BOARD OF STUDIES
NEW SOUTH WALES

**2013**

**HIGHER SCHOOL CERTIFICATE EXAMINATION**

# Mathematics Extension 1

**General Instructions**

- Reading time – 5 minutes
- Working time – 2 hours
- Write using black or blue pen
  Black pen is preferred
- Board-approved calculators may be used
- A table of standard integrals is provided at the back of this paper
- In Questions 11–14, show relevant mathematical reasoning and/or calculations

**Total marks – 70**

**Section I** Pages 2–7

**10 marks**

- Attempt Questions 1–10
- Allow about 15 minutes for this section

**Section II** Pages 8–15

**60 marks**

- Attempt Questions 11–14
- Allow about 1 hour and 45 minutes for this section

## Section I

**10 marks**
**Attempt Questions 1–10**
**Allow about 15 minutes for this section**

Use the multiple-choice answer sheet for Questions 1–10.

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**1** The polynomial $P(x) = x^3 - 4x^2 - 6x + k$ has a factor $x - 2$.

What is the value of $k$?

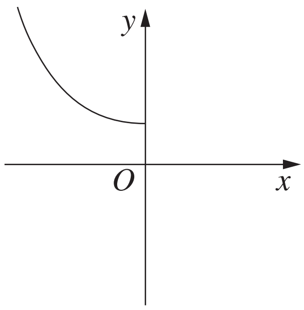
(A) 2

(B) 12

(C) 20

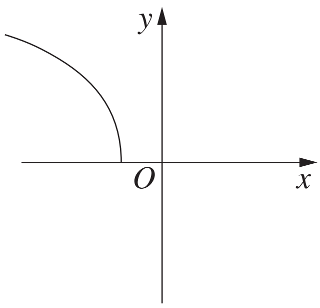
(D) 36

**2** The diagram shows the graph $y = f(x)$.

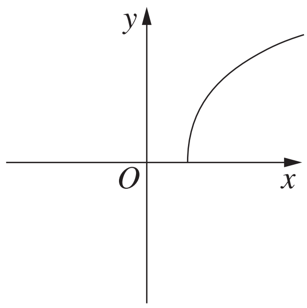



Which diagram shows the graph $y = f^{-1}(x)$?

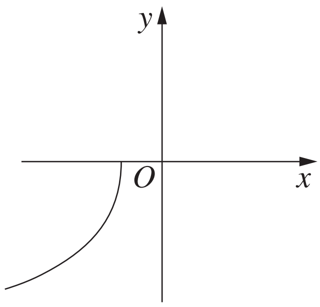
(A)



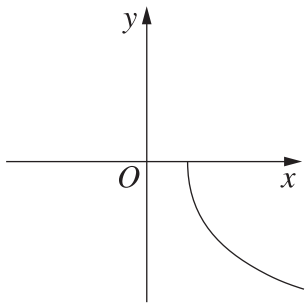

(B)




(C)

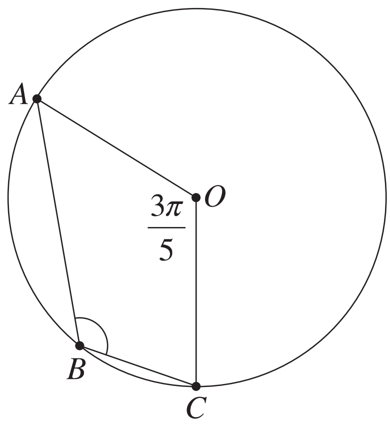



(D)



**3** The points $A$, $B$ and $C$ lie on a circle with centre $O$, as shown in the diagram.

The size of $\angle AOC$ is $\dfrac{3\pi}{5}$ radians.




NOT TO SCALE

What is the size of $\angle ABC$ in radians?

(A) $\dfrac{3\pi}{10}$

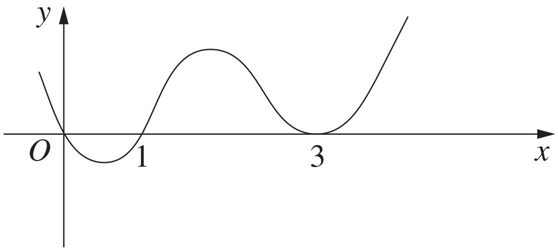
(B) $\dfrac{2\pi}{5}$

(C) $\dfrac{7\pi}{10}$

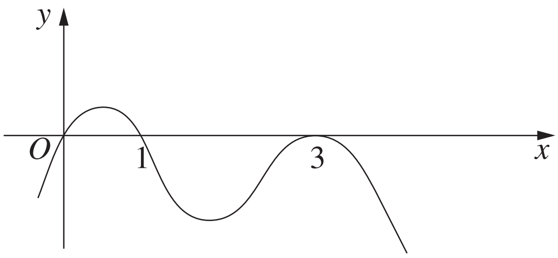
(D) $\dfrac{4\pi}{5}$

**4** Which diagram best represents the graph $y = x\,(1 - x)^3\,(3 - x)^2$?

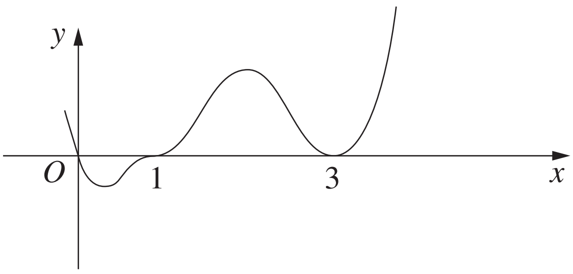
(A)



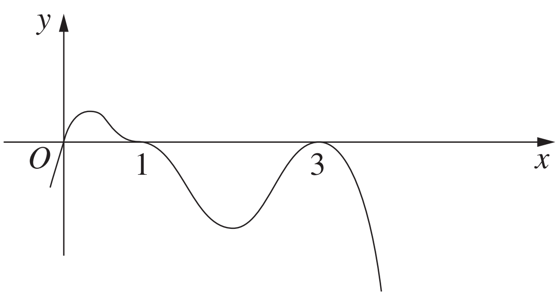

(B)




(C)




(D)



**5** Which integral is obtained when the substitution $u = 1 + 2x$ is applied to $\int x\sqrt{1+2x}\,dx$?

(A) $\frac{1}{4}\int (u-1)\sqrt{u}\,du$

(B) $\frac{1}{2}\int (u-1)\sqrt{u}\,du$

(C) $\int (u-1)\sqrt{u}\,du$

(D) $2\int (u-1)\sqrt{u}\,du$

**6** Let $|a| \leq 1$. What is the general solution of $\sin 2x = a$?

(A) $x = n\pi + (-1)^n \frac{\sin^{-1} a}{2}$, $n$ is an integer

(B) $x = \frac{n\pi + (-1)^n \sin^{-1} a}{2}$, $n$ is an integer

(C) $x = 2n\pi \pm \frac{\sin^{-1} a}{2}$, $n$ is an integer

(D) $x = \frac{2n\pi \pm \sin^{-1} a}{2}$, $n$ is an integer

**7** A family of eight is seated randomly around a circular table.

What is the probability that the two youngest members of the family sit together?

(A) $\dfrac{6!2!}{7!}$

(B) $\dfrac{6!}{7!2!}$

(C) $\dfrac{6!2!}{8!}$

(D) $\dfrac{6!}{8!2!}$

**8** The angle $\theta$ satisfies $\sin\theta = \dfrac{5}{13}$ and $\dfrac{\pi}{2} < \theta < \pi$.

What is the value of $\sin 2\theta$?

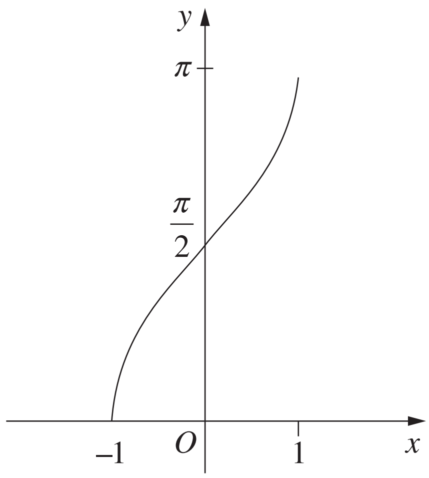
(A) $\dfrac{10}{13}$

(B) $-\dfrac{10}{13}$

(C) $\dfrac{120}{169}$

(D) $-\dfrac{120}{169}$

**9** The diagram shows the graph of a function.




Which function does the graph represent?

(A) $y = \cos^{-1} x$

(B) $y = \dfrac{\pi}{2} + \sin^{-1} x$

(C) $y = -\cos^{-1} x$

(D) $y = -\dfrac{\pi}{2} - \sin^{-1} x$

**10** Which inequality has the same solution as $|x+2| + |x-3| = 5$?

(A) $\dfrac{5}{3-x} \geq 1$

(B) $\dfrac{1}{x-3} - \dfrac{1}{x+2} \leq 0$

(C) $x^2 - x - 6 \leq 0$

(D) $|2x-1| \geq 5$

## Section II

**60 marks**
**Attempt Questions 11–14**
**Allow about 1 hour and 45 minutes for this section**

Answer each question in a SEPARATE writing booklet. Extra writing booklets are available.

In Questions 11–14, your responses should include relevant mathematical reasoning and/or calculations.

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**Question 11** (15 marks) Use a SEPARATE writing booklet.

(a) The polynomial equation $2x^3 - 3x^2 - 11x + 7 = 0$ has roots $\alpha$, $\beta$ and $\gamma$. **1**

Find $\alpha\beta\gamma$.

(b) Find $\displaystyle\int \frac{1}{\sqrt{49 - 4x^2}}\,dx$ . **2**

(c) An examination has 10 multiple-choice questions, each with 4 options. In each question, only one option is correct. For each question a student chooses one option at random. **2**

Write an expression for the probability that the student chooses the correct option for exactly 7 questions.

(d) Consider the function $f(x) = \dfrac{x}{4 - x^2}$.

(i) Show that $f'(x) > 0$ for all $x$ in the domain of $f(x)$. **2**

(ii) Sketch the graph $y = f(x)$, showing all asymptotes. **2**

**Question 11 continues on page 9**

(e) Find $\lim_{x \to 0} \frac{\sin \frac{x}{2}}{3x}$. **1**

(f) Use the substitution $u = e^{3x}$ to evaluate $\int_0^{\frac{1}{3}} \frac{e^{3x}}{e^{6x}+1}\, dx$. **3**

(g) Differentiate $x^2 \sin^{-1} 5x$. **2**

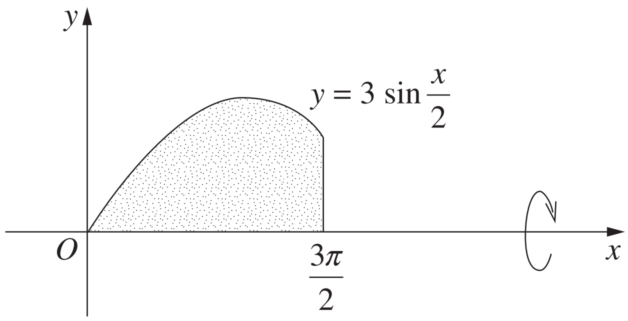
**End of Question 11**

**Question 12** (15 marks) Use a SEPARATE writing booklet.

(a) (i) Write $\sqrt{3}\cos x - \sin x$ in the form $2\cos(x + \alpha)$, where $0 < \alpha < \dfrac{\pi}{2}$. **1**

(ii) Hence, or otherwise, solve $\sqrt{3}\cos x = 1 + \sin x$, where $0 < x < 2\pi$. **2**

(b) The region bounded by the graph $y = 3\sin\dfrac{x}{2}$ and the $x$-axis between $x = 0$ and $x = \dfrac{3\pi}{2}$ is rotated about the $x$-axis to form a solid. **3**




Find the exact volume of the solid.

(c) A cup of coffee with an initial temperature of 80°C is placed in a room with a constant temperature of 22°C. **3**

The temperature, $T$°C, of the coffee after $t$ minutes is given by

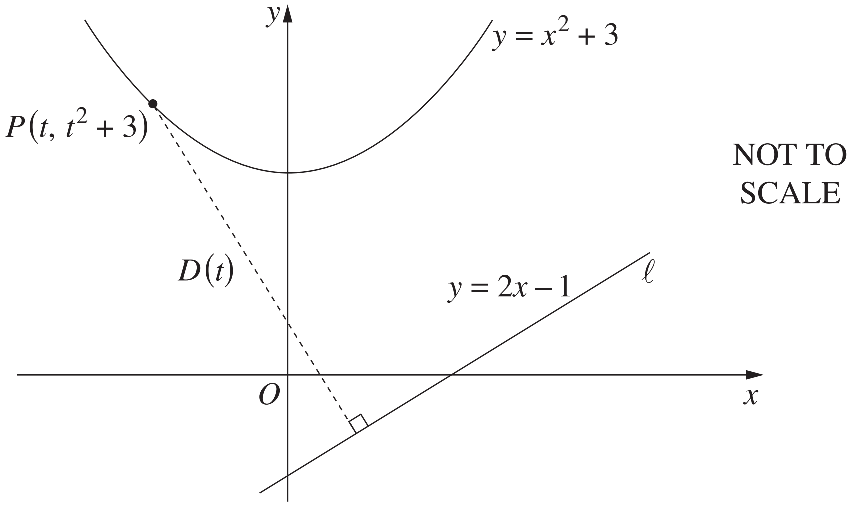
$$T = A + Be^{-kt},$$

where $A$, $B$ and $k$ are positive constants. The temperature of the coffee drops to 60°C after 10 minutes.

How long does it take for the temperature of the coffee to drop to 40°C? Give your answer to the nearest minute.

**Question 12 continues on page 11**

(d) The point $P(t,\ t^2+3)$ lies on the curve $y = x^2 + 3$. The line $\ell$ has equation $y = 2x - 1$. The perpendicular distance from $P$ to the line $\ell$ is $D(t)$.




(i) Show that $D(t) = \dfrac{t^2 - 2t + 4}{\sqrt{5}}$. **2**

(ii) Find the value of $t$ when $P$ is closest to $\ell$. **1**

(iii) Show that, when $P$ is closest to $\ell$, the tangent to the curve at $P$ is parallel to $\ell$. **1**

(e) A particle moves along a straight line. The displacement of the particle from the origin is $x$, and its velocity is $v$. The particle is moving so that $v^2 + 9x^2 = k$, where $k$ is a constant. **2**

Show that the particle moves in simple harmonic motion with period $\dfrac{2\pi}{3}$.

**End of Question 12**

**Question 13** (15 marks) Use a SEPARATE writing booklet.

(a) A spherical raindrop of radius $r$ metres loses water through evaporation at a rate that depends on its surface area. The rate of change of the volume $V$ of the raindrop is given by

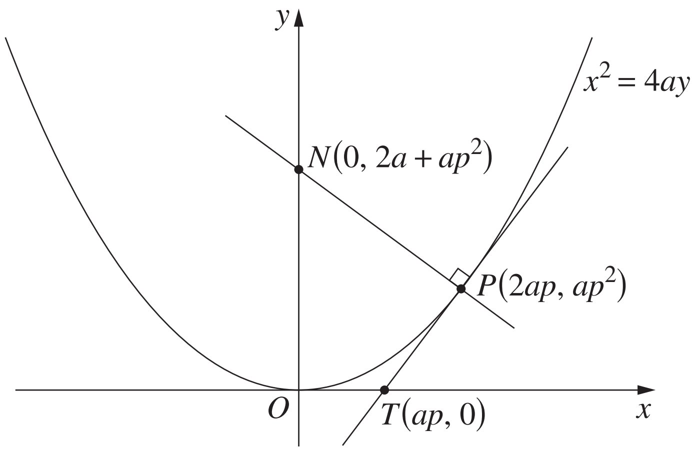
$$\frac{dV}{dt} = -10^{-4}A,$$

where $t$ is time in seconds and $A$ is the surface area of the raindrop. The surface area and the volume of the raindrop are given by $A = 4\pi r^2$ and $V = \frac{4}{3}\pi r^3$ respectively.

(i) Show that $\frac{dr}{dt}$ is constant. **1**

(ii) How long does it take for a raindrop of volume $10^{-6}$ m$^3$ to completely evaporate? **2**

(b) The point $P(2ap, ap^2)$ lies on the parabola $x^2 = 4ay$. The tangent to the parabola at $P$ meets the $x$-axis at $T(ap, 0)$. The normal to the tangent at $P$ meets the $y$-axis at $N(0, 2a + ap^2)$.




The point $G$ divides $NT$ externally in the ratio $2:1$.

(i) Show that the coordinates of $G$ are $(2ap, -2a - ap^2)$. **2**

(ii) Show that $G$ lies on a parabola with the same directrix and focal length as the original parabola. **2**

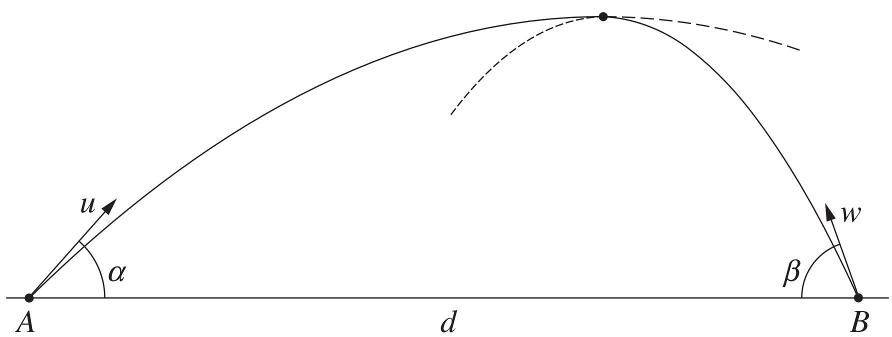
**Question 13 continues on page 13**

Question 13 (continued)

(c) Points $A$ and $B$ are located $d$ metres apart on a horizontal plane. A projectile is fired from $A$ towards $B$ with initial velocity $u$ m s$^{-1}$ at angle $\alpha$ to the horizontal.

At the same time, another projectile is fired from $B$ towards $A$ with initial velocity $w$ m s$^{-1}$ at angle $\beta$ to the horizontal, as shown on the diagram.

The projectiles collide when they both reach their maximum height.




The equations of motion of a projectile fired from the origin with initial velocity $V$ m s$^{-1}$ at angle $\theta$ to the horizontal are

$$x = Vt\cos\theta \quad \text{and} \quad y = Vt\sin\theta - \frac{g}{2}t^2. \qquad \text{(Do NOT prove this.)}$$

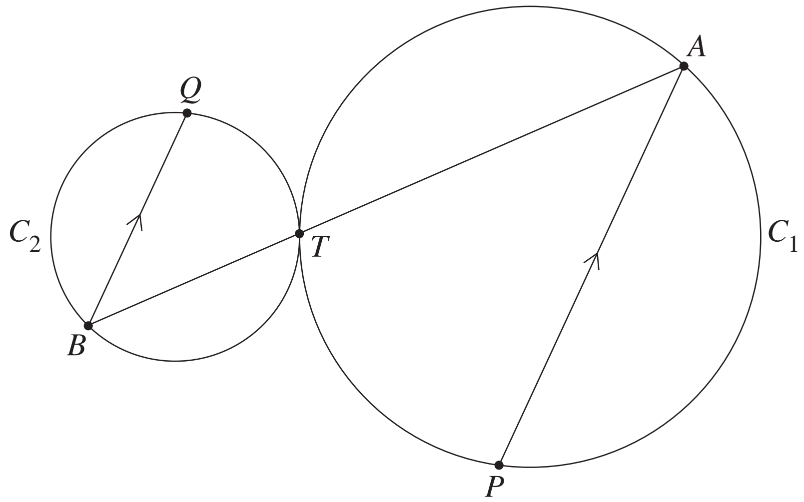
(i) How long does the projectile fired from $A$ take to reach its maximum height? **2**

(ii) Show that $u\sin\alpha = w\sin\beta$. **1**

(iii) Show that $d = \dfrac{uw}{g}\sin(\alpha + \beta)$. **2**

**Question 13 continues on page 14**

(d) The circles $C_1$ and $C_2$ touch at the point $T$. The points $A$ and $P$ are on $C_1$. The line $AT$ intersects $C_2$ at $B$. The point $Q$ on $C_2$ is chosen so that $BQ$ is parallel to $PA$. **3**




Copy or trace the diagram into your writing booklet.

Prove that the points $Q$, $T$ and $P$ are collinear.

**End of Question 13**

**Question 14** (15 marks) Use a SEPARATE writing booklet.

(a) (i) Show that for $k > 0$, $\dfrac{1}{(k+1)^2} - \dfrac{1}{k} + \dfrac{1}{k+1} < 0$. **1**

(ii) Use mathematical induction to prove that for all integers $n \geq 2$, **3**

$$\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \cdots + \frac{1}{n^2} < 2 - \frac{1}{n}.$$

(b) (i) Write down the coefficient of $x^{2n}$ in the binomial expansion of $(1+x)^{4n}$. **1**

(ii) Show that $\left(1 + x^2 + 2x\right)^{2n} = \displaystyle\sum_{k=0}^{2n} \binom{2n}{k} x^{2n-k}(x+2)^{2n-k}$. **2**

(iii) It is known that **3**

$$x^{2n-k}(x+2)^{2n-k} = \binom{2n-k}{0} 2^{2n-k}\, x^{2n-k} + \binom{2n-k}{1} 2^{2n-k-1}\, x^{2n-k+1} + \cdots + \binom{2n-k}{2n-k} 2^0\, x^{4n-2k}.$$

(Do NOT prove this.)

Show that

$$\binom{4n}{2n} = \sum_{k=0}^{n} 2^{2n-2k} \binom{2n}{k}\binom{2n-k}{k}.$$

(c) The equation $e^t = \dfrac{1}{t}$ has an approximate solution $t_0 = 0.5$.

(i) Use one application of Newton's method to show that $t_1 = 0.56$ is another approximate solution of $e^t = \dfrac{1}{t}$. **2**

(ii) Hence, or otherwise, find an approximation to the value of $r$ for which the graphs $y = e^{rx}$ and $y = \log_e x$ have a common tangent at their point of intersection. **3**

**End of paper**