}{i} + q\underset{\sim}{j} + r\underset{\sim}{k}$ is perpendicular to both $\overrightarrow{OA}$ and $\overrightarrow{OC}$.

ii) Show that $q = 0$ and determine the exact values of p & r.

✓ uses dot product equal to zero
✓ sets up two linear eqn
✓ shows $q=0$
✓ solves for p + r using cross product

$\begin{pmatrix}p\\q\\r\end{pmatrix} \cdot \begin{pmatrix}-2\\5\\-2\end{pmatrix} = 0$ $\begin{pmatrix}p\\q\\r\end{pmatrix} \cdot \begin{pmatrix}4\\1\\4\end{pmatrix} = 0$

$-2p + 5q - 2r = 0 \quad \ldots (1)$

$4p + q + 4r = 0 \quad \ldots (2)$

$2 \times (1) + (2) \ldots \quad 11q = 0$

$q = 0$

iii) Hence determine the exact height of the pyramid.

$\begin{pmatrix}p\\q\\r\end{pmatrix} \parallel \overrightarrow{OA} \times \overrightarrow{OC} = \begin{pmatrix}-22\\0\\22\end{pmatrix}$

$\therefore \quad p = -r$

$\left|\begin{pmatrix}p\\0\\-p\end{pmatrix}\right| = 1 \qquad p^2 + p^2 = 1$

$2p^2 = 1$

$p = \pm\frac{1}{\sqrt{2}} \quad q = 0 \quad r = \mp\frac{1}{\sqrt{2}}$

iii) $\text{height} = \left|\overrightarrow{OD} \cdot \begin{pmatrix}\frac{1}{\sqrt{2}}\\0\\-\frac{1}{\sqrt{2}}\end{pmatrix}\right| = \left|\begin{pmatrix}3\\4\\-\frac{1}{3}\end{pmatrix} \cdot \begin{pmatrix}\frac{1}{\sqrt{2}}\\0\\-\frac{1}{\sqrt{2}}\end{pmatrix}\right| = \frac{3}{\sqrt{2}} + \frac{1}{3\sqrt{2}}$

$= \frac{10}{3\sqrt{2}}$ ✓

$= \frac{5}{3}\sqrt{2}$

✓ uses dot product

✓ expresses dot with normal

No need to rationalise for height

Q6 (5 marks)

Consider a sphere of centre $(-3,2,7)$ and radius of a units , where a is a constant.

The line $\underset{\sim}{r} = \begin{pmatrix} 2 \\ 1 \\ -8 \end{pmatrix} + \lambda \begin{pmatrix} 4 \\ 1 \\ -3 \end{pmatrix}$ is a tangent to the above sphere.

Determine the possible value(s) of a

$$\left| \underset{\sim}{r} - \begin{pmatrix} -3 \\ 2 \\ 7 \end{pmatrix} \right| = a$$

✓ subs line into vector eqn of sphere.

$$\left| \begin{pmatrix} 2+4\lambda \\ 1+\lambda \\ -8-3\lambda \end{pmatrix} - \begin{pmatrix} -3 \\ 2 \\ 7 \end{pmatrix} \right| = a$$

✓ uses magnitude of 3D vector equated to a

$$\left| \begin{pmatrix} 5+4\lambda \\ \lambda-1 \\ -15-3\lambda \end{pmatrix} \right| = a$$

✓ obtains a quadratic eqn for λ in terms of a

✓ uses $b^2-4ac=0$ to solve for a values

✓ states one positive value of a and discards negative.

$$(5+4\lambda)^2 + (\lambda-1)^2 + (-15-3\lambda)^2 = a^2$$

$$16\lambda^2 + 40\lambda + 25 + \lambda^2 - 2\lambda + 1 + 9\lambda^2 + 90\lambda + 225 = a^2$$

$$26\lambda^2 + 128\lambda + 251 - a^2 = 0$$

One solution for λ $\therefore \Delta = 0$

$$128^2 - 4(26)(251-a^2) = 0$$

$$a = \pm\frac{9\sqrt{195}}{13} \quad \text{but} \quad a > 0$$

$$\therefore a = \frac{9\sqrt{195}}{13} \quad \text{or} \approx 9.6675$$

Q7 (2, 3 & 3 = 8 marks)

Consider the function $f(x) = ax^4 + bx^3 + cx^2 + dx$ where $a, b, c \& d$ are constants.

The graph has a stationary point ($f' = 0$) at $(1,1)$ and passes through the point $(-1,4)$.

i) Write down three linear equations satisfied by $a, b, c \& d$.

$1 = a + b + c + d \quad \ldots (1)$

$4 = a - b + c - d \quad \ldots (2)$ } ✓

$f'(x) = 4ax^3 + 3bx^2 + 2cx + d$

$0 = 4a + 3b + 2c + d \quad \ldots (3)$ ✓

ii) Express $a, b \& c$ in terms of d.

$$\left[\begin{array}{ccc|c} 1 & 1 & 1 & 1-d \\ 1 & -1 & 1 & 4+d \\ 4 & 3 & 2 & -d \end{array}\right]$$

$$\left[\begin{array}{ccc|c} 1 & 1 & 1 & 1-d \\ 0 & 2 & 0 & -3-2d \\ 0 & 1 & 2 & 4-3d \end{array}\right] \begin{array}{l} \\ R_1 - R_2 \\ 4R_1 - R_3 \end{array}$$

✓ Obtains an equation with only one variable from a,b,c

✓ solves for one of a,b,c in terms of d

✓ Solves all three of a,b,c in terms of d

$2b = -3 - 2d$

$b = -\frac{3}{2} - d$

$b + 2c = 4 - 3d$

$2c = 4 - 3d + \frac{3}{2} + d$

$c = \frac{11}{4} - d$

$a + b + c = 1 - d$

$a = 1 - d + \frac{3}{2} + d + d - \frac{11}{4}$

$a = d - \frac{1}{4}$

$a = -\frac{1}{4} + d$

$b = -\frac{3}{2} - d$

$c = \frac{11}{4} - d$

iii) Determine the value of d for which the graph has a stationary point where $x = 4$

$f'(x) = 4ax^3 + 3bx^2 + 2cx + d$

$0 = 256a + 48b + 8c + d$

$0 = 256\left(-\frac{1}{4} + d\right) + 48\left(-\frac{3}{2} - d\right) + 8\left(\frac{11}{4} - d\right) + d$

Solve on classpad

$d = \frac{38}{67}$ OR ≈ 0.567

✓ obtains equation for a,b,c&d using $f' = 0$ at $x = 4$

✓ solves all variables in terms of d

✓ Solves for d.