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MATHEMATICS (H1) — 8864/01

Paper 1 Suggested Solutions — October/November 2010

1. **Topic: Equations & Inequalities (Quadratic Roots)**

$4x^2 - 2kx + 9 = 0$

For two real distinct roots to exist, discriminant $b^2 - 4ac > 0$:

$(-2k)^2 - 4(4)(9) > 0$

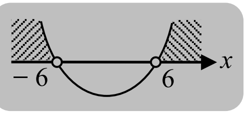
$4k^2 - (12)^2 > 0$

$(2k-12)(2k+12) > 0$

$2k+12 < 0$ or $2k-12 > 0$

$k < -6$ or $k > 6$

> For two real and *distinct* roots, discriminant > 0 (no equal sign)
> $a = 4$, $b = -2k$, c = 9



∴ **The set of values of k for the equation to havetwo real and distinct roots is $\{k \in \mathbb{R}: k<-6 \text{ or } k>6\}$**

> Note: Final answer expressed in set notation as question asks for <u>set</u> of values of k.

2. **Topic: Integration**

(i) $\int e^{1-2x}\,dx = -\frac{1}{2}e^{1-2x} + c$

> $\int e^{ax+b} = \frac{1}{a}e^{ax+b} + c$

(ii) $\int \frac{2}{(x+1)^3}\,dx = 2\int (x+1)^{-3}\,dx$

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

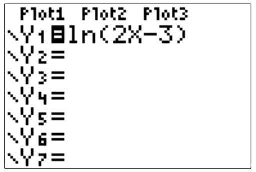
$= -\frac{1}{(x+1)^2} + c$

> $\int (ax+b)^n dx = \frac{(ax+b)^{n+1}}{a(n+1)} + c$

3. **Topic: Graphs**

(i) $y = \ln(2x-3) \Rightarrow$ Equation of asymptote: $2x - 3 = 0 \Rightarrow x = \frac{3}{2}$

Using G. C. (refer to Appendix for detailed steps),



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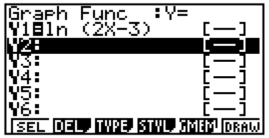

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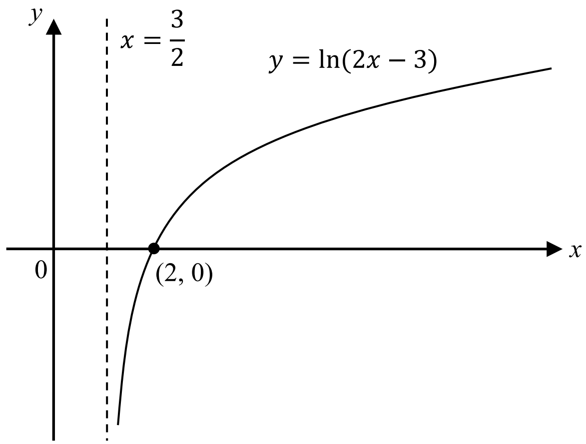
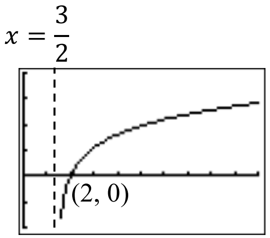




(ii) $y = \ln(2x-3)$

$\frac{dy}{dx} = \frac{2}{2x-3}$

> $\frac{d}{dx}\ln(ax+b) = \frac{a}{ax+b}$

(iii) When $x = 3$,

$$y = \ln[2(3)-3] = \ln 3$$

Gradient of tangent, $m_T = \frac{2}{2(3)-3} = \frac{2}{3}$

$\Rightarrow$Gradient of normal, $m_N = -\frac{1}{m_T} = -\frac{3}{2}$

> Sub $x = 3$ into $\frac{dy}{dx}$ obtained in (ii).

$\therefore$ Equation of normal:

$$y - \ln 3 = -\frac{3}{2}(x-3)$$
$$2y - 2\ln 3 = -3x + 9$$
$$\mathbf{3x + 2y = 9 + 2\ln 3}$$

> Equation of straight line with gradient m passing through (x_1, y_1): $y - y_1 = m(x - x_1)$

4. **Topic: Differentiation (Maxima & Minima)**

(i) Given $AB = 2x$ m

$\Rightarrow AE = \frac{5}{8}AB = \frac{5}{4}x$ m

Since $ABCD$ is a rectangle,

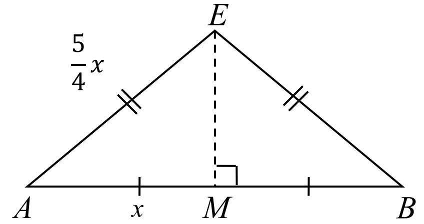
$\Rightarrow AD = BC$

$\Rightarrow DC = AB = 2x$

Given total perimeter $AEBCDA = 6$ m

$$AE + EB + BC + CD + AD = 6$$
$$\frac{5}{4}x + \frac{5}{4}x + 2AD + 2x = 6$$
$$2\,AD = 6 - \frac{9}{2}x$$
$$\mathbf{AD = \left(3 - \frac{9}{4}x\right)\ m\ (shown)}$$

(ii) Since ΔAEB is isosceles,



$$AM = MB = x\ (EM \perp AB)$$
$$EM = \sqrt{\left(\frac{5}{4}x\right)^2 - x^2} = \frac{3}{4}x$$

> By Pythagoras' theorem

$\therefore$ Area of the window, A = Area of ΔAEB + Area of rectangle $ABCD$

$$= \frac{1}{2}(2x)\left(\frac{3}{4}x\right) + (2x)\left(3 - \frac{9}{4}x\right)$$
$$= \frac{3}{4}x^2 + 6x - \frac{9}{2}x^2$$
$$= \left(6x - \frac{15}{4}x^2\right)\ \mathbf{m^2 (shown)}$$

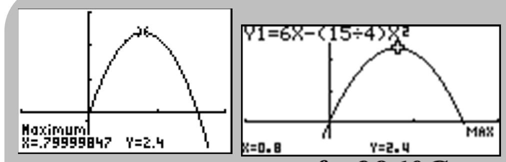
> Length of AD shown in part (i)

(iii) A is maximum when $\frac{dA}{dx} = 0$ i.e.

$$\frac{dA}{dx} = 6 - \frac{15}{2}x = 0$$
$$x = \frac{4}{5}\ \text{m}$$

By 2[nd] derivative test, $\frac{d^2A}{dx^2} = -\frac{15}{2} < 0 \Rightarrow A$ is maximum when $x = \frac{4}{5}$.

$$\therefore A_{max} = 6\left(\frac{4}{5}\right) - \frac{15}{4}\left(\frac{4}{5}\right)^2$$
$$= \mathbf{\frac{12}{5}\ m^2}$$



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Check final answer with G. C. (time permitting)

> Second Derivative Test:

Sign of $\frac{d^2y}{dx^2}$	Nature of stationary point
–	Maximum
+	Minimum
0	Point of inflexion

5. **Topic : Applications of Differentiation & Integration**

(i) Given $y = 6 - 4x^3 - 3x^4$

$$\frac{dy}{dx} = -12x^2 - 12x^3 = -12x^2(1+x)$$

At stationary points, $\frac{dy}{dx} = 0$

$-12x^2(1+x) = 0$

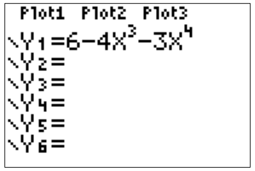
$x = 0$ or $x = -1$

$y = 6$ or $y = 6 - 4(-1)^3 - 3(-1)^4 = 7$

$\therefore$ Stationary points of curve C are **(0, 6) and (−1, 7)**

Final answer should be given in coordinates.

(ii) Using G. C. (refer to Appendix for detailed steps),



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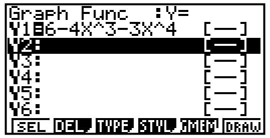

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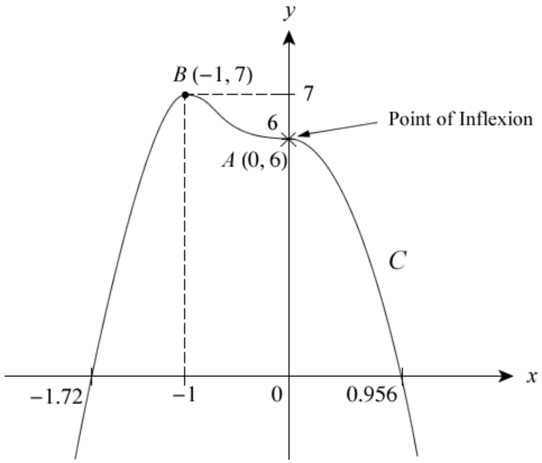
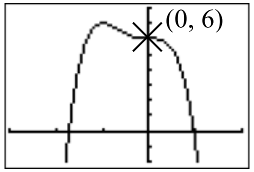
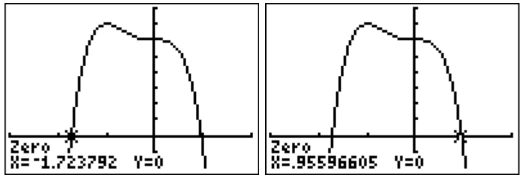




(iii) Using G. C. (refer to Appendix for detailed steps),



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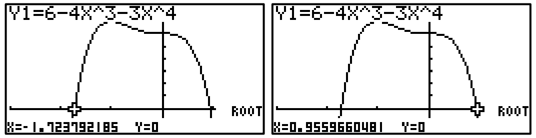

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$\therefore$ ***x*-coordinates are −1.72 (2d.p.) and 0.96 (2d.p.)**

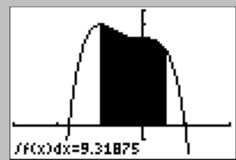
(iv) $\int (6 - 4x^3 - 3x^4)\,dx = \mathbf{6x - x^4 - \frac{3}{5}x^5 + c}$

$$\therefore \text{Area} = \int_{-1}^{\frac{1}{2}} (6 - 4x^3 - 3x^4)\,dx$$

$$= \left[6x - x^4 - \frac{3}{5}x^5\right]_{-1}^{\frac{1}{2}}$$

$$= \left[6\left(\frac{1}{2}\right) - \left(\frac{1}{2}\right)^4 - \frac{3}{5}\left(\frac{1}{2}\right)^5\right] - \left[6(-1) - (-1)^4 - \frac{3}{5}(-1)^5\right]$$

$$= \mathbf{9\frac{51}{160}}\ \textbf{units}^2$$



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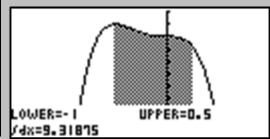

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Check final answer with G. C. (time permitting)

6. **Topic: Probability (Venn Diagram)**

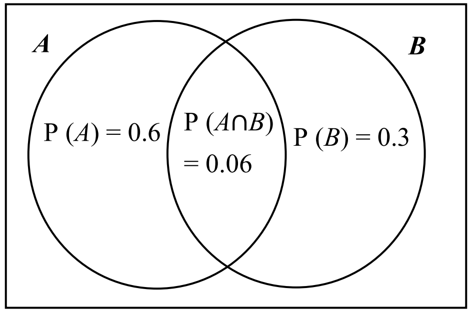
(i) P(both A and B occur) $= P(A \cap B)$
$= P(A|B)P(B)$
$= 0.2 \times 0.3$
$= \mathbf{0.06}$

$P(A|B) = \frac{P(A \cap B)}{P(B)}$

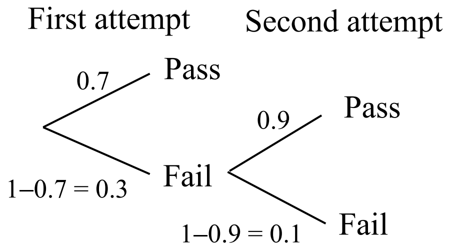
(ii) P(at least one of A and B occurs) $= P(A \cup B)$
$= P(A) + P(B) - P(A \cap B)$
$= 0.6 + 0.3 - 0.06$
$= \mathbf{0.84}$

(iii) P (exactly one of A and B occurs) $= P(A \cup B) - P(A \cap B)$
$= 0.84 - 0.06$
$= \mathbf{0.78}$

Venn Diagram (for illustration):



7. **Topic: Probability (Probability Tree)**



(i) P (fails at both attempt) $= 0.3 \times 0.1$
$= \mathbf{0.03}$

(ii) P(passes the examination) $= 1 - 0.03 = 0.97$

$= 0.7 + 0.3 \times 0.9$ from tree diagram

P (pass at 2nd attempt) = P(fail on 1st attempt AND pass at 2nd attempt)
$= 0.3 \times 0.9 = 0.27$

P (pass at second attempt | passes the exam)

$P(A|B) = \frac{P(A \cap B)}{P(B)}$

$= \frac{\text{P(pass at 2nd attempt} \cap \text{passes the exam)}}{\text{P(passes the exam)}}$

$= \frac{\text{P(pass at 2nd attempt)}}{\text{P(passes the exam)}}$

Pass at 2nd attempt $\subseteq$ passes the exam

$= \frac{0.27}{0.97}$

$= \mathbf{\frac{27}{97}}$

(iii) P (two pass at the 1st attempt and the other passes at 2ndattempt)
$= (0.7 \times 0.7) \times 0.27 \times 3$ cases
$= 0.3969$
$\approx$ **0.397 (3 sig. fig.)**

3 Possibilities:
Case 1: 1st& 2nd students pass at 1stattempt
Case 2: 2nd& 3rd students pass at 1st attempt
Case 3: 3rd& 1st students pass at 1st attempt

8. **Topic: Sampling and Hypothesis Testing**

(i) **To obtain a stratified sample of 60 students, we divide the population into the following strata: Year One students, Year Two students and Year Three students.**

We then pick <u>random samples</u> of the following sizes within each stratum:

$\frac{1400}{3000} \times 60 = $ **28 Year One students**

$\frac{900}{3000} \times 60 = $ **18 Year Two students**

$\frac{700}{3000} \times 60 = $ **14 Year Three students**

> **Year One:** $\frac{1400}{3000}$ **of population**
> **Year Two:** $\frac{900}{3000}$ **of population**
> **Year Three:** $\frac{700}{3000}$ **of population**

(ii) **Stratified sampling provides a more <u>accurate representation</u> of the large and varied student population, since the amount spent may vary according to year. As such, stratified sampling allows data for each year to be examined separately whereas this cannot be achieved with simple random sampling.**

(iii) Given $\Sigma x = 10450$, $\Sigma x^2 = 2\ 235\ 000$, $n = 50$.

Unbiased estimate of μ $= \frac{\Sigma x}{50} = \frac{10450}{50} = \mathbf{209}$

> Unbiased estimate of population mean, $\hat{\mu} = \frac{\sum x}{n}$

Unbiased estimate of σ^2 $= \frac{1}{n-1}\left[\Sigma x^2 - \frac{(\sum x)^2}{n}\right]$

$= \frac{1}{50-1}\left[2235000 - \frac{(10450)^2}{50}\right]$

$= \mathbf{1039\frac{39}{49}}$

> Unbiased variance estimate formula <u>from MF15</u>.

(iv) 1. **By the Central Limit Theorem, we assume that the amount of money spent by a student, X, is normally distributed, since the sample size is sufficiently large ($n \geq 50$).**

2. **Since σ^2 is not given, we assume that the value of the unbiased estimate of σ^2 computed in (iii) is sufficiently close to the actual population variance.**

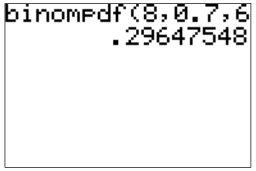
9. **Topic: Binomial Distribution & Its Normal Approximation**

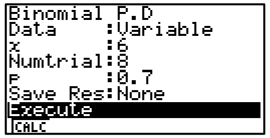
(i) Let X be the random variable for the number of germinating sunflower seeds out of 8 sown, where

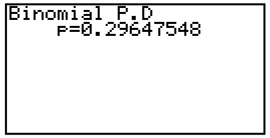
$X \sim B(8, 0.7)$

> <u>Binomial Distribution</u>:
> $X \sim B(n, p)$ where n = no. of trials = 8
> p = probability of success = 0.7 (given)

Using G. C. (refer to Appendix for detailed steps),







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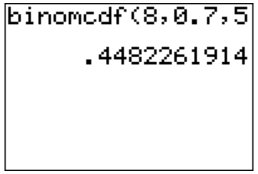
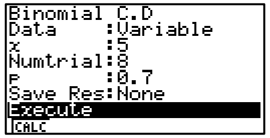
P ($X = 6$) = 0.29647 ≈ **0.296 (3 sig.fig)**

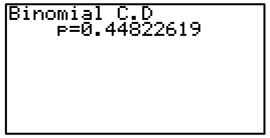
> G. C.'s binomial probability (PD) function is used.

(ii) P ($X \geq 6$) = 1 − P ($X \leq 5$)

Using G. C. to calculate P ($X \leq 5$) (refer to Appendix for detailed steps),







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∴ P ($X \geq 6$) = 1 − 0.44823 = 0.55177 ≈ **0.552 (3 sig.fig)**

> G. C.'s binomial cumulative probability (CD) function is used.

Let Y be the random variable for the number of germinating sunflower seeds out of 60 sown, where $Y \sim B(60, 0.7)$.

Since n = 60 > 50 and $p = 0.7$,

$$np = 60 \times 0.7 = 42 > 5$$
$$nq = 60 \times (1 - 0.7) = 18 > 5$$

Since $np > 5$ and $nq > 5$, we use a normal distribution to approximate the binomial distribution with

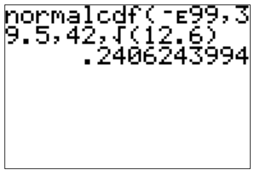
$$E(Y) = np = \mathbf{42}$$
$$Var(Y) = npq = 60 \times 0.7 \times 0.3 = \mathbf{12.6}$$

$\Rightarrow \quad Y \sim N(42, 12.6)$ approximately

$P(Y < 40) \rightarrow P(Y < 39.5)$ by continuity correction.

When n is large and $np > 5$ and $nq > 5$, $X \sim N(n, p) \approx N(np, npq)$

Using G. C. (refer to Appendix for detailed steps),



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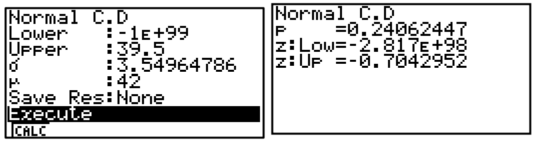

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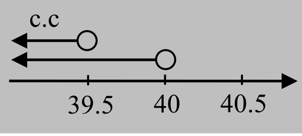
$\therefore P(Y < 40) = P(Y < 39.5)$ by Continuity Correction

$= 0.24062$

$\approx$ **0.241(3sig.fig)**

Approximating a discrete distribution with a continuous distribution by Continuity Correction:



10. **Topic: Hypothesis Testing**

Let the random variable X be the mass of a components (in grams), and μ the mean mass, where $X \sim N(15, 1.2^2)$.

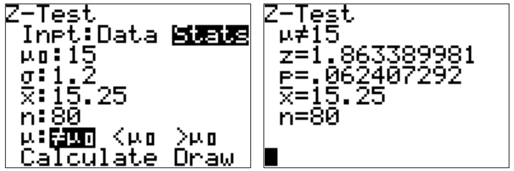
For a random sample of 80 components, $\bar{X} \sim N\left(15, \frac{1.2^2}{80}\right)$

To test $H_o : \mu = 15$ against
$H_1 : \mu \neq 15$ at 5% of significance

Testing for change in $\mu \Rightarrow$ Two-tailed test

Reject H_o if p-value < 0.05.

Applying z-test with $\bar{x} = 15.25$, $n = 80$, $\sigma = 1.2$ using G. C. (refer to Appendix for detailed steps),



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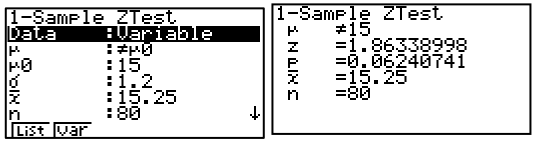

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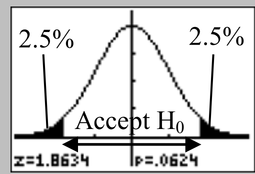


From GC, the p-value = **0.0624** > 0.05, we do not reject H_o.

Hence, there is insufficient evidence at the 5% significance level to conclude that the mean mass of the components is not 15 grams.

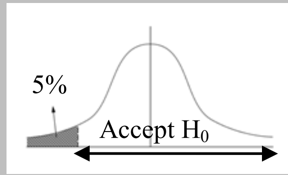
Under H_o, $\bar{X} \sim N\left(15, \frac{1.2^2}{80}\right)$

To test $H_o: \mu = 15$ against

$H_1: \mu < 15$ at 5% of significance

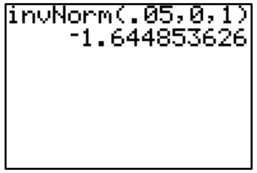
Reject H_o if z-value $< z_{0.05}$.

Testing for <u>decrease</u> in μ i.e. H_1: $\mu < 15$, the critical region is in the lower tail of the distribution $\Rightarrow$ left-tailed test



To obtain $z_{0.05}$, the critical value of z at 5%,

Using G. C. (refer to Appendix for detailed steps),



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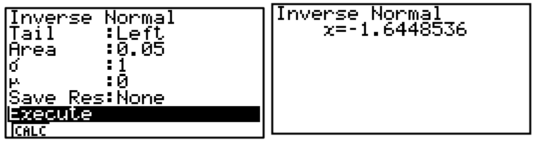

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$z_{0.05} = -1.64485$

For H_o to be rejected at 5% level of significance, test statistic

$$z = \frac{\bar{x}-\mu}{\frac{\sigma}{\sqrt{n}}} = \frac{\bar{x}-15}{\frac{1.2}{\sqrt{80}}} < z_{0.05}$$

$$\frac{\bar{x}-15}{\frac{1.2}{\sqrt{80}}} < -1.645$$

$$\bar{x} < 14.779$$

$$\bar{x} < 14.8 \text{ grams}$$

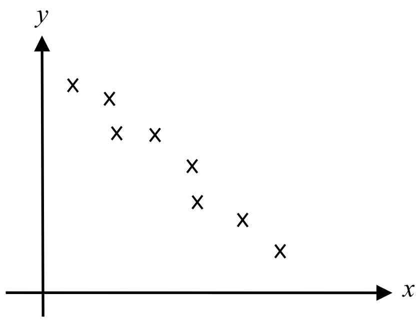
$\therefore$ **Set of values:** $\{\bar{x} \in \mathbb{R}^+ : \bar{x} < 14.78\}$

Note: Final answer expressed in set notation as question asks for <u>set</u> of values.

11. **Topic: Correlation and Regression**

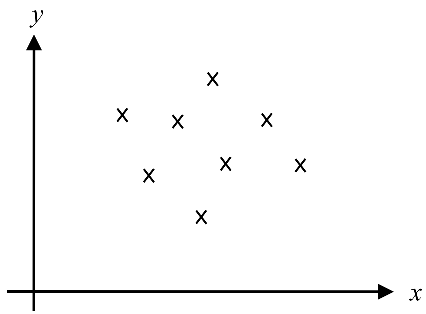
(a) (i) Product moment correlation coefficient≈ 0

$\Rightarrow$the eight points are randomly distributed with little or no pattern.

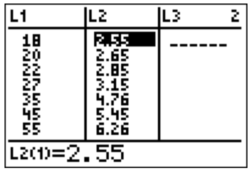


(ii) Product moment correlation coefficient ≈ -0.8

$\Rightarrow$the eight points lie moderately close to a straight line with negative gradient.



(b) (i) Using G. C. (refer to Appendix for detailed steps),



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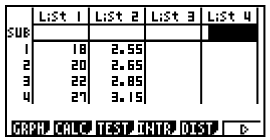
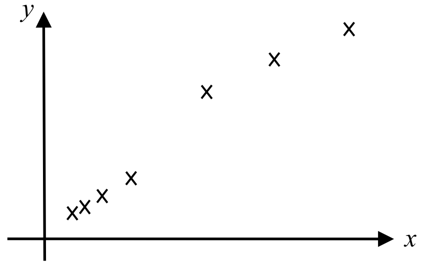
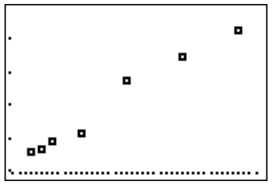
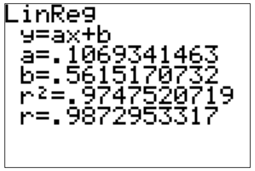


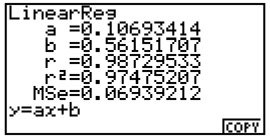
fx-9860G





(ii) Using G. C. (refer to Appendix for detailed steps),





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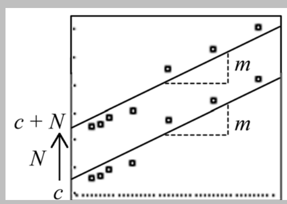
r = 0.98729 ≈ **0.987 (3 sig.fig)**

(iii) Sub values of a and b obtained by G.C. in part (ii) into m and c respectively ⇒ $\boldsymbol{y = 0.1069x + 0.5615}$

(iv) When $x = 40$, y = 0.1069(40) + 0.5615 = 4.8375 ≈ 4.84 (3 sig. fig.)
∴ **Estimated monthly earnings of a 40-year-old worker is $4840**.
Since $x = 40$ is within the range of given data values [18, 55], the estimate is reliable as we are interpolating within the data range.

Note: y is in thousand dollars!

(v) m will remain the same and the constant c becomes $(c + N)$.

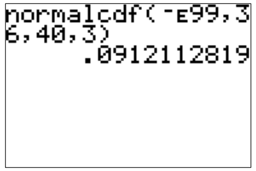


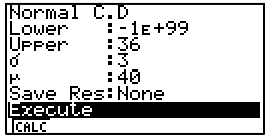
Remember to square the standard deviations when calculating the variance!

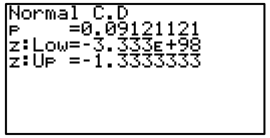
12. **Topic: Normal Distribution**

(i) Let U be the random variable for the mass of an unwrapped sweet, where $U \sim N(40, 3^2)$

Using G. C. (refer to Appendix for steps to access the normal distribution functions),







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$P(U < 36)$ = 0.091211 ≈ **0.0912 (3 sig.fig)**

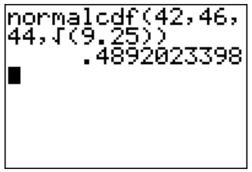
(ii) Let W be the random variable for the mass of a wrapper, where $W \sim N(4, 0.5^2)$

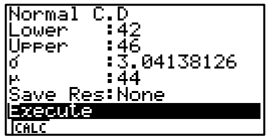
Let S be the random variable for the mass of a wrapped sweet.

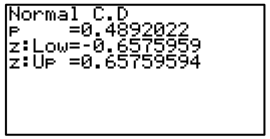
$$E(S) = E(U) + E(W) = 40 + 4 = 44$$
$$Var(S) = Var(U) + Var(W) = 3^2 + 0.5^2 = 9.25$$
$$\therefore \boldsymbol{S \sim N(44, 9.25)}$$

If $X \sim N(\mu_X, \sigma_X^2)$ and $Y \sim N(\mu_Y, \sigma_Y^2)$ are two independent normal distributions, $X \pm Y \sim N(\mu_X \pm \mu_Y, \sigma_X^2 + \sigma_Y^2)$

Using G. C. (refer to Appendix for steps to access the normal distribution functions),







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$P(42 < S < 46) = 0.48920 \approx$ **0.489 (3 sig.fig)**

(iii) Let C be the random variable for the mass of an empty cardboard tube, where $C \sim N(50, 5^2)$.

Let T be the random variable for the total mass of a tube containing 12 wrapped sweets.

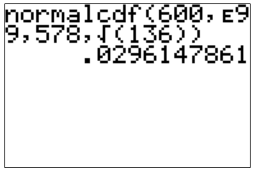
$$T = S_1 + S_2 + \ldots + S_{12} + C$$
$$E(T) = E(S_1 + S_2 + \ldots + S_{12}) + E(C)$$
$$= 12E(S) + E(C)$$
$$= 12 \times 44 + 50 = 578$$
$$Var(T) = Var(S_1 + S_2 + \ldots + S_{12}) + Var(C)$$
$$= 12Var(S) + Var(C)$$
$$= 12 \times 9.25 + 5^2 = 136$$
$$T \sim N(578, 136)$$

If $X_1, X_2, X_2, \ldots, X_n$ are n independent observations of the normal variable X where $X \sim N(\mu, \sigma^2)$,

$X_1 + X_2 + X_2 + \ldots + X_n \sim N(n\mu, n\sigma^2)$

N.B. n is NOT squared for the variance! This is different from $nX \sim N(n\mu, n^2\sigma^2)$!

Using G. C. (refer to Appendix for steps to access the normal distribution functions),



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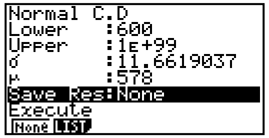
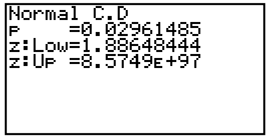




fx-9860G

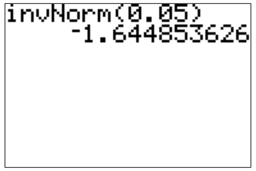
$\therefore$ P (T> 600)=0.029614 ≈**0.0296 (3 sig.fig)**

(iv) Let Y be the random variable for the total mass of a tube containing 12 wrapped sweets produced by the rival company,where $Y \sim N(\mu, \sigma^2)$.

Given P (Y< 450) = 0.05 and P (Y> 550) = 0.08

$$P\left(Z < \frac{450-\mu}{\sigma}\right) = 0.05 \qquad P\left(Z > \frac{550-\mu}{\sigma}\right) = 0.08$$

Using G. C. (refer to Appendix for detailed steps),



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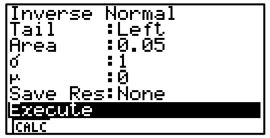

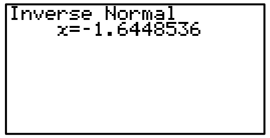

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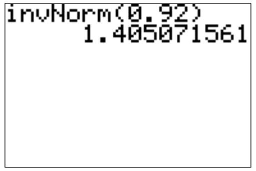

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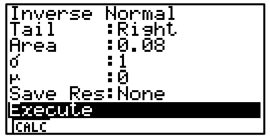
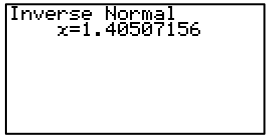




fx-9860G

$$\frac{450-\mu}{\sigma} = -1.64485 \qquad \frac{550-\mu}{\sigma} = 1.40507$$
$$\mu = 450 + 1.64485\sigma \ldots (1) \qquad 550 - \mu = 1.40507\sigma \ldots (2)$$

Sub (1) into (2): $550 - 450 - 1.64485\sigma = 1.405076$

$$\sigma = 32.7877 \Rightarrow \sigma^2 = 1075.0 \approx 1080$$
$$\Rightarrow \mu = 503.9309 \approx 504$$

∴Mean ≈ 504 and variance ≈ 1080 (3 sig.fig)

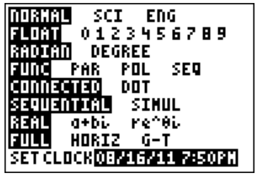
Appendix: Detailed G. C. Steps (for those still trapped in G. C. limbo)

Q3 (i), 5 (ii): Graph Sketching

TI-84 Plus

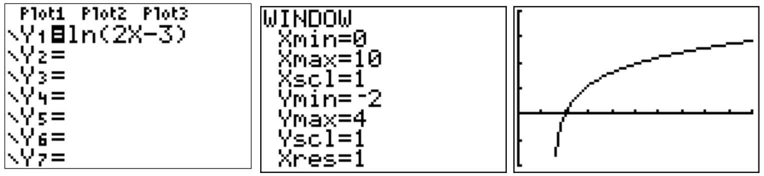
MODE

→ Ensure G. C. is in **FUNC** mode.

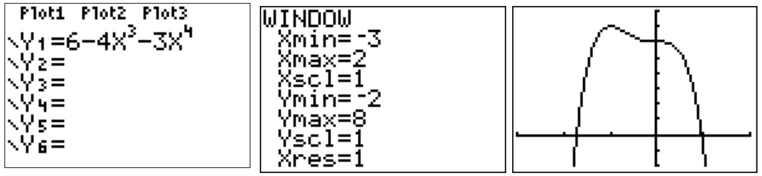


Y= WINDOW GRAPH

3(i)



5(ii)



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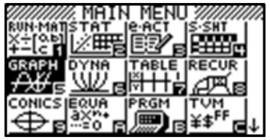
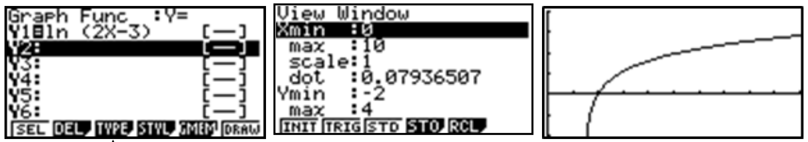
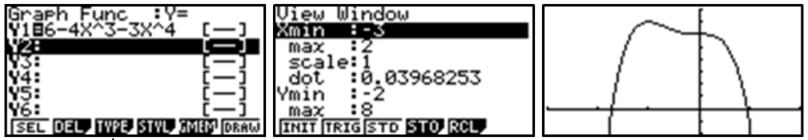


3(i)



[SHIFT] ↑ [EXIT] [F6]

5(ii)



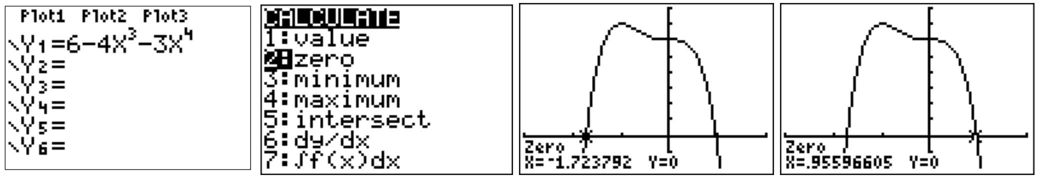
[SHIFT] ↑ [EXIT] [F6]

Q5 (iii): Finding the Roots of a Function

TI-84 Plus

Method I: Using Zero Values of Graphs

→ Define approximate left/right bounds of value for 1st root.
→ Repeat steps for 2nd root.

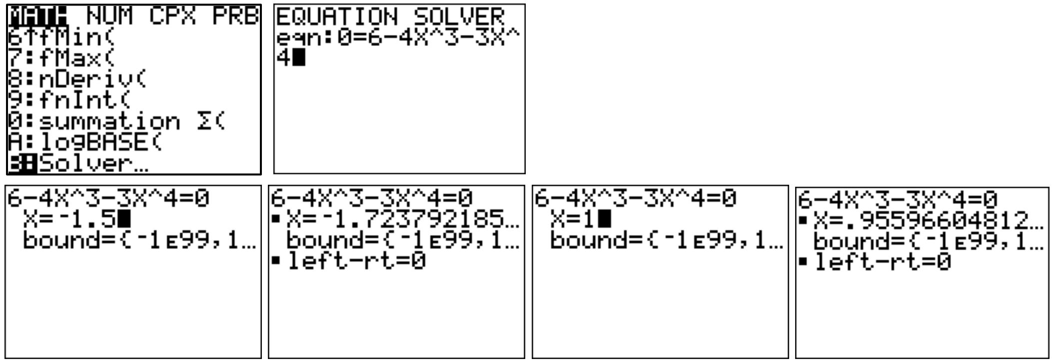


Note: This is the preferred method for Q5(iii) since we are already in Graphing mode having just sketched *C* in part (ii).

Method II: Using Solver

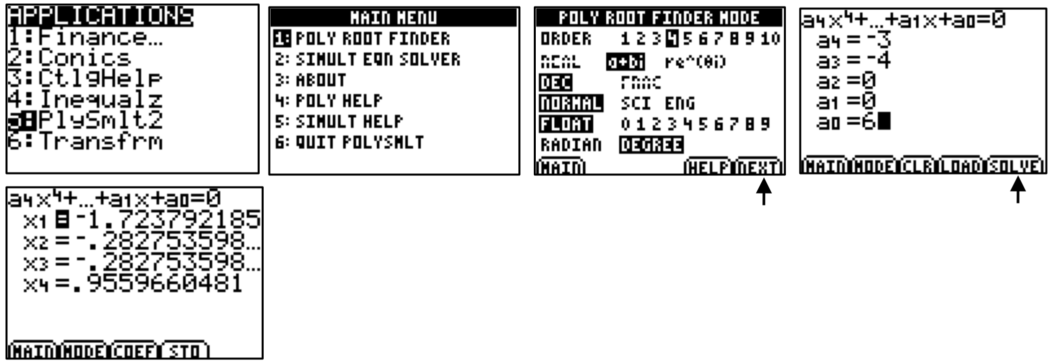
→ Enter **Solver** (last item on MATH menu)
→ Enter equation.

→ Enter an approximate value of x (i.e. $x = -1.5$) for 1st root.
→ Enter an approximate value of x (i.e. $x = 1$) for 2nd root.

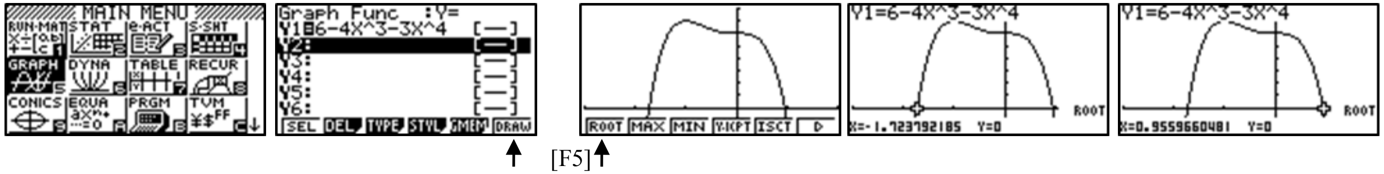


Method III: Using Poly Root Finder Application

→ Enter **PlySmlt2**



fx-9860G **Find Roots in Graph**

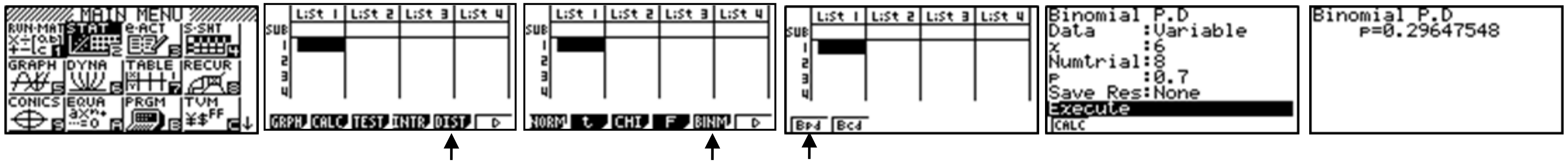


Q9 (i): Binomial Distribution (Computing Probability)

TI-84 Plus 2nd VARS ALPHA MATH

→ Key in the parameters.

fx-9860G

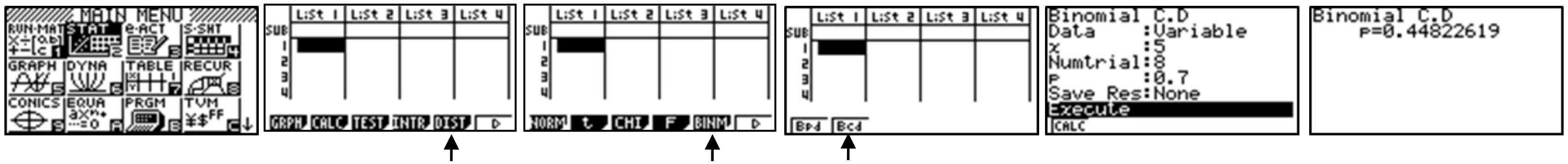


Q9 (ii): Binomial Distribution (Computing Cumulative Probability)

TI-84 Plus 2nd VARS ALPHA APPS

→ Key in the parameters.

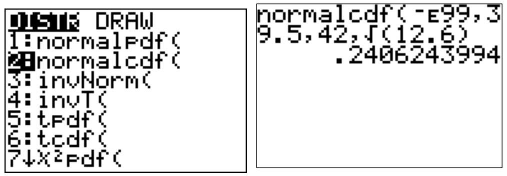
fx-9860G



Q9, Q12(i), (ii), (iii): Normal Distribution

TI-84 Plus

→ Key in the relevant parameters. Results shown are for Q9



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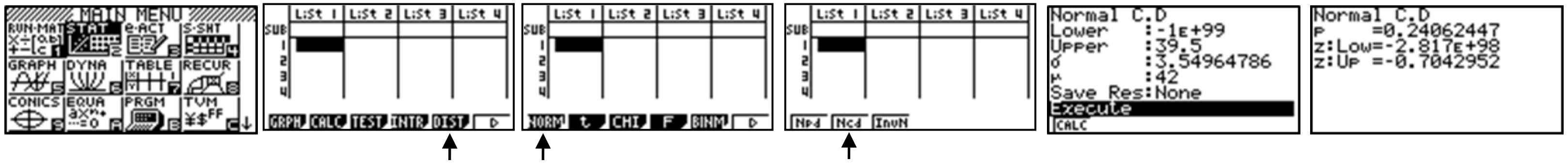
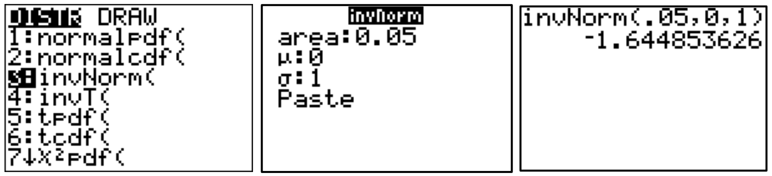


Q10, Q12 (iv): Finding *z*-value

TI-84 Plus

→ Key in the desired probability /level of significance. Results shown are for Q10



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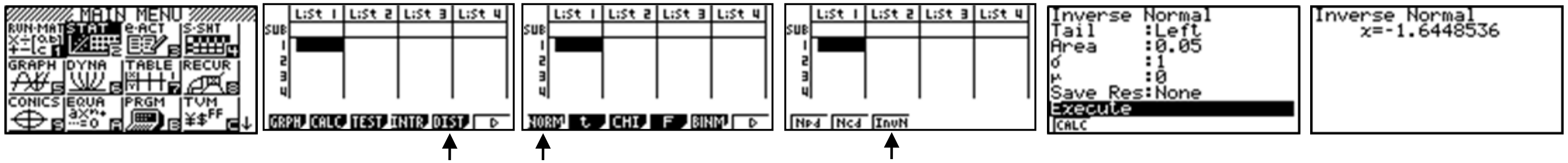


Q10: Hypothesis Testing (*z*-Test with Data Summary)

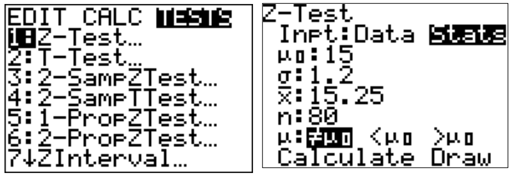
TI-84 Plus

STAT ◀ 1

→ Select **Stats** input method.

→ Enter the population/sample mean, √(variance), sample size.

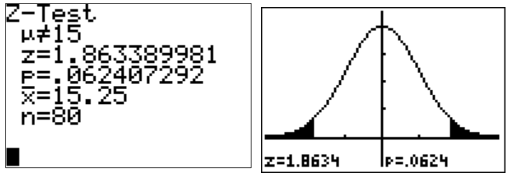
→Select μ: **≠μ$_0$** for two-tailed test.



→ Select **Calculate** for results in summary view.

→ Select **Draw** for results in graphical view.

ENTER



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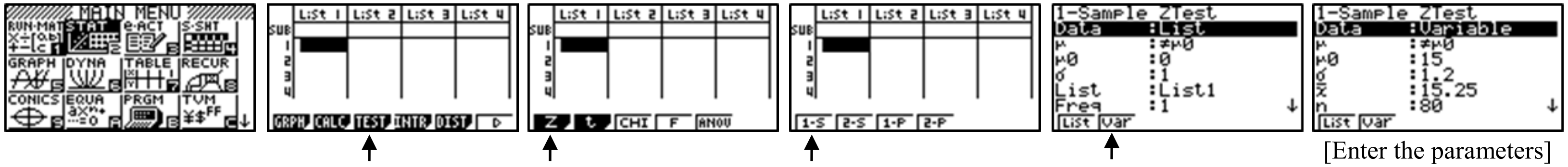
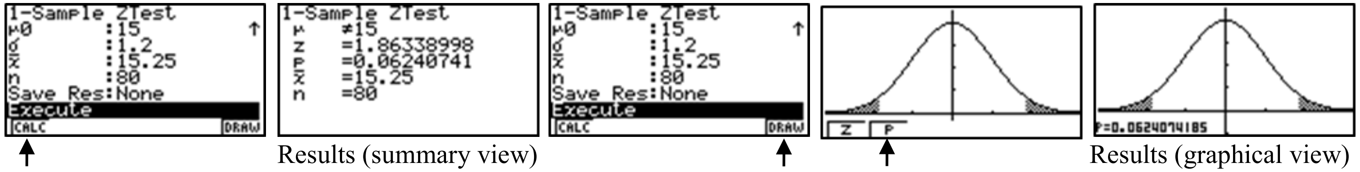


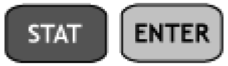
[Enter the parameters]



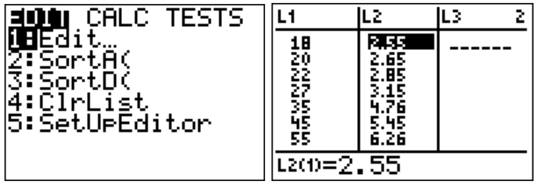
Results (summary view) Results (graphical view)

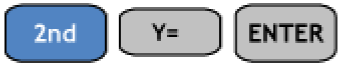
Q11 (b)(i): Plotting Scatter Diagram

TI-84 Plus

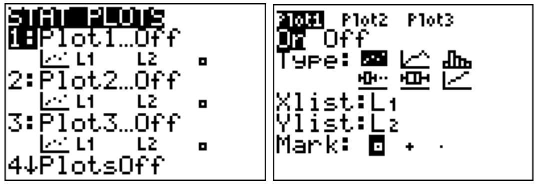


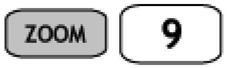
→ Enter *x* and *y* values in L1 and L2 respectively

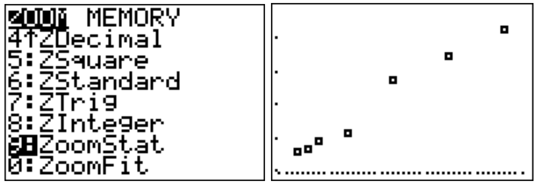




→ Turn On Plot1







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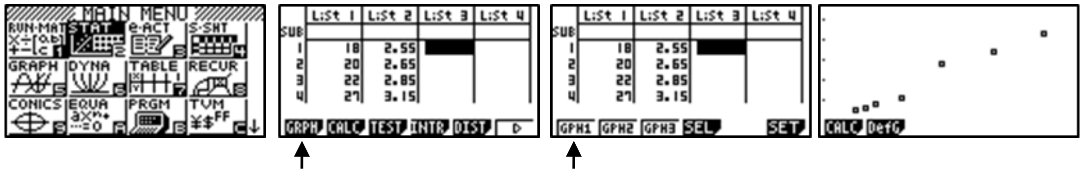
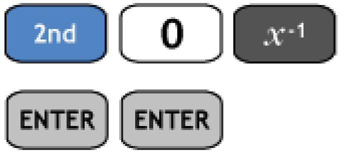
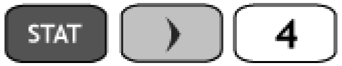


Q11 (b)(ii): Finding Correlation Coefficient

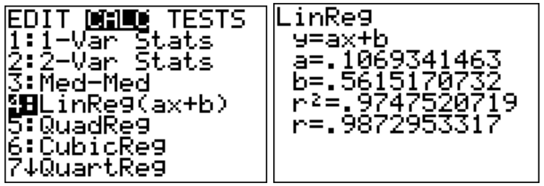
TI-84 Plus



Note: The *r* value will not appear if you miss this step!



Note: L1 contains the values of *x* (independent variable) and L2 the values of *y* (dependent variable) as populated in 11(b)(i).



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