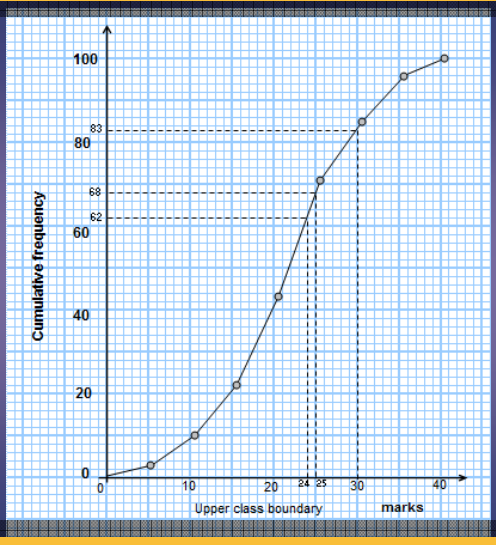
OMEGA LEARNING SOLUTIONS

CXC–MATHEMATICS WORKBOOK



STATISTICS

- Practice Questions
- CSEC Curriculum
- Detailed Solutions

A self study guide for CXC Math Students

John Spencer

CXC MATHEMATICS
Workbook & Tutorial
Series

Statistics

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MODULE 7

Statistics & Probability

Statistics - General concepts

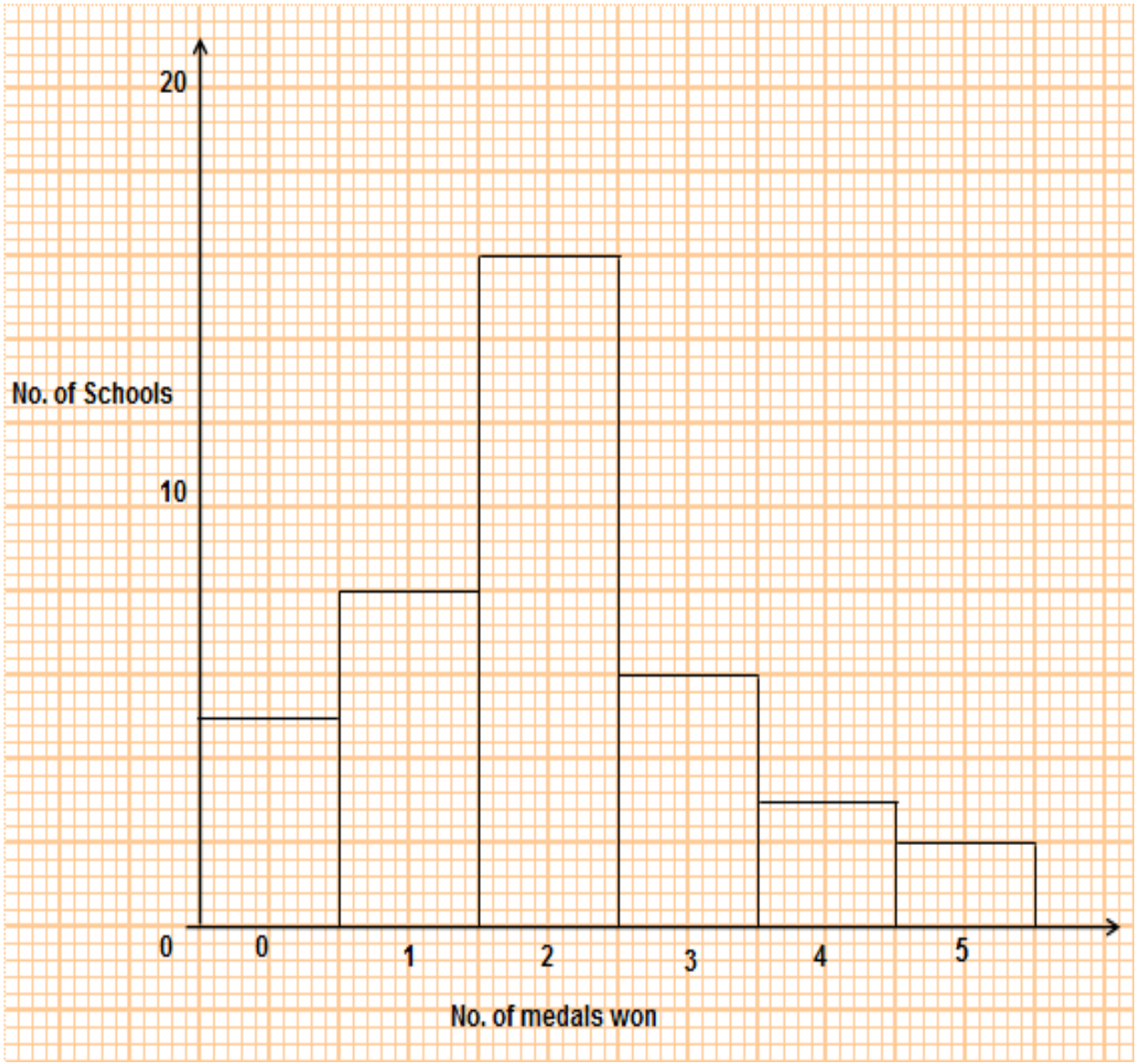
#	Item	Ungrouped Data (x)	Grouped Data (x)
1	Mean	$\frac{\sum (f.x)}{n}$	$\frac{\sum (f.x_{mid})}{n}$
2	Median - Q2	If n is the total number of items, the median is the value $(1/2(n+1)^{th}$ ranked item in the cumulative frequency table	Q2, the median, is the value corresponding to the $1/2(n)^{th}$ ranked item on the cumulative frequency Curve
3	Mode	Value with the highest frequency	Value with highest frequency as estimated by construction using the histogram
4	Class Interval	n/a	grouping of the data ex. (40 to 45)
5	Class Limits	n/a	The starting and ending values as defined in the class boundaries ex. Lower class limit LCL = 40 and Upper class limit UCL = 45
6	Class boundaries	n/a	If lower class limit = 40, then the lower class boundary = 39.5. similarly if upper class limit = 45, then the upper class boundary = 45.5
7	Class Class width	n/a	**Class width** = (upper class boundary - lower class boundary) ** n.b ** be careful not to use the class limits in this equation as this will be **incorrect**.
8	Cumulative frequency table	Table of the data x, and the cumulative frequency	Table of the data x, and the cumulative frequency
9	Cumulative frequency curve - Ogive	n/a	Graph of upper class limit and Cumulative frequency, OR, graph of upper class boundary and cumulative frequency.
10	Lower Quartile - Q1	If n is the total number of items, Q1 is the value of the item at position $1/4(n+1)^{th}$ in the cumulative frequency table	If n is the total number of items, Q1 is the value of the item at position $1/4(n)^{th}$ in the cumulative frequency Curve - Ogive
11	Middle quartile - Q2	Q2 is the value of the $1/2(n+1)^{th}$ ranked item the cumulative frequency table	Q2 is the value of the $1/2(n)^{th}$ ranked item in the cumulative frequency Curve
12	Upper Quartile - Q3	Q3 is the value of the $3/4(n+1)^{th}$ ranked item in the cumulative frequency table	Q3 is the value of the $3/4(n)^{th}$ ranked item on the cumulative frequency Curve
13	Interquartile Range- IQR	Q3 - Q1	Q3 - Q1
14	Semi- Interquartile Range- SIQR	1/2(Q3-Q1)	1/2(Q3-Q1)

Example 7.1 – Ungrouped data

In a school basketball competition, the number of medal's won in the year 2001 is shown on the histogram above.

1. Draw a frequency table from the information given in the graph
2. How many schools participated in basketball competition
3. What is the total number of basketball medals won in 2001
4. What is mean number of medals won
5. What is the modal number of medals won
6. What is the median number of medals won
7. If a school is chosen at random, calculate the probability that it won:

- exactly 3 medals
- less that three medals
- more than 4 medals
- either 2 or 3 medals



Solution: 7.1

1. **Frequency Table**

# Medals	# Schools (f)
0	5
1	8
2	16
3	6
4	3
5	2
Total schools	40

****

2. Number of schools in competition = 40

3. Total medals won by all the schools
= (5 x 0) + (8 x 1) + (16 x 2) +(6 x 3) + (3 x 4) + (2 x 5) = 80

4. The **mean** number of medals won = total medals over total schools = 80/40 = 2

5. Modal number of medals won = 2 since the highest number of schools **won 2 medals**

6. The median number of medals won:
We need to draw a cumulative frequency table to find the median.

Cumulative frequency table

# Medals	# Schools (frequency)	Cumulative frequency
0	5	5
1	8	13
2	16	29
3	6	35
4	3	38
5	2	40

The median is the value corresponding to the
½(n+1)th ranked school
= ½(40+1)th = 20.5th ranked school

where: 20.5th is the average of the 20th and 21st ranked schools

From the cumulative frequency table, the shaded number indicates that two medals each were awarded to schools that were ranked greater than 13th and less than or equal to 29th. That is: (14, 15, 16 …20, 21,…29).
So the 20th and 21st ranked school had 2 medals each:
so median = 2

7. 1 $P(\text{medals} = 3) = \dfrac{\textit{Frequency of observation}}{\textit{total frequency}}$

$$= \frac{\#\ \textit{schools with exactly three medals}}{\textit{total \# schools}}$$

$$= \frac{6}{40} = \frac{3}{20}$$

****

$$P(\text{medals} < 3) = \frac{(\#\ \textit{schools with} < 3\ \textit{medals})}{\textit{total schools}}$$

$$= \frac{(16+8+5)}{40} = \frac{29}{40}$$

$$P(\text{medals} > 4) = \frac{(\#\ \textit{schools with} > 4\ \textit{medals})}{\textit{total schools}}$$

$$= \frac{2}{40} = \frac{1}{20}$$

****

P (2 or 3 medals)

schools with 3 medals = 6
schools with 2 medals = 16

so: P (2 or 3 medals) = $\dfrac{(16+6)}{40}$

$$= \frac{22}{40} = \frac{11}{20}$$

Activity 7.1 – Ungrouped data

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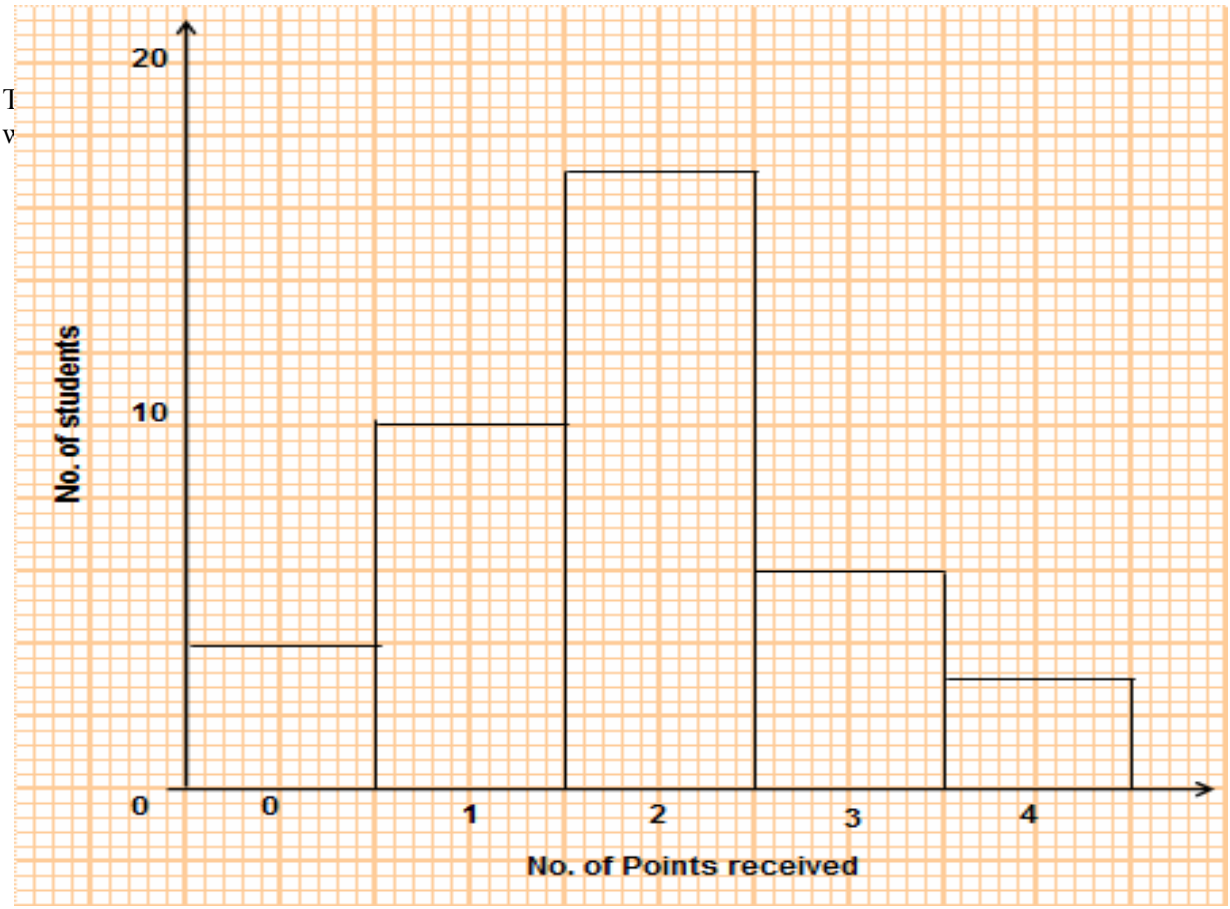


1. Frequency Table

# Points (x)	# Students (f)	$f \times x$
Total		

Example 7.2 – Grouped data

Height (cm)	# Students (f)	Cumulative Frequency
141 - 145	10	10
146 - 150	45	55
151 - 155	80	135
156 - 160	115	250
161 - 165	75	325
166 - 170	25	350
171 - 175	10	360

The table above shows the height of students in a particular institution.

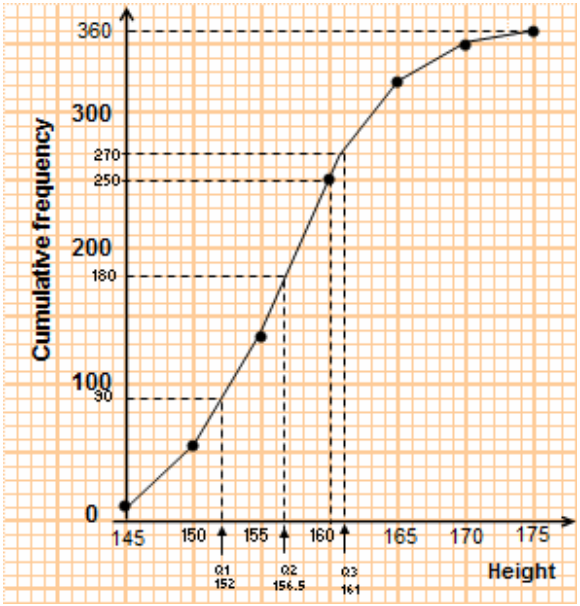
Draw the cumulative frequency curve to represent the data.

From the curve drawn, estimate the following:

1. The median height
2. The inter quartile range of the heights
3. The number of students who are taller than 160 cm
4. The probability that a student chosen at random will be between 150cm and 160cm inclusive.

Solution:

Since we will need to find # students who are " taller than" 160cm, we will use the upper class limit and plot a "less than or equal to (<=) " curve.



<= Upper class limit of height	Cumulative Frequency
<=145	10
<= 150	55
<=155	150
<=160	270
<= 165	345
<= 170	370
<= 175	384

Tip:

- If the question says [<= or >] , Plot the upper class limit Vs. Cum. Frequency.
- If the question says [< or >=] Plot upper class boundary Vs. Cum. Frequency.

Cumulative frequency curve

1. The median Q2 correspond to the 1/2 n th ranked student, where n = 360.
So Q2 is the height that corresponds to the 180th ranked student on the curve.

⇒ Q2 = 156.5 cm

Similarly Q1 corresponds to the height of the ¼ n th ranked or the 90th student

⇒ Q1 = 152 cm

also Q3 corresponds to the height of the 3/4 n th ranked or the 270th student

⇒ Q3 = 161 cm

2. Inter quartile range = Q3 – Q1 = 161 – 152 = 9 cm

****

3.
# of students with height <= 160 = 250 (fr. graph)
so # of students with height > 160 = 360 – 250 = 110

****

4.From Chart: # students with height <= 160 = 250
and # students with height <= 150 = 55
⇒ # students between 150cm and 160 cm
= 250 – 55 = 195 students

Total students measured = 360

⇒ P (150 <= height <= 160) = 195 / 360

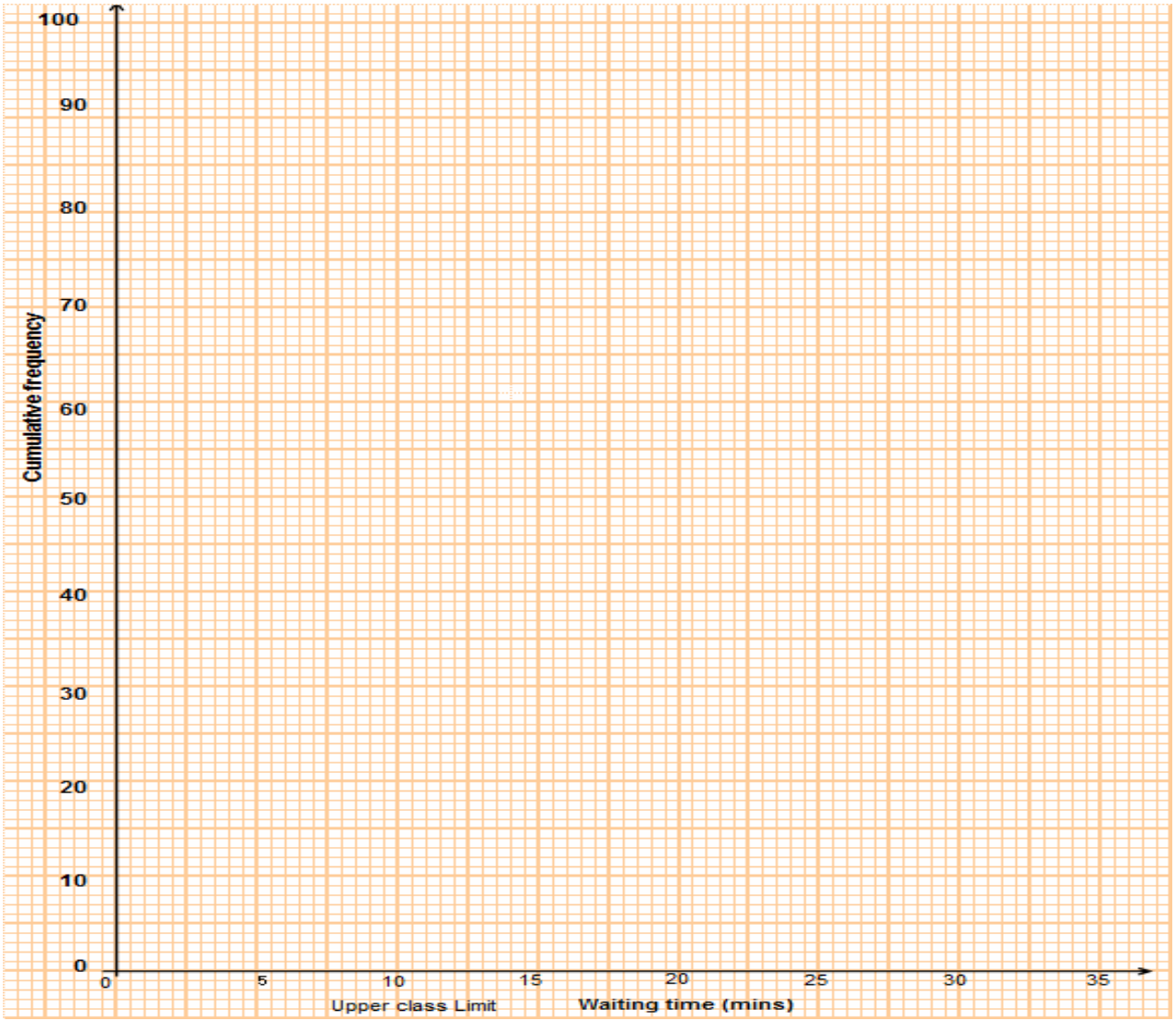
= 0.54

Activity 7.2 - Grouped data

A cable company conducted a survey to determine the amount of time customers had to wait in line for service at one of their locations. The data from the survey is shown below.

1. Fill out the cumulative frequency column of the table
2. Draw the cumulative frequency curve.
3. Determine the number of customers who waited for more than 19 minutes
4. What is the probability that a randomly chosen customer will have to wait between 19 and 25 minutes.
5. The target for the company is that no more than 10% of its customers should wait more than 30 mins.
6. State , giving reasons whether this target is being met

Waiting Time (mins)	# Customers	Cumulative Frequency
1 - 5	7	
6 - 10	12	
11 - 15	16	
16 - 20	21	
21 - 25	28	
26 - 30	11	
31 - 35	5	



Activity 7.2 contd.

#	Question	Answer
1	# customers who waited longer than 19 mins	
2	P(19<= x <= 25)	
3	% of customers waiting longer than 30 mins .	

Example 7.3

The marks obtained by students who took a college entrance exam is shown in the frequency table.
Complete the table and draw a cumulative frequency curve

Determine:

1. The mean marks of the students
2. The number of students who scored less than 25 marks
3. the probability that a randomly chosen student will score between 25 and 30 marks
4. The pass mark if there are places available for only 38 applicants

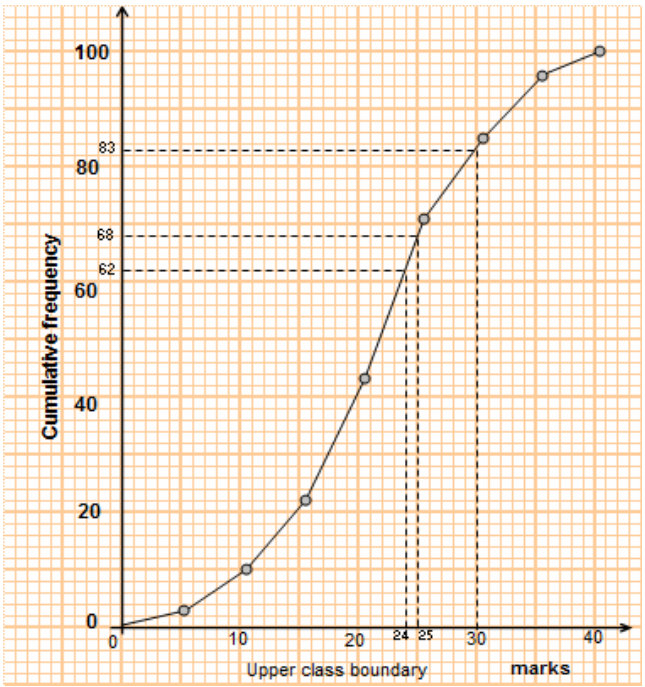
Solution:

Since we are asked to find # students who score "less than" 25 marks, we will use upper class boundary and plot a "less than" curve

Frequency table

Marks	frequency (f)	Upper class Boundary	Cumulative Frequency
1 - 5	3	< 5.5	3
6 - 10	7	< 10.5	10
11 - 15	12	< 15.5	22
16 - 20	21	< 20.5	43
21 - 25	28	< 25.5	71
26 - 30	14	< 30.5	85
31 - 35	11	< 35.5	96
36 - 40	4	< 40.5	100

1. Mean of the frequency distribution:



Marks (x)	Mid point x_{mid}	# students or frequency (f)	$f \times x_{mid}$
1 - 5	3	3	9
6 - 10	8	7	56
11 - 15	13	12	156
16 - 20	18	21	378
21 - 25	23	28	644
26 - 30	28	14	392
31 - 35	33	11	363
36 - 40	38	4	152
Sum = $\sum$		100	2150

$$Mean = \frac{\sum f \times x_{mid}}{\sum f} = \frac{2150}{100} = 21.5 \text{ marks}$$

n.b x_{mid} *= (upper limit + lower limit) /2*

2.
Since the curve is a "less than " curve, the number of who scored less than 25 marks can be read directly from the graph.
So # students that corresponds to (< 25) = 68

3.
The probability that a student will score between 25 and 30 marks is equal to the proportion of students who score between 25 and 30 marks.

students scoring less than 25 marks = 68
students scoring less than 30 marks = 83

scoring between 25 and 30 marks = 83 – 68 = 15

so Probability of a randomly selected student scoring between 25 and 30 marks = $\frac{15}{100}$ = 0.15

4.
If 38 places are available, then number of applicants who must fail = 100 – 38 = 62.
From the graph, 62 applicants got less than 24 marks, so the pass mark is 24.

Tip: Always draw dotted lines on your graph to show how your answers are obtained

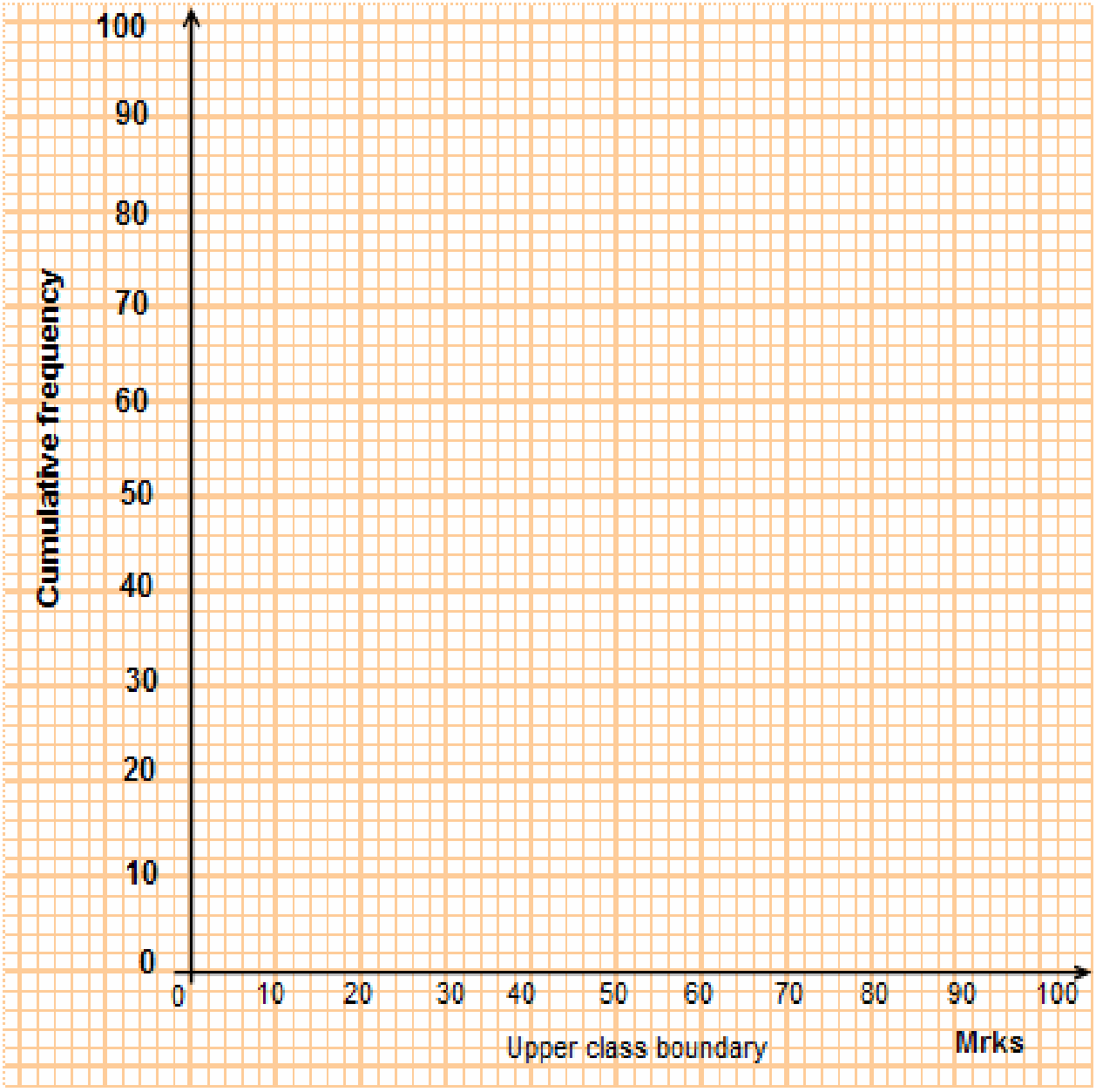
Activity 7.3

The marks obtained by 100 foreign students who sat an English exam is shown below.
Complete the tables and:
Find the mean mark.

1. Draw the cumulative frequency curve.

From your curve, estimate:

1. The median mark.
2. The probability that a randomly selected student scored at least 80.
3. The number of students who scored between 40 and 60 marks
4. The pass mark if 75% of the students failed the exam.



Frequency distribution

Marks (x)	# Students (f)	x_{mid}	$f \times x_{mid}$
1 - 10	1	5.5	5.5
11 - 20	4		
22 - 30	6		
33 - 40	19		
44 - 50	25		
55 - 60	17		
66 - 70	11		
77 - 80	4		
88 - 90	2		
99 - 100	1		
Sum =			

Mean =

Cumulative frequency table

Marks	# Students	Marks	Cumulative Frequency
1 - 10	1	< 10.5	1
11 - 20	4		
22 - 30	6		
33 - 40	19		
44 - 50	25		
55 - 60	17		
66 - 70	11		
77 - 80	4		
88 - 90	2		
99 - 100	1		

Example 7.4 – Pie Chart

During a particular 24 hour period, a teacher estimates that her time was spent on different activities as shown in the table below.

Subject	Time (hr)
Mathematics	6
English	4
Science	4
Resting	8
Other activities	2

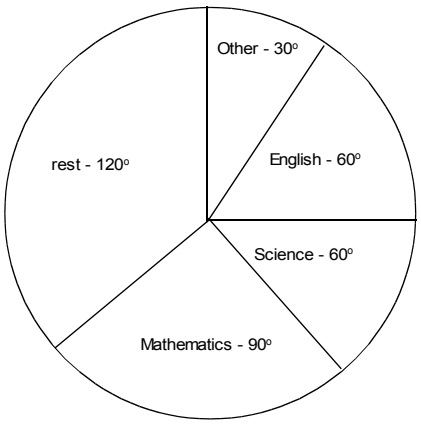
1. Draw a pie chart to represent the information given in the table.

2. What is the probability that in any particular hour chosen at random, the teacher is:
   - Resting
   - Doing Other activities
   - Doing Science or Mathematics.
   - NOT doing English

Solution:

The pie chart is drawn so that 24hrs represents 360°.
Note that the chart is arranged in ascending order

Subject	Time hrs)	Angle
Other	2	30
English	4	60
Science	4	60
Mathematics	6	90
Rest	8	120
Total	24	360



The proportion of time spent on an activity will be used to determine the probability of that activity occurring.

n.b: P(x) = Probability of the event x occurring

- P (Resting) = 8/24 = 1/3
- P (Other activities) = 2/24 = 1/12
- P (mathematics or Science) = (6 + 4)/24 = 10/24 = 5/12

P (not doing English) = 1 – P(doing English)

so: P(doing English = 4/24 = 1/6
P (not doing English) = 1 - 1/6 = 5/6

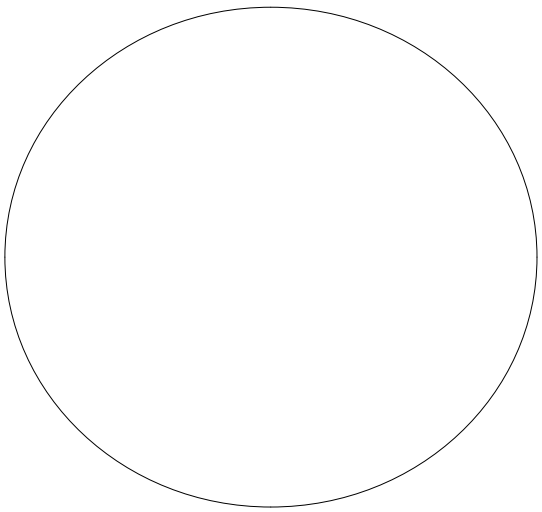
Activity 7.4

A random sample of 1000 students were surveyed to determine how they traveled to school.
The results were as follows

# students	Type of transportation
300	Walk
100	Private Car
400	Public Taxi
200	Bus

1. Draw a pie chart to represent the result.
2. What is the probability that a randomly selected student:
   - walks to school
   - Travels by taxi or private car
   - Does **not** take the bus

Solution:



Example 7.5

The number of points scored by teams in a competition is shown below:

Points	# Teams
3 - 7	4
8 - 12	17
13 - 17	25
18 - 22	11
23 - 27	3

1. Determine the number of teams
2. The mean number of points scored
3. Calculate the probability that a team chosen at random will:
   - score at most 17 points
   - score between 13 and 22 points - inclusive
4. Draw a frequency polygon to represent the data

Solution:

Points (x)	# Teams (f)	x_{mid}	$f.x_{mid}$
3 - 7	4	5	20
8 - 12	17	10	170
13 - 17	25	15	375
18 - 22	11	20	220
23 - 27	3	25	75
Total	$\sum f = 60$		$\sum f \times x_{mid} = 860$

1. # Teams = 60

2. Mean number of points = $\frac{\sum f \times x_{mid}}{\sum f} = \frac{860}{60} = 14.33$

3. # teams scoring <= 17 points = 4 + 17 + 25 = 46

so : P(score <= 17 points) = $\frac{46}{60} = 0.767$

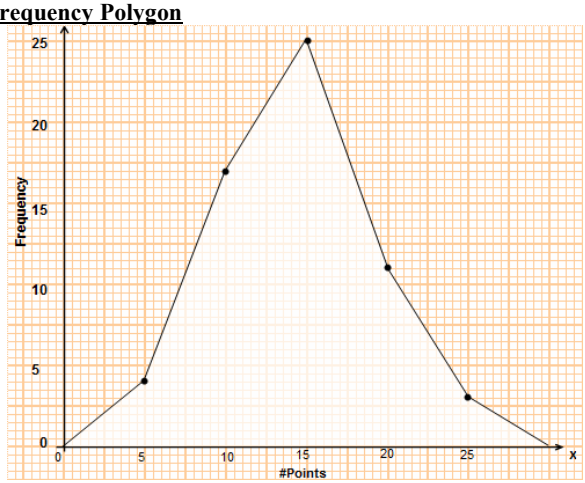
teams scoring between 13 and 22 points = 15 + 20 = 35

so : P(13<= score <= 22) = $\frac{35}{60} = 0.58$ to 2 d.p

4. Frequency Polygon plots x_{mid} Vs frequency

x_{mid}	# Teams (f)
5	4
10	17
15	25
20	11
25	3

Frequency Polygon



Activity 7.5

The level of water in a vessel was measured over a period of time and the results shown in the table below.

Level (cm)	# days
1 - 5	4
6 - 10	9
11 - 15	6
16 - 20	4
21 - 25	2
26 - 30	1

Determine:

1. The mean water level
2. The probability that on any day chosen at random, the water level is:

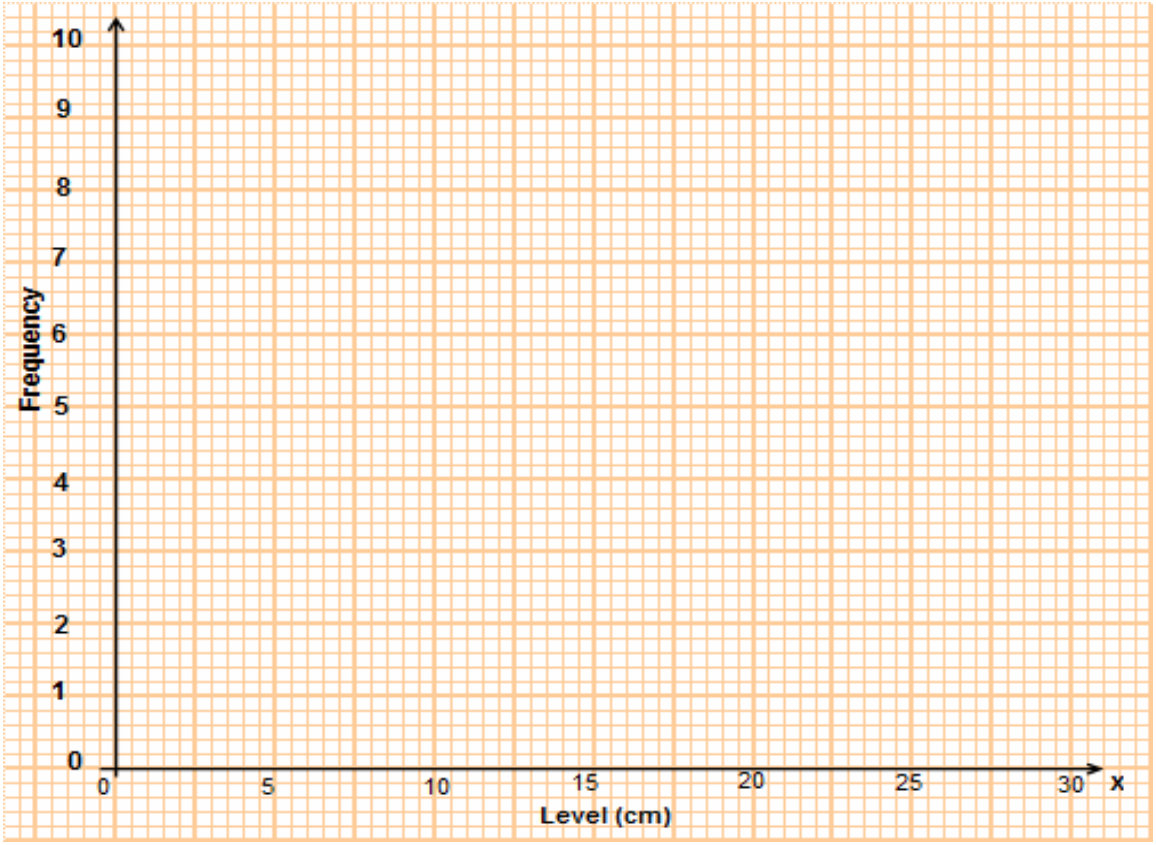
   i) at least 21 cm

   ii) between 11 and 20 cm, both levels inclusive.

3. Draw a frequency polygon to represent the data

Use 2cm to represent a level of 5cm on the x axis and 1cm to represent 1day on the y axis.

Solution:



Level (x)	# days (f)	x_{mid}	$f.x_{mid}$

Activity 7.5 contd

Probability:

Experimental probability:

If 50 out of 300 students got more that 60 marks on a math test, then the probability that a student selected at random got more than 60 marks is given by:
P (> 60) = 50/300 = 1/6
This is an experimental probability, which can be determined from the results of a survey or an experiment.

Theoretical probability:

If a box contains 5 red balls and 3 blue balls, then we can find the probability of choosing a red ball using the formula:

$$P(\text{of an event}) = \frac{\textit{number of favorable outcomes}}{\textit{total number of possible outcomes}}$$

so P (red ball) = $\frac{5}{8}$
This is an example of theoretical probability.

Example 7.6

A jar contains 10 red balls, 4 green balls and 6 yellow balls.

1. Determine the probability of choosing a red ball
2. If the red ball is not replaced, find the probability of now choosing another red ball.
3. If the two red balls are not replaced, find the probability of NOT choosing a yellow ball.

If the Jar above now contains 6 red balls, 3 green balls and 5 yellow balls.

4. What is the probability of choosing a yellow ball or a green ball

If the Jar above now contains 8 red balls, 2 green balls and 6 yellow balls.

5. What is the probability of selecting a red ball followed by another red ball without replacing the first ball.

Solution:

1. $P(\text{red ball}) = \frac{\textit{number of red balls}}{\text{Total \# of balls}} = \frac{10}{20} = 0.5$

2. Given that a red ball has been removed

$P(\text{red ball}) = \frac{9}{19} = 0.47$

3. Given that two red ball have been removed

$P(\text{yellow ball}) = \frac{6}{18} = 1/3$

But: The probability of NOT choosing a yellow ball is 1 minus the probability of choosing a yellow ball

P(Not a yellow ball) = 1 – P (yellow ball)
= 1 – 1/3 = 2/3

4. P (yellow or green ball)

$= \frac{(\text{\# yellow balls} + \text{\# green balls})}{\textit{total balls}}$

$= \frac{(5+3)}{14} = 8/14 = 0.57$

5. P (red and red) = P (1st red ball) x P(2nd red ball)

P(1st red ball) = 8 / 16 = 0.5

P(2nd red ball) = 7 / 15 = 0.466 (1st ball not replaced)

P (red and red) = 0.5 x 0.466 = 0.233

Notes

Example 7.6 –

In a certain school, there is a 58% chance that a girl will be captain of the annual debating team.
Over the next three years, Find the probability that
1. all three team captains are boys
2. at least one team captain is a girl

Solution:

P (boy as captain) = 1 – P (Girl as captain)
= 1 – 0.58 = 0.42

The probability of three boys being captain over the next three years = P (boy, boy, boy)
= P(boy) x P(boy) x P(boy) = (0.42)(0.42)(0.42) =.074

The probability of selecting at least one girl is
= 1 – P(boy, boy, boy) = 1 – 0.074 = 0.926

Example 7.7

Three fair coins are tossed:
Draw the sample space and determine the probability of
Exactly two heads appearing
At least two heads appearing

Solution:
The sample space is the set of all possible outcomes, U where :

U = {HHH, HHT, HTT, HTH; THH, TTH, THT, TTT}

1. There are 3 outcomes with exactly two heads
(HHT, HTH, THH) so:

P(exactly two heads) = 3/8

2. There are four outcomes with at least two heads
(HHH, HHT, HTH, THH) so:

P(at least two heads) = 4/8 = 1/2

Example 7.8

In a biscuit manufacturing plant, a pack of biscuit will be rejected if it has any one of the following three possible defects.
A: The pack is not sealed
B: The pack is underweight
C: The blend is wrong

Given that these three events can occur independently of each other. And that P(A) = 1/60; P(B) = 1/100 and P(C) = 1/1000, and that :

$P(A \cup B \cup C)$ = P(A) + P(B) + P(C) - $P(A \cap B)$ - $P(A \cap C)$ - $P(B \cap C)$ + $P(A \cap B \cap C)$

Find
the probability that a pack of biscuit
1. will exhibit A, B and C (all three defects).
2. Will exhibit A and B
3. Will exhibit A, or B, or C

4. The plant produces 20,000 packs of biscuit on each shift. Estimate the number of rejected packs per shift

Solution

1. P(A and B and C) = $P(A) \times P(B) \times P(C)$
= (1/60)(1/100)(1/1000)
= $(1.67) \times 10^{-7}$

2. P(A and B) = $P(A) \times P(B)$
= (1/60)(1/100)
= 1.67×10^{-4}

3. P (A or B or C) = $P(A \cup B \cup C)$

P(A) + P(B) + P(C) = 1/60+1/100+1/1000 = 0.0276

$P(A \cap B) = P(A) \times P(B) = 1.67 \times 10^{-4}$

$P(A \cap C) = P(A) \times P(C) = \frac{1}{60} \times \frac{1}{1000}$
$= 1.67 \times 10^{-5}$

$P(B \cap C) = P(B) \times P(C) = \frac{1}{100} \times \frac{1}{1000}$
$= 1 \times 10^{-5}$

$P(A \cap B \cap C) = P(A) \times P(B) \times P(C)$
= (1/60)(1/100)(1/1000) = $(1.67) \times 10^{-7}$

so $P(A \cup B \cup C)$ = 0.0276
- 1.67×10^{-4}
- 1.67×10^{-5}
- 1×10^{-5}
+ $(1.67) \times 10^{-7}$
= 0.02747

4.Given 20,000 packs produced per shift and :
P(A or B or C) = 0.02747
rejects = $0.02747 \times 20{,}000$ = 549 packs

Activity 7.6

A bag contains 15 red balls, 4 green balls and 6 white balls.

1. Find the probability of choosing a white ball followed by a green ball without replacing the balls.

If the bag contains 11 red balls, 4 green balls and 5 white balls.

2. Find the probability of :

- Choosing a red or a green ball
- NOT choosing a red ball

Activity 7.7

In a certain village, there is a 62% chance that a male will be chosen to lead an annual fund raising event.

Over the next three years, Find the probability that

1. all three fundraisers will have a male leader
2. at least one fundraiser will be led by a female

Answers to Activity Questions:

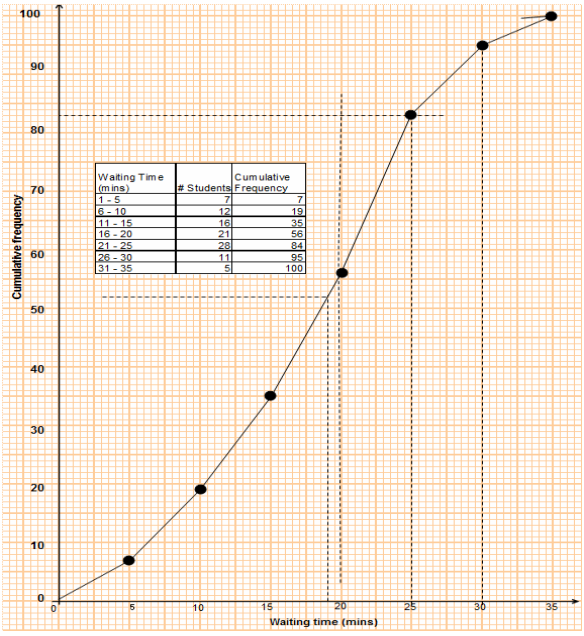
Activity: 7.1

# Points (x)	# Students (f)
0	4
	10
2	17
3	6
4	3

2. *# students = 40*
3. *# points = 74*
4. *Mean = 74 / 40 = 1.85*
5. *Mode = 2 (corresponds to highest frequency)*
6. *P(x >= 2) = (17+6+3)/40 = 0.65*
7. *P(x < 2) = (10+4)/40 = = 14/40 = 0.35*
8. *P(x >=3) = (6+3)/40 = = 9/40 = 0.225*

Activity: 7.2

Waiting Time (mins)	# Customers	Cumulative Frequency
1 - 5	7	7
6 - 10	12	19
11 - 15	16	35
16 - 20	21	56
21 - 25	28	84
26 - 30	11	95
31 - 35	5	100



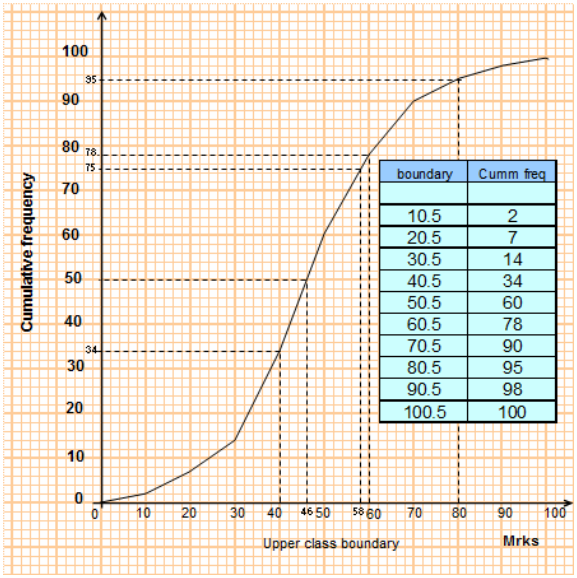
2. *# customers > 19 mins = (100-52) = 48*
3. *P(19<= x <= 25) = (84-52)/100 = 0.32*
4. *% customers > 30 mins = (100-95)/100 = 5% so target of less than 10% is being met.*

Activity: 7.3

Marks (*x*)	# Students (*f*)	x_{mid}	$f \times x_{mid}$
1 - 10	2	5.5	11
11 - 20	5	15.5	77.5
21 - 30	7	25.5	178.5
31 - 40	20	35.5	710
41- 50	26	45.5	1183
51 - 60	18	55.5	999
61 - 70	12	65.5	786
71- 80	5	75.5	377.5
81 - 90	3	85.5	256.5
91 - 100	2	95.5	191
Sum =	100		4770

1. Mean = (4770/100) = 47.7

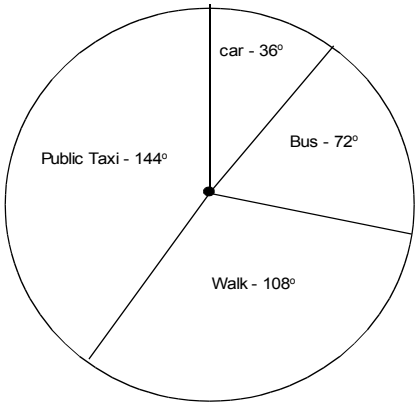
Marks	# Students	< Marks	Cumulative Frequency
1 - 10	2	< 10.5	2
'11 - 20	5	< 20.5	7
22 - 30	7	< 30.5	14
33 - 40	20	< 40.5	34
44 - 50	26	< 50.5	60
55 - 60	18	< 60.5	78
66 - 70	12	< 70.5	90
77 - 80	5	< 80.5	95
88 - 90	3	< 90.5	98
99 - 100	2	< 100.5	100



from graph:

2. *Median = 46*
3. *P(>=80) = (100 – 95)/100 = .05*
4. *# students scoring between 40 and 60 marks = 78 - 34 = 44*
5. *Pass mark = 58*

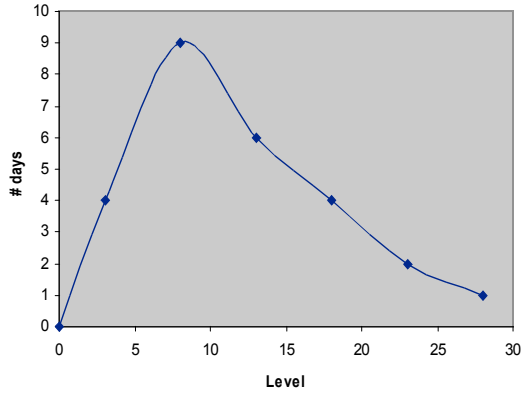
Activity: 7.4



2. P(walk) = 300/1000 = 0.3
3. P(taxi or car) = (400+100)/1000 = 0.5
4. (Not Bus) = 1 – P(bus) = 1 – (200/1000) = 0.8

Activity: 7.5

Level (x)	# days (f)	X_mid	f. x_mid
1 - 5	0	0	0
1 - 5	4	3	12
6 - 10	9	8	72
11 - 15	6	13	78
16 - 20	4	18	72
21 - 25	2	23	46
26 - 30	1	28	28
sum	26		308



Mean = 11.8, P(>=21) = 3/26; P(11 <= x <=20) = 10/26=5/13

Activity: 7.6

P(white and green) = (6/25)(4/24) = 1/25
P(red or green) = 3 / 4 ; P (not Red) = 9/20

Activity: 7.7

P(male,male,male) = 0.62^3 = 0.238
p(at least one female) = 1 - 0.62^3 = 0.761

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John Spencer is a former Senior Lecturer and Head of section- at the University of Technology – Jamaica, and a former Lecturer at the John Donaldson Technical Institute – Trinidad & Tobago.