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VCE Mathematical Methods ½
Quadratics Exam Skills [0.4]
Workshop

Section A: Recap

Sub-Section: Factorising Quadratics

Factorising Quadratics

$$y = (x - a)(x - b)$$

- **Steps:**

1. Divide by the coefficient of the leading term. (If applicable)
2. Consider the factors of the constant term.
3. (If Positive Constant Term): See which pair of factors can add up to the coefficient of the x term.

   (If Negative Constant Term): See which pair of factors can subtract from the coefficient of the x term.
4. Construct the linear factors.

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Sub-Section: Perfect Squares

Perfect Squares

$$(a+b)^2 = a^2 + 2ab + b^2$$

$$(a-b)^2 = a^2 - 2ab + b^2$$

- Perfect squares are special quadratic expressions that are made up of two **identical** linear factors.
- In other words, when a linear factor is squared, it becomes a perfect square.

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Sub-Section: Difference of Squares

Difference of Squares

$$a^2 - b^2 = (a-b)(a+b)$$

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Sub-Section: Completing the Square

Completing the Square

- When we complete the square of a quadratic $x^2 + bx + c$, we write it in the form:

$$x^2 + bx + c = \left(x + \frac{b}{2}\right)^2 - \left(\frac{b}{2}\right)^2 + c$$

- **Steps:**

  1. We halve the coefficient of x.
  2. Subtract the half of the coefficient of x squared outside the square bracket.

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Sub-Section: Solving by Factorisation

Solving by Factorisation

Null factor

$$\underbrace{(x-a)}_{=0}\underbrace{(x-b)}_{=0} = 0$$

$$x = a \text{ or } b$$

- **Steps:**
  1. Factorise the quadratic.
  2. Equate each factor to 0 and solve for x.

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Sub-Section: Quadratic Formula

The Quadratic Formula

$$\text{for } ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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Sub-Section: Discriminant

The Discriminant

- **Definition:**
  - The discriminant, often denoted by **Δ** (Delta), is the part **inside** the square root of the quadratic formula.

$$Discriminant = \Delta = b^2 - 4ac$$

if $\Delta > 0$, there are 2 solution.

if $\Delta = 0$, there is 1 solution.

if $\Delta < 0$, there are 0 solutions.

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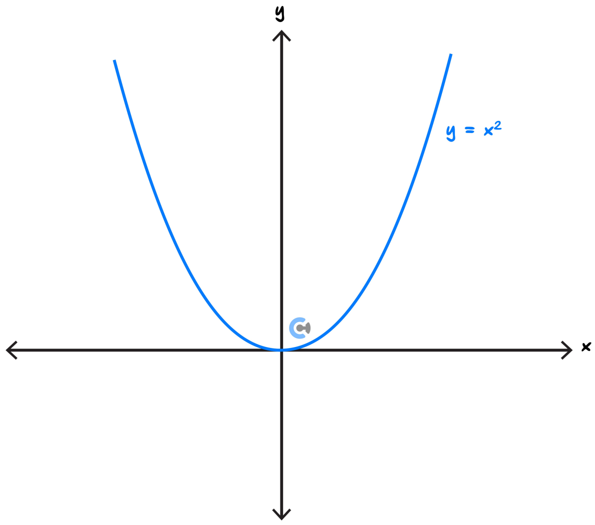
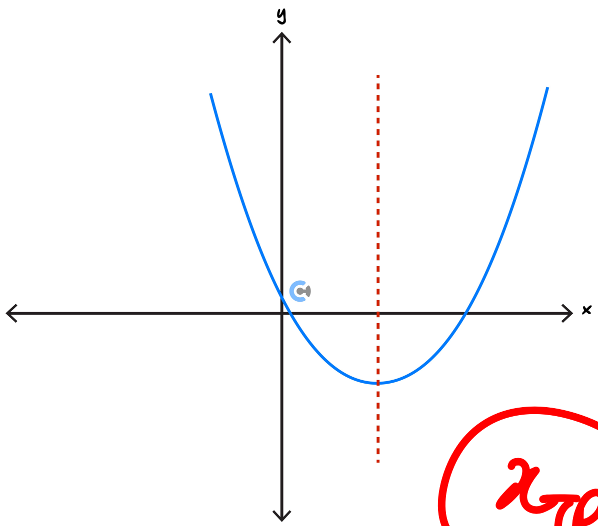
Sub-Section: Parabola and Symmetry

Parabola

- **Definition:**
  - The shape of the graph of a quadratic is known as a parabola.



Axis of Symmetry



x_{TP}

$$\textit{Axis of symmetry}: x = -\frac{b}{2a}$$

Sub-Section: Graphing Quadratics

Turning Point Form

- The turning point form of a quadratic is given by:

$$y = a(x - h)^2 + k$$

$$\textit{Turning point} = (h, k)$$

- The turning point form is obtained by **completing the square.**

Intercept Form

- The x-intercept form of a quadratic is given by:

$$0 \; y = a(x - b)(x - c)$$

$$x\textit{-intercepts}: (b, 0) \textit{ and } (c, 0)$$

- The axis of symmetry is located exactly in the middle of the two x-intercepts.

NOTE: When a is negative, the x-intercepts stay the same, but the **shape** of the parabola becomes a **negative** parabola instead.

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Sub-Section: Finding a Rule of a Quadratic from a Graph

Finding the Equation of a Quadratic

- **Form 1: Turning Point Form**

Sub in another point

$$y = a(x-h)^2 + k$$

  - Recommended when a turning point is easy to identify.

- **Form 2: x-intercept Form**

$$y = a(x-b)(x-c)$$

  - Recommended when both x-intercepts are easy to identify.

NOTE: Never forget the a coefficient!

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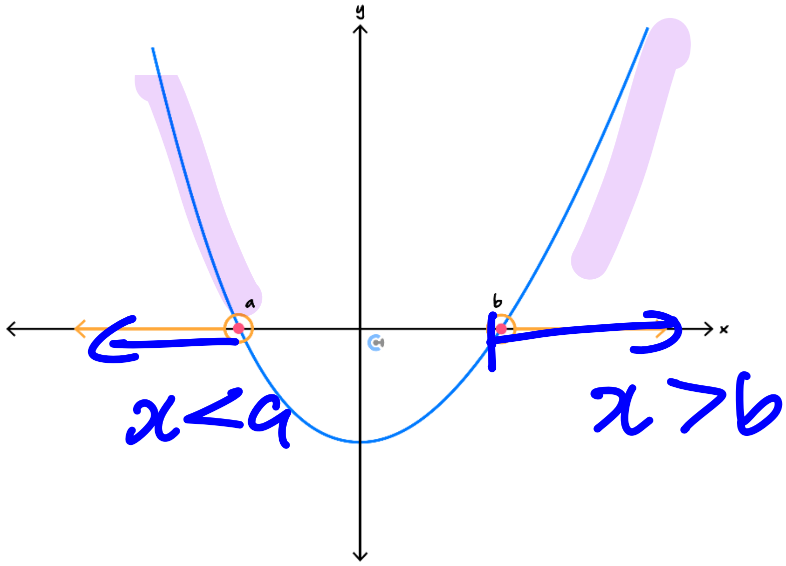
Sub-Section: Quadratic Inequalities

Quadratic Inequalities



>0

- For quadratic inequalities, we always sketch the function.
- **Steps:**

1. Sketch the function.
2. See where the y-value is within the inequality.
3. Find the corresponding x-values.

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Sub-Section: Hidden Quadratics

$(x^2)^2$

x^4 $A = x^2$

Hidden Quadratics

- Instead of:

$$af(x)^2 + bf(x) + c = 0$$

- We can let $f(x) = X$ to have:

$$aX^2 + bX + c = 0$$

Completing the square quickly.

$$y = a(x-h)^2 + k$$

- **Steps**

1. Find the turning point using $\left(-\frac{b}{2a}, f\left(-\frac{b}{2a}\right)\right)$.
2. Use the leading coefficient as a.

Modelling with Quadratics

- Focus on key points such as turning points, x-intercepts and y-intercepts.

Family of Functions

- **Definition:** Functions with unknowns.
- **Question Type:** Find the unknown value to satisfy a certain condition.

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Section B: Warmup

Question 1

Let $f(x) = -\frac{x^2}{2} + 3x - \frac{5}{2}$.

a. Write $f(x)$ in turning point form. → complete the square

$-\frac{1}{2}(x^2 - 6x + 5)$

$= -\frac{1}{2}((x-3)^2 + 5 - (-3)^2)$

$= -\frac{1}{2}((x-3)^2 - 4)$

$= -\frac{1}{2}(x-3)^2 + 2$

b. Solve the equation $f(x) = 0$.

$0 = -\frac{1}{2}(x-3)^2 + 2$

$\frac{1}{2}(x-3)^2 = 2$

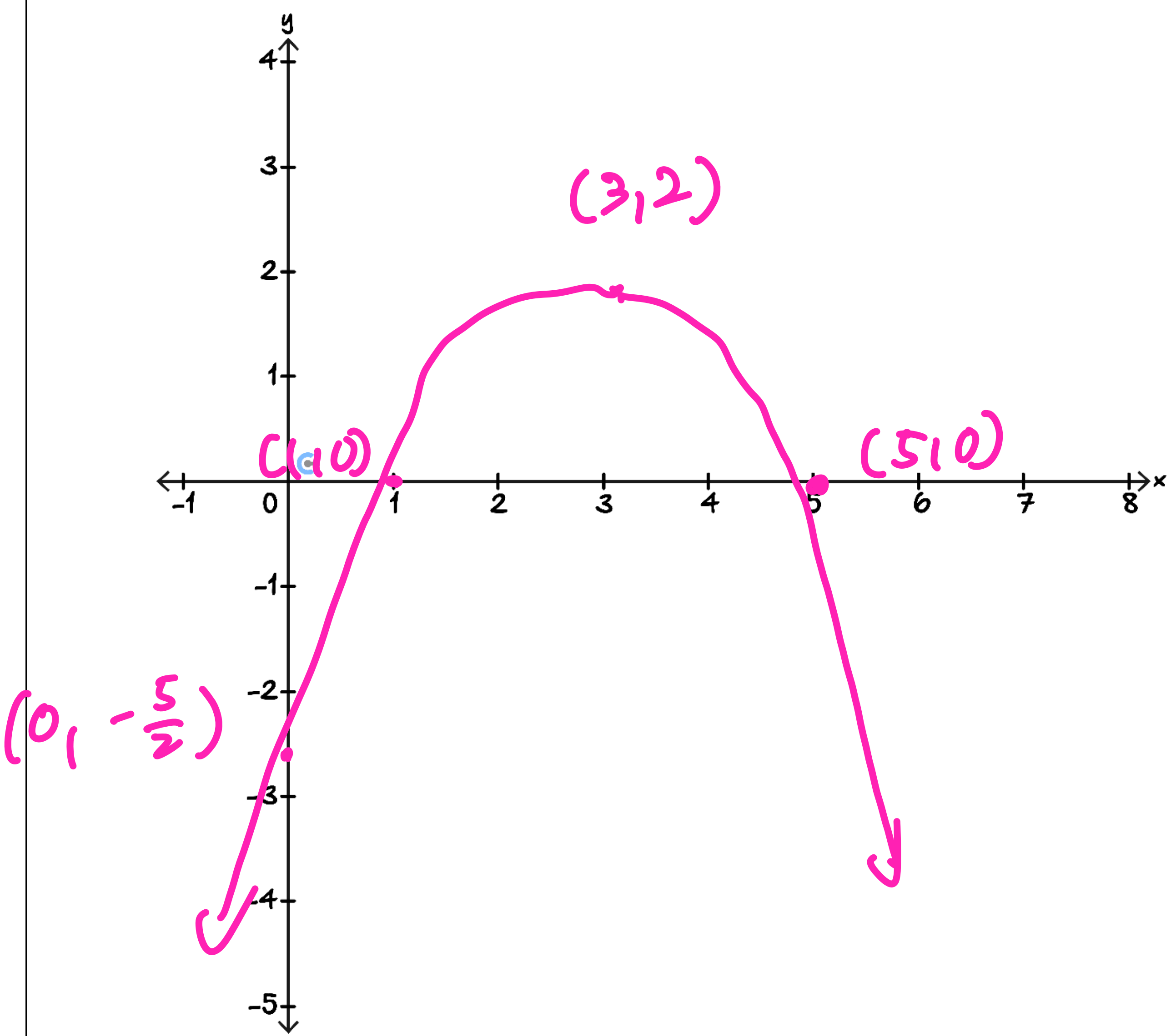
$(x-3)^2 = 4$

$x - 3 = \pm 2$

$x = 3 \pm 2$

$x = 5, 1$

c. Sketch the graph of $y = f(x)$ on the axes below, Label all axes intercepts and the turning point.



d. Find the value of m such that the line $y = mx - 2$ intersects the graph of $y = f(x)$ exactly once.

$$y = -\frac{x^2}{2} + 3x - \frac{5}{2}$$

$$mx - 2 = -\frac{x^2}{2} + 3x - \frac{5}{2}$$

$$0 = -\frac{x^2}{2} + 3x - mx - \frac{5}{2} + 2$$

$$0 = -\frac{x^2}{2} + (3-m)x - \frac{1}{2}$$

$$\Delta = 0 \qquad (3-m)^2 - 4\left(-\tfrac{1}{2}\right)\left(-\tfrac{1}{2}\right) = 0$$

$$(3-m)^2 - 1 = 0$$
$$(3-m)^2 = 1$$
$$3 - m = \pm 1$$
$$m = 3 \pm 1$$
$$m = 2, 4$$

Section C: Exam 1 (22 Marks)

Question 2 (3 marks)

y x

The sum of the ages of a man and his son is 30, and the product of their ages is 125.

a. Write down a quadratic equation in the form $ax^2 + bx + c = 0$ that can be solved to find the ages of the man and his son, where x is the age of the son. (1 mark)

$$\begin{cases} x+y = 30 \Rightarrow y = -x+30 \\ xy = 125 \end{cases}$$

$$x(-x+30) = 125$$

$$-x^2+30x = 125$$

$$0 = x^2 - 30x + 125$$

b. Find the ages of the man and his son. (2 marks)

$$0 = (x-5)(x-25)$$

$x = 5$, 25

$y = -5+30$ | $y = -25+30$

$y = 25$ | $y = 5$

$x = 5$, $y = 25$ | $x = 25$, $y = 5$

$\therefore$ Son is 5 yrs old and father is 25 yrs old

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Question 3 (6 marks)

Consider the function $f(x) = 2x^2 - 4x - 6$.

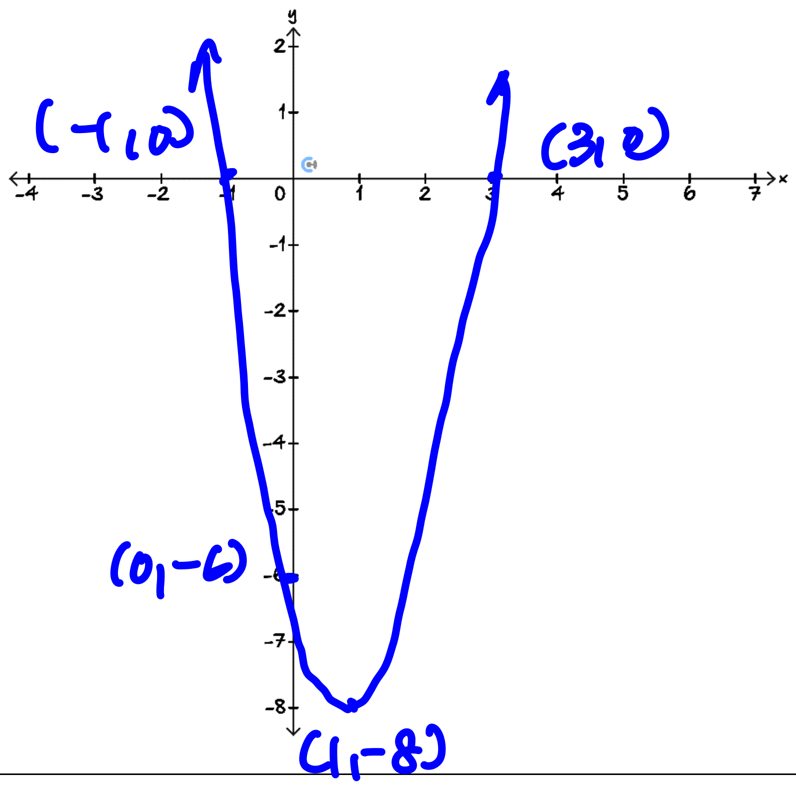
a. Solve the equation $f(x) = 0$. (1 mark)

$2x^2-4x-6=0$
$2(x^2-2x-3)=0$
$2(x-3)(x+1)=0$
$x=3,-1$

b. Write $f(x)$ in turning point form. (1 mark)

$f(x)=2x^2-4x-6$
$=2(x^2-2x-3)$
$=2((x-1)^2-(-1)^2-3)$
$=2((x-1)^2-4)$
$=2(x-1)^2-8$

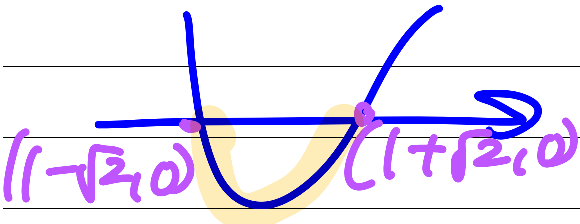
c. Sketch the graph of $y = f(x)$ on the axes below. Label the turning point and all axes intercepts with coordinates. (2 marks)



d. Find the value(s) of x such that $f(x) + 4 < 0$. (2 marks)

$2x^2 - 4x - 6 + 4 < 0$

$2x^2 - 4x - 2 < 0$



$2x^2 - 4x - 2 = 0$

$x^2 - 2x - 1 = 0$

$x = \frac{2 \pm \sqrt{4+4}}{2}$

$x = \frac{2 \pm 2\sqrt{2}}{2}$

$x = 1 \pm \sqrt{2}$

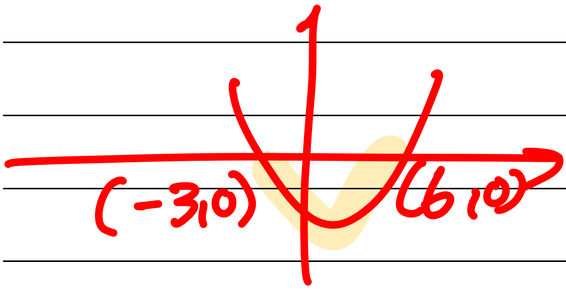
$1 - \sqrt{2} < x < 1 + \sqrt{2}$

Question 4 (2 marks)

Solve the inequality $-x^2 + 3x + 18 \geq 0$.

$x^2 - 3x - 18 \leq 0$

$(x+3)(x-6) \leq 0$



$-3 \leq x \leq 6$

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Question 5 (3 marks)

Solve the equation $2x^4 - 20x^2 + 18 = 0$, for real values of x.

$(x^2)^2$

Let $A = x^2$

$2A^2 - 20A + 18 = 0$

$2(A^2 - 10A + 9) = 0$

$2(A-9)(A-1) = 0$

$A = 1, 9$

$x^2 = 1, 9$

$x = \pm 1, \pm 3$

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Question 6 (4 marks)

Consider the function $f(x) = x^2 - 3kx + 6$, where k is a real number.

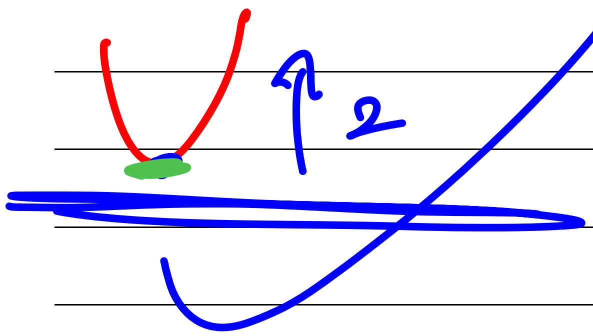
a. Find the turning point of $f(x)$ in terms of k. (2 marks)

$f(x) = \left(x - \frac{3k}{2}\right)^2 - \left(-\frac{3k}{2}\right)^2 + 6$

$= \left(x - \frac{3k}{2}\right)^2 - \frac{9k^2}{4} + 6$

$TP\left(\frac{3k}{2}, 6 - \frac{9k^2}{4}\right)$

b. Find all possible values of k if $f(x)$ is always greater than 2. (2 marks)



$6 - \frac{9k^2}{4} > 2$

$-\frac{9k^2}{4} > -4$

$\frac{9k^2}{4} < 4$

$9k^2 < 16$

$k^2 < \frac{16}{9}$

$k^2 - \frac{16}{9} < 0$

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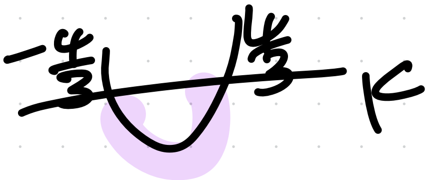
$k^2 - \left(\frac{4}{3}\right)^2 < 0$

$$\left(k-\frac{4}{3}\right)\left(k+\frac{4}{3}\right)<0$$



$$-\frac{4}{3}<k<\frac{4}{3}$$

Question 7 (4 marks)

Consider the function $f(x) = x^2 + 2kx - 4$, where k is a real number.

a. Show that the graph $y = f(x)$ always has two x-intercepts. (1 mark)

$\Delta = (2k)^2 - 4(1)(-4)$

$= 4k^2 + 16$

$k^2 \geq 0$

$4k^2 \geq 0$

$4k^2 + 16 > 0$

$\Delta > 0$

$\Rightarrow 2$ roots

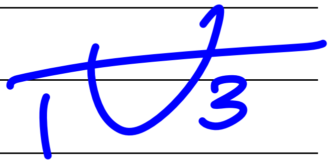
b. Find the values of k such that the distance between the two x-intercepts is less than 6. (3 marks)

$y = x^2 + 2kx - 4$

$x = \dfrac{-2k \pm \sqrt{4k^2+16}}{2}$

$= \dfrac{-2k \pm 2\sqrt{k^2+4}}{2}$

$= -k \pm \sqrt{k^2+4}$



$-k + \sqrt{k^2+4}$ $\quad$ $-k - \sqrt{k^2+4}$

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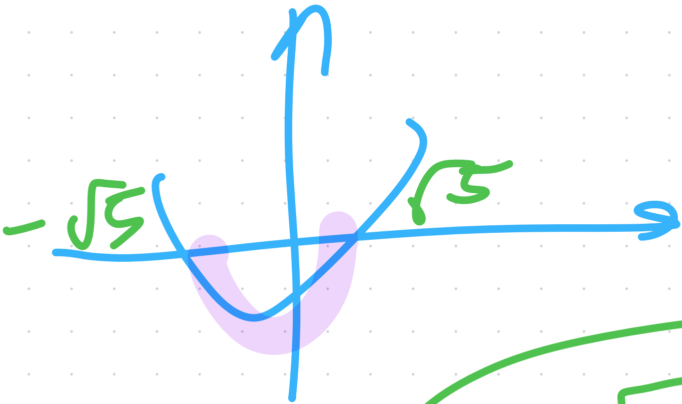
$(-k + \sqrt{k^2+4}) - (-k - \sqrt{k^2+4})$

$2\sqrt{k^2+4} < 6$

$\sqrt{k^2+4} < 3$

$k^2 + 4 < 9$

$$k^2-5<0$$



$$k^2-5=0$$

$$k=\pm\sqrt{5}$$

$$-\sqrt{5}<k<\sqrt{5}$$

Section D: Tech Active Exam Skills

Calculator Commands: Solving equations

- **Mathematica**
  - Solve[].

```
In[122]:= Solve[x^2 - 4 x - 9 == 0, x]
Out[122]= {{x → 2 - √13}, {x → 2 + √13}}
```

- **TI-Nspire**
  - Menu→ 3 → 1.

$\text{solve}\left(x^2-4\cdot x-9=0,x\right) \quad x=-\left(\sqrt{13}-2\right) \text{ or } x=\sqrt{13}+2$

- **Casio Classpad**
  - Action→Advanced→Solve.

$\text{solve}(x\text{^}2-4x-9=0,x)$

$\{x=-\sqrt{13}+2, x=\sqrt{13}+2\}$

Calculator Commands: Completing the Square

- **TI-Nspire**
  - Menu→ 3 → 5 completeSquare (func, var).

$\text{completeSquare}\left(x^2-6\cdot x+8,x\right) \quad (x-3)^2-1$

- **Mathematica**
  - No inbuilt function need udf.

Compsq

Compsq[a x² + b x + c, x]
Converts a standard form quadratic to turning point form.

Compsq[a, b, c]
Uses the coefficients of a quadratic to return the turning point form.

```
Compsq[1, 2, 3]
2 + (1 + x)^2
Compsq[2 x^2 + 3 x - 5, x]
Compsq[-5 + 3 x + 2 x^2, x]
```

- **Casio Classpad**
  - No function

conics

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Section E: Exam 2 (28 Marks)

Question 8 (1 mark)

Find the value(s) of k for which the quadratic equation below has exactly one unique real solution.

$$2x^2 - 3kx + 3k = 0$$

$\Delta = 0$

A. $k = \frac{8}{3}$

B. $k = 0, \frac{8}{3}$

C. $k > \frac{8}{3}$

D. $k = 0, 3$

solve$\left((-3\cdot k)^2 - 4\cdot 2\cdot 3\cdot k = 0, k\right)$ $\quad k=0$ or $k=\frac{8}{3}$

Question 9 (1 mark)

A quadratic function has a turning point at $(4, 3)$ and goes through the point $(6, 7)$. What is the equation of the function?

A. $2(x-4)^2 + 3$

B. $-(x-4)^2 + 3$

C. $(x-3)^2 + 4$

D. $(x-4)^2 + 3$

solve$\left(y = a(x-4)^2 + 3, a\right) | x=6$ and $y=7$ $\quad a=1$

$y = a(x-4)^2 + 3$

Question 10 (1 mark)

The function $f(x) = x^2 + mx + 2$ is always greater than -1. The possible values of m are:

A. $-\sqrt{3} < m < \sqrt{3}$

B. $-2\sqrt{2} < m < 2\sqrt{2}$

C. $-2\sqrt{3} < m < 2\sqrt{3}$

D. $-1 < m < 1$

completeSquare$\left(x^2 + m\cdot x + 2, x\right)$ $\quad \left(x + \frac{m}{2}\right)^2 - \frac{m^2}{4} + 2$

$m^2 < 12$

solve$\left(-\frac{m^2}{4} + 2 > -1\right)$

$-\frac{m^2}{4} > -3$

$-m^2 > -12$

Question 11 (1 mark)

If one root of the quadratic equation $\boxed{2x^2 + px - 35 = 0}$ is -7 the value of p is:

A. -9

B. 9

solve$\left(2\cdot x^2+p\cdot x-35=0,p\right)|x=-7$ $\quad$ $p=9$

C. -4

D. 4

Question 12 (1 mark)

The equation $ax^2 + 6x + c = 0$ has only one real solution if:

$\Delta = 0$

A. $ac > -9$

B. $2ac = 9$

$$6^2-4\cdot a\cdot c=0$$

C. $ac = -9$

D. $ac = 9$

$36 = 4ac$

$9 = ac$

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Question 13 (14 marks) ① define

Consider the quadratic function $f(x) = x^2 - 4x + 2$.

a.

i. Solve the equation $f(x) = 0$. (1 mark)

$\pm\sqrt{2}+2$

ii. State the distance between the x-axis intercepts. (1 mark)

$\sqrt{2}+2-(-\sqrt{2}+2) = 2\sqrt{2}$

iii. Find the turning point of the graph of $y = f(x)$. (1 mark)

com. sq.

$-\frac{b}{2a} \rightarrow f(\ )$

$(2, -2)$

iv. Hence write $f(x)$ in turning point form. (1 mark)

$f(x) = (x-2)^2 - 2$

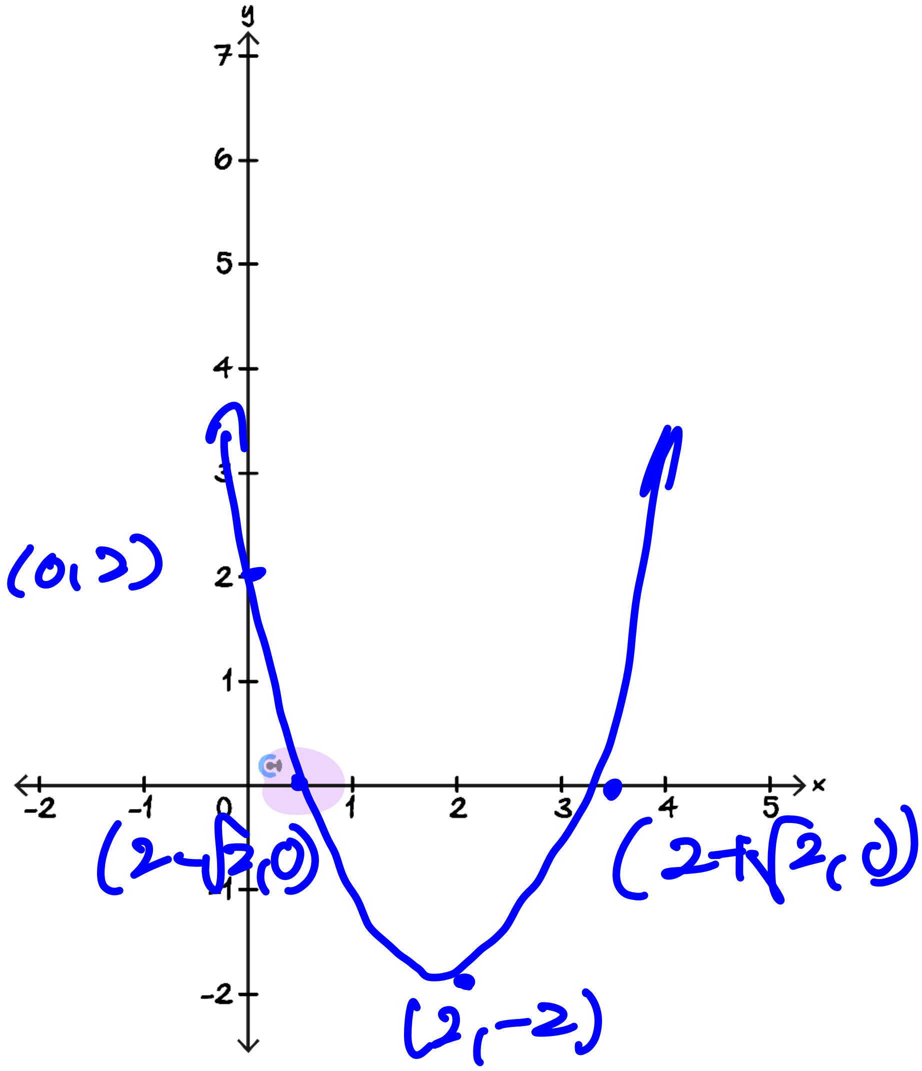
v. Find the y-intercept of the graph of $y = f(x)$. (1 mark)

$x=0$ $\quad f(0) = 2$ $\quad (0, 2)$

define

$f(x):=x^2-4\cdot x+2$	*Done*
$\text{solve}(f(x)=0,x)$	$x=-(\sqrt{2}-2)$ or $x=\sqrt{2}+2$
$-(\sqrt{2}-2)-(\sqrt{2}+2)$	$-2\cdot\sqrt{2}$
$\frac{--4}{2\cdot 1}$ $\quad -\frac{b}{2a}$	2
$f(2)$	-2
$f(0)$	2

b. Sketch the graph of $y = f(x)$ on the axes below. (2 marks)



c. If the graph of $y = f(x)$ is shifted k units to the left, find the values of k for which there is one negative x-axis intercept. (2 marks)

$2-\sqrt{2} < k < 2+\sqrt{2}$

d. The graph of $y = f(x)$ is translated 1 unit to the left and 4 units up and now has the equation:

$$y = a(x-h)^2 + k, \quad a, h, k \in \mathbb{R}$$

Determine the values of a, h, k. (2 marks)

$(2, -2) \to (1, 2)$

$y = 1(x-1)^2 + 2$

$a = 1 \quad h = 1 \quad k = 2$

e. Consider the graph of the function $g(x) = 4x^2 + kx + 2(k+1)$.

Find the value(s) of k for which $g(x)$ will have:

i. No real root. (1 mark)

$\Delta < 0$ CAS $16 - 12\sqrt{2} < k < 16 + 12\sqrt{2}$

ii. One real root. (1 mark)

$\Delta = 0$ CAS $k = 16 \pm 12\sqrt{2}$

iii. Two unique real roots. (1 mark)

$\Delta > 0$ $k < 16 - 12\sqrt{2}$

$k > 16 + 12\sqrt{2}$

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Question 14 (9 marks)

A cricket player hits a ball, and the ball's trajectory is modelled by the quadratic equation:

$$h(x) = ax^2 + bx + c,$$

(16,25)

(8,15)

where $h(x)$ is the height of the ball (in metres) above the ground, and x is the horizontal distance (in metres) from where the ball was hit.

(0,2)

The following conditions are given:

- The ball is hit from a height of 2 metres, i.e., $h(0) = 2$.
- The ball reaches a height of 15 metres when it has travelled 8 metres horizontally.
- The ball reaches a height of 25 metres when it has travelled 16 metres horizontally.

a. Using the given conditions, set up and solve a system of equations to determine the values of a, b, and c. (3 marks)

(0,2) $2 = a \times 0 + b \times 0 + c$

(8,15) $15 = 64a + 8b + c$

(16,25) $25 = 256a + 16b + c$

$\boxed{\text{CAS}}$ menu 3 ~~7~~ 1

~~x and~~

Define $h(x)=a\cdot x^2+b\cdot x+c$ Done

$\text{solve}\left(\begin{cases} h(0)=2 \\ h(8)=15 \\ h(16)=25 \end{cases}, \{a,b,c\}\right)$ $a=\frac{-3}{128}$ and $b=\frac{29}{16}$ and $c=2$

b. Determine the maximum height that the ball reaches. Give your answer correct to 2 decimal places. (1 mark)

Define $h(x)=a\cdot x^2+b\cdot x+c \mid a=\frac{-3}{128}$ and $b=\frac{29}{16}$ and $c=2$ Done

$h(x)$ $\frac{-3\cdot x^2}{128}+\frac{29\cdot x}{16}+2$

$\text{completeSquare}\left(\frac{-3\cdot x^2}{128}+\frac{29\cdot x}{16}+2,x\right)$ $\frac{889}{24}-\frac{3\cdot\left(x-\frac{116}{3}\right)^2}{128}$

$\text{completeSquare}\left(\frac{-3\cdot x^2}{128}+\frac{29\cdot x}{16}+2,x\right)$ $37.0417-0.023438\cdot(x-38.6667)^2$

OR TP

$-\frac{b}{2a} \rightarrow$ sub in

comp. sq

$\frac{889}{24} = 37.04$

c. Determine the horizontal distance the ball has travelled when its height is 20 metres. Provide both possible horizontal distance correct to two decimal places. (2 marks)

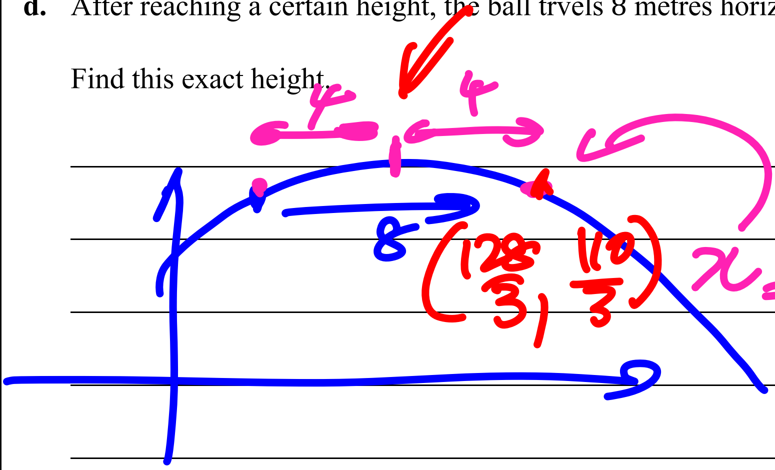
$h(x) = 20$

solve$(h(x)=20,x)$ $x=11.7017$ or $x=65.6317$

$\left(\frac{116}{3}, \frac{889}{24}\right)$

d. After reaching a certain height, the ball trvels 8 metres horizontally to drop down to that height again.

Find this exact height.



$x = \frac{116}{3} + 4 = \frac{128}{3}$

$h\left(\frac{128}{3}\right) = \frac{110}{3}$ m

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Section F: Extension Exam 1 (16 Marks)

Question 15 (4 marks)

The parabola $y = ax^2 + bx + c$ passes through the points $\left(1, -\frac{1}{2}\right)$, $(4, -5)$, and $(6, -3)$.

Determine the values of real numbers a, b, and c.

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Question 16 (4 marks)

Let $f(x) = 2x^2 - 4x + 5$.

a. Find the turning point of the parabola $y = f(x)$. (1 mark)

b. Reflect this turning point in the line $x = 3$ and then in the line $y = 2$. (1 mark)

c. The parabola $y = f(x)$ is reflected in the line $x = 3$ and then reflected in the line $y = 2$. Find the equation of the resulting parabola in the form $y = ax^2 + bx + c$, where $a, b,$ and c are real numbers. (2 marks)

Space for Personal Notes

Question 17 (4 marks)

Solve $(x^2+1)^2+4 \geq 8x^2$ for all real x.

Space for Personal Notes

Question 18 (4 marks)

Let $f(x) = x^4 - 4kx^2 + 4 - k^2$, where k is a real constant.

Find the values of k for which the equation $f(x) = 0$ has no real solutions.

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Section G: Extension Exam 2 (16 Marks)

Question 19 (1 mark)

If $px^2 + 5x + q = 0$ has two roots $x = -2$ and $x = 1$, the value of $p - q$ is:

A. -5

B. 5

C. 10

D. 15

Question 20 (1 mark)

The equation of the parabola that passes through the points $(1, 2)$, $(3, 2)$ and $(4, 5)$ is:

A. $y = x^2 - 4x - 5$

B. $y = (x - 2)^2 + 1$

C. $y = x^2 + 4x + 5$

D. $y = (x - 1)^2 + 2$

Question 21 (1 mark)

Consider the graph of $y = x^2 - 2kx - 2$ where k is a real constant.

The values of k for which the distance between the two x-intercepts is less than 6 are:

A. $-\sqrt{5} < k < \sqrt{5}$

B. $-\sqrt{6} < k < \sqrt{6}$

C. $-\sqrt{7} < k < \sqrt{7}$

D. $-\sqrt{11} < k < \sqrt{11}$

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Question 22 (1 mark)

Let $y = 2x^2 - 4x - 2$.

If $-2 < x < 3$, the possible values of y are:

A. $-4 < y \leq 14$

B. $-4 \leq y < 14$

C. $4 < y < 14$

D. $-4 < y < 14$

Question 23 (1 mark)

Find all values of k, such that $x^2 + kx + k^2 - 4$ has two real roots for x, where one is positive and one is negative.

A. $k < 2$

B. $k > -2$

C. $-2 < k < 2$

D. $-2 \leq k \leq 2$

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Question 24 (11 marks)

Consider the function $f(x) = x^2 + (k-2)x + \frac{k^2-4k-4}{2}$, where k is a real constant.

a.

i. Find all values of k such that $f(x) = 0$ has one real root.. (1 mark)

ii. Find all values of k such that $f(x) = 0$ has two real roots. (1 mark)

iii. Find all values of k such that $f(x) = 0$ has two real roots, where one is positive and the other is negative. (2 marks)

b. Find all values of k for which the graph of $y = f(x)$ and the graph $y = kx + 2$ do not intersect. (2 marks)

c. Find all values of k such that $f(x) > 2$ for all real x. (2 marks)

d. Find all values of k such that the graph of $y = f(x)$ has two x-intercepts that have a distance between them that is less than 2. (3 marks)

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