Introduction

Road Safety Objectives

- Students know how speed affects safety, and understand the forces and energy involved in road movement.

Links with the New Zealand Curriculum Framework

Essential Learning Areas

Changing Gear: **Mathematics** will help students meet Achievement Objectives of ***Mathematics in the New Zealand Curriculum***. Details of these are given at the beginning of each activity.

Essential Skills

(see Appendix pages 43 - 45)

Changing Gear: **Mathematics** will help students develop the following essential skills:

Numeracy

Calculate accurately

Use calculators and a range of measuring instruments confidently and competently

Recognise, understand and respond to information which is presented in mathematical ways.

Organise information to support logic and reasoning

Information

Organise information to support logic and reasoning

Using this Resource

- Activities 1-4 are designed as basic activities that could be incorporated into an existing school Mathematics programme.
- Activity 5 is an advanced activity, and could be used for extension.
- The entire package could be used as a unit of work in the context of road safety or Transport Mathematics.
- Though the underlying message is one of road use, the intention is to deliver this message as secondary to the immediate learning of the class. Thus the class will cover a 'Maths' lesson, but there is a road safety twist to the follow-up questions which makes the Mathematics more relevant.

Overview

Activity	Copysheet
1 A Lapse in Concentration	1 A - C. A Lapse in Concentration pages 12-14
2 Road Statistics	2 Accidents where Driver Alcohol was a Contributing Factor 1980-1998 page 17 3 Injury Accidents by Time of Day and Day of Week Year Ending 31.12.98 page 18 4 Fatal Accidents by Time of Day and Day of Week Year Ending 31.12.98 page 19 5 Accidents Involving Pedestrians by Time of Day and Day of Week Year Ending 31.12.98 page 20 6 Pedestrians Injured while Crossing the Road Year Ending 31/12/98 page 21 7 Accidents where Speed was a Contributing Factor 1980-1998 page 22 8 A-C Traffic Legislation since 1965 pages 23-25
3 Calculating Reaction Time	9 A-B Reaction Time - Statistics Exercise pages 28-29 10 Data Sheet – Adult Reaction Times page 30
4 Stopping Distances for Cars	11 A-C Stopping Distances for Cars page 33-35
5 Stopping Distances for Cars – an advanced activity	12 A-E Stopping Distances for Cars page 38-42

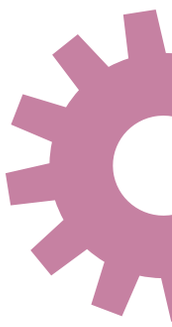
Activity 1: *A Lapse in Concentration*

Explanation

This is a trigonometry activity. It relates to 'micropauses' that tired drivers are known to take, during which time they either close their eyes and nod off, or they may keep their eyes open but not see or react to what is happening. When a driver takes a micropause, he or she often turns the wheel slightly so that the car veers off course.

The same thing happens if a driver looks down or is distracted, for example if changing a tape in the car stereo.

The students use trigonometry to work out the 'danger distance/time' for a car during a micropause or lapse in driver concentration ie the distance/time a car will travel before it is in a dangerous situation.



Curriculum Links

Mathematics in the New Zealand Curriculum

Measurement	Level 4 Objective 5	Perform calculations with time.
Geometry	Level 5 Objective 5	Find an unknown side in a right angle triangle using an appropriate trig ratio.

Equipment

Copysheet 1A-C **A Lapse in Concentration** pages 12-14

Teaching

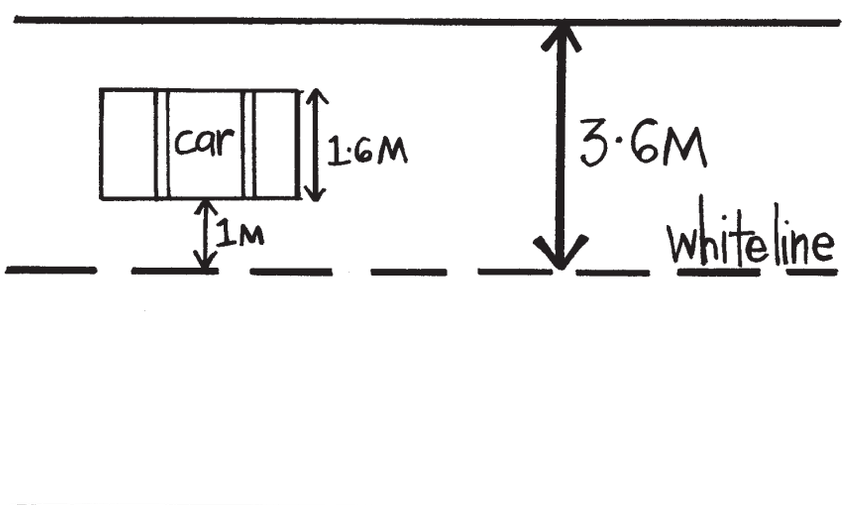
1 Students work on exercises from Copysheet 1.

A Lapse in Concentration - a Trigonometry Exercise

When drivers start to get tired, they are known to take 'micropauses', during which they either close their eyes and nod off, or they may keep their eyes open but not see or react to what is happening. When drivers take micropauses they often turn the wheel slightly so the car veers off course. The same thing happens when a driver is distracted by something, for example fiddling with the car radio or a tape.

We can use trigonometry to work out the distance a car will travel off course during a micropause, before it touches another car in the opposing lane.

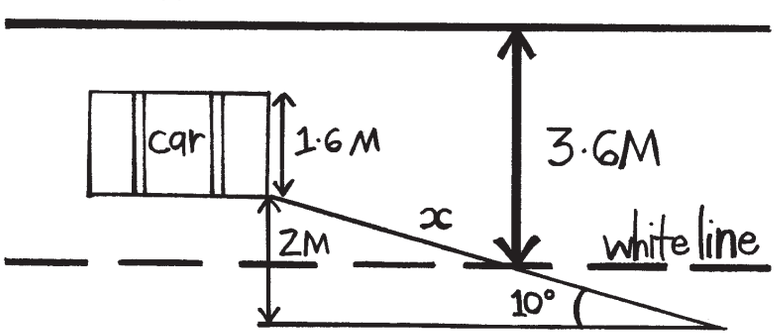
A lane on State Highway One is on average 3.6 m wide and a car is often 1.6m wide. If the car is travelling in the centre of its lane, it is 1m from the middle of the road.



Problems

1 A car is travelling at 50Kmh^{-1} on a straight road, with 3.6 m wide lanes. The driver takes a 'micropause' and she turns the wheel slightly so that the car veers 10^{o} off course towards the middle of the road.

a) How many metres would the car travel before it could touch a car travelling in the centre of the opposite lane?



b) How long would it take the car to travel this distance?

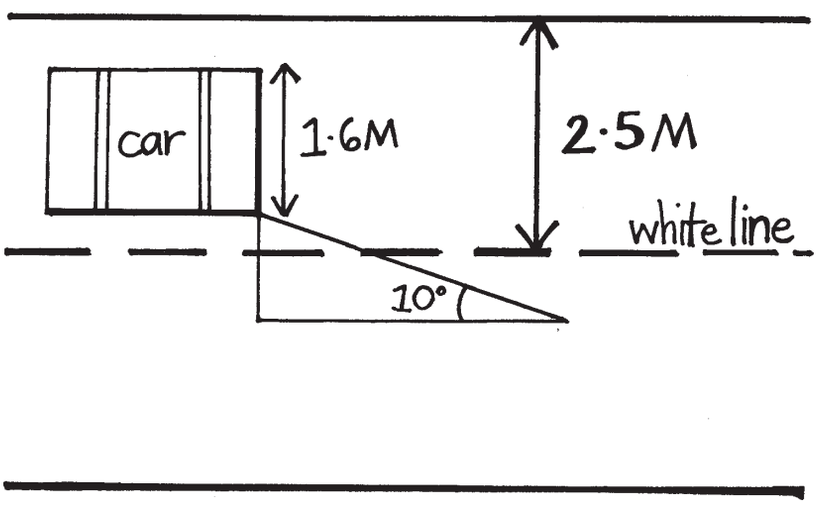
2 A young driver is travelling on State Highway One (3.6 m wide lanes). He takes one hand off the wheel and glances down to try to find a good radio station on his car radio. As he does this, he makes the car veer to the right, 4° off course.

a) How many metres could he travel before he might hit a car in the opposing lane?

b) If the driver is travelling at 80Kmh^{-1}, how long would it take him to travel that distance?

3 **a)** If the driver above was travelling at 100Kmh^{-1}, how long would it take him to travel the distance in question 2?

Some parts of State Highway One are narrower than others, for example each lane might be only 2.5m wide



4 If the road is only 2.5metres wide for each lane, as shown above, how far would you travel before hitting another car if you are 10° off course?

5 You decide to change the tape in the car stereo. The roadway is clear in front of you for at least 200m but there are ditches on either side of the road. The road lanes are 3.6 m wide. You are travelling at 90Kmh^{-1}.

a) If you veer 5° to the right and travel for 1 second while looking down, where are you in relation to where you started and to the ditches?

Sketch a diagram to show this.

b) If you veer 5° to the left and travel 1 second at 90Kmh^{-1}, where are you in relation to where you started and to the ditches?

c) What happens if you look down for 2 seconds and not 1?

6 Explore other possibilities.

What happens with different widths (such as 3 m) and different speeds and different angles?

Make a table such as:

If I veer 5^0 off course-

Speed	**Danger time or Distance**
50 km/h	
70 km/h	
90 km/h	
100 km/h	

Activity 2: *Road Statistics*

Explanation

In this activity, a variety of sets of statistics relating to traffic incidents have been included. Students graph these, and then attempt to analyse them to come up with reasons for the patterns they see. Some helpful teacher information has been provided to assist with this.

Curriculum Links

Mathematics in the New Zealand Curriculum

Statistics: Level 4	Objective 3:	Choose and construct quality data displays.
	Objective 4:	Collect and display time-series data.
	Objective 7:	Make statements about implications and possible actions consistent with the results of statistical investigation.

Equipment

Copysheet 2	**Accidents where Driver Alcohol was a Contributing Factor 1980 - 1998** page 17
Copysheet 3	**Injury Accidents by Time of Day and Day of Week Year Ending 31.12.98** page 18
Copysheet 4	**Fatal Accidents by Time of Day and Day of Week Year Ending 31.12.98** page 19
Copysheet 5	**Accidents Involving Pedestrians by the Time of Day and Day of Week Year Ending 31.12.98** page 20
Copysheet 6	**Pedestrians Injured while Crossing the Road Year Ending 31.12.98** page 21
Copysheet 7	**Accidents where Speed was a Contributing Factor 1980 -1998** page 22
Copysheet 8A-C	**Traffic Legislation since 1965** pages 23 -25

*Note: Statistics were taken from **Motor Accidents in New Zealand 1998 LTSA.***

Police education officers will have access to the new edition each year, for updating statistics.

Teaching

Students can work with the data from Copysheets 2-7 to construct quality data displays. They then make statements about implications of the data and possible actions consistent with the results. Copysheet 8 may be useful to help students decide why patterns have occurred.

The following teacher information may be useful to you.

Teacher Information

Relating to Copysheet 2

1 In December 1988 the legal breath alcohol level was lowered from 500 micrograms of alcohol per litre of breath to 400 micrograms of alcohol per litre of breath.

2 From April 1993 for those aged under 20 years, the legal breath alcohol limit was lowered to 150 micrograms of alcohol per litre of breath, and the legal blood alcohol level was reduced to 30 mg of alcohol per 100ml of blood.

3 April 1993 Compulsory breath testing started

Relating to Copysheets 3 and 6

Note the high pedestrian accidents at times that correlate with going to, and coming home, from school.

Relating to Copysheet 7

1 1985 Open road speed limit increased from 80kms to 100kms

2 1989 Increased fines for speeding infringements

3 October 1993 speed cameras operational

Accidents where Driver Alcohol was a Contributing Factor 1980-1998

Year	No of fatal accidents	No of deaths from fatal accidents
80	192	217
81	199	241
82	232	267
83	205	241
84	222	249
85	238	274
86	266	328
87	271	329
88	266	318
89	264	321
90	268	318
91	225	269
92	221	273
93	185	227
94	190	225
95	162	200
96	129	148
97	127	147
98	118	142

Injury Accidents by Time of Day and Day of Week: Year Ending 31 December 1998

Time of Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Totals
Midnight to 12.59am	7	13	17	18	27	55	42	179
1am to 1.59am	11	4	9	18	26	49	50	167
2am to 2.59am	8	3	7	11	21	53	43	146
3am to 3.59am	5	7	4	12	20	34	39	121
4am to 4.59am	4	1	3	11	13	34	34	100
5am to 5.59am	11	10	13	11	16	22	35	118
6am to 6.59am	30	15	23	32	29	25	29	183
7am to 7.59am	49	60	53	58	45	37	34	336
8am to 8.59am	76	88	100	84	78	46	32	504
9am to 9.59am	55	52	50	52	49	53	38	349
10am to 10.59am	45	43	44	61	61	71	45	370
11am to 11.59am	50	54	57	57	65	77	42	402
Noon to 12.59pm	46	64	70	77	63	79	85	484
1pm to 1.59pm	58	49	57	71	65	59	70	429
2pm to 2.59pm	58	59	58	84	74	74	84	491
3pm to 3.59pm	98	106	102	138	131	84	95	754
4pm to 4.59pm	87	113	87	95	118	92	67	659
5pm to 5.59pm	86	89	106	103	107	66	64	621
6pm to 6.59pm	49	59	61	56	78	77	54	434
7pm to 7.59pm	40	62	71	61	92	57	48	431
8pm to 8.59pm	24	38	44	48	65	41	40	300
9pm to 9.59pm	31	32	34	40	54	46	30	267
10pm to10.59pm	22	17	29	41	49	54	21	233
11pm to11.59pm	10	18	29	29	51	66	19	222
Unknown time	5	2	6	6	3	5	7	34
TOTALS	**965**	**1058**	**1134**	**1274**	**1400**	**1356**	**1147**	**8334**

Fatal Accidents by Time of Day and Day of Week: Year Ending 31 December 1998

Time of Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Totals
Midnight to 12.59am	1	3	1	2	-	4	3	14
1am to 1.59am	1	-	1	3	2	5	3	15
2am to 2.59am	-	-	-	-	2	2	4	8
3am to 3.59am	-	-	-	1	1	4	4	10
4am to 4.59am	-	-	1	2	1	3	2	9
5am to 5.59am	1	-	-	2	2	2	1	8
6am to 6.59am	1	1	1	3	1	2	2	11
7am to 7.59am	1	-	-	1	2	4	2	10
8am to 8.59am	6	3	3	5	4	2	2	25
9am to 9.59am	1	5	2	1	5	5	1	20
10am to 10.59am	3	1	3	4	3	3	3	20
11am to 11.59am	1	-	5	3	4	5	7	25
Noon to 12.59pm	3	2	4	1	1	1	1	13
1pm to 1.59pm	3	4	2	2	5	2	6	24
2pm to 2.59pm	3	1	3	5	2	1	2	17
3pm to 3.59pm	4	3	6	5	9	3	4	34
4pm to 4.59pm	2	8	1	2	4	1	5	23
5pm to 5.59pm	2	4	4	5	6	7	4	32
6pm to 6.59pm	4	7	2	3	7	5	3	31
7pm to 7.59pm	2	-	7	2	3	5	2	21
8pm to 8.59pm	2	3	1	6	3	6	2	23
9pm to 9.59pm	2	-	1	4	2	3	-	12
10pm to10.59pm	3	-	3	-	4	4	1	15
11pm to11.59pm	-	-	2	5	4	2	1	14
Unknown time	-	-	-	-	-	1	1	2
TOTALS	**46**	**45**	**53**	**67**	**77**	**82**	**66**	**436**

Accidents Involving Pedestrians by Time of Day and Day of Week:Year Ending 31 December 1998

Time of Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Totals
Midnight to 12.59am	-	-	-	2	2	3	9	16
1am to 1.59am	-	-	-	-	1	6	3	10
2am to 2.59am	1	1	-	1	1	3	3	10
3am to 3.59am	-	-	1	2	3	2	4	12
4am to 4.59am	-	-	1	-	-	2	3	6
5am to 5.59am	-	1	1	-	1	1	2	6
6am to 6.59am	4	-	-	2	-	1	1	8
7am to 7.59am	3	4	1	4	2	1	-	15
8am to 8.59am	12	12	16	9	18	4	1	72
9am to 9.59am	6	4	7	5	4	3	1	30
10am to 10.59am	6	4	3	5	7	7	6	38
11am to 11.59am	3	6	2	7	10	10	4	42
Noon to 12.59pm	8	8	8	10	4	7	7	52
1pm to 1.59pm	10	7	5	4	8	6	8	48
2pm to 2.59pm	-	3	6	15	7	10	5	46
3pm to 3.59pm	16	23	20	28	34	9	7	137
4pm to 4.59pm	10	21	10	14	16	9	6	86
5pm to 5.59pm	17	7	6	17	18	3	4	72
6pm to 6.59pm	8	5	7	3	8	14	5	50
7pm to 7.59pm	7	3	8	4	11	8	4	45
8pm to 8.59pm	2	4	4	4	3	7	4	28
9pm to 9.59pm	3	-	1	3	2	3	-	12
10pm to10.59pm	4	3	1	2	4	4	-	18
11pm to11.59pm	1	-	-	2	5	10	-	18
Unknown time	-	-	-	-	-	-	2	2
TOTALS	**121**	**116**	**108**	**143**	**169**	**133**	**89**	**879**

Pedestrians Injured while Crossing the Road: Year Ending 31 December 1998

Pedestrians Injured because:	**No of pedestrians**
Walking heedless of traffic	187
Stepping out from behind parked vehicle	52
Running heedless of traffic	323
Failed to use crossing within 20 metres	12
Waiting on roadway in moving traffic	10
Confused by traffic or stepping back	12
Stepping suddenly onto crossing	14
Misjudged speed and/or distance of vehicle	11
Did not comply with traffic signals or patrols	26
Other	5
Total	652

Accidents where Speed was a Contributing Factor 1980-1998

Year	No of Fatal Accidents	No of Fatal Casualties
80	185	216
81	183	219
82	215	244
83	167	194
84	197	218
85	193	218
86	192	224
87	251	292
88	231	267
89	257	311
90	224	265
91	190	225
92	195	241
93	192	228
94	191	228
95	182	221
96	153	177
97	137	162
98	140	162

Traffic Legislation since 1965

The following is a brief listing of traffic legislation introduced since 1965.

1965 (1) All new motor cars, station wagons and light trucks must be fitted with safety belts.

1967 (1) Introduction of the demerit points system.

(2) Driving at an "unreasonably slow speed" became a traffic offence.

1969 (1) Introduction of breath and blood alcohol tests.

(2) Introduction of parking infringement system.

(3) Minimum tread depth for pneumatic tyres prescribed.

1971 (1) Speeding Infringement System introduced.

1972 (1) Compulsory testing for blood alcohol of accident victims at hospitals

(2) Compulsory fitting and wearing of safety belts for certain drivers and front seat passengers 15 years and over in light vehicles registered since 1965.

1973 (1) Safety helmets compulsory for motor cyclists and pillion riders at all speeds, previously (from 1956) they were only compulsory if travelling in excess of 30mp/h (50km/h).

(2) Maximum open road speed limit reduced from 55 mph to 50 mph (80 km/h) as part of fuel conservation measures. Effective from 4 December 1973.

1975 (1) Seat belt requirements (see 1972 above) extended to all motor vehicles registered on or after 1 January 1955.

(2) Change over to metric speed limits and road signs.

1977 (1) New traffic regulations. (Traffic Regulations 1976) came into effect bringing major changes to give way rules, intersections and pedestrian crossings.

1978 (1) Introduction of evidential breath testing. Lowering of permissible blood alcohol level from 100 milligrams of alcohol per 100 millilitres of blood to 80 milligrams per 100 millilitres. Tougher criteria for issue of limited licences to disqualified drivers.

1979 (1) Age for compulsory seat belt use lowered to 8 years old.

1980 (1) Introduction of Traffic Infringement Systems to speed up processing of minor traffic offences plus notices of prosecution servable on roads.

1981 (1) Traffic Regulations 1976 heavily amended to provide legal framework for safe installation and inspection of alternative fuel systems.

1983 (1) The Transport Amendment Act (No 2) 1983. Introduced to provide an orderly phase-out of the 150-km rail protection by allowing shippers, upon payment of a long distance haulage fee, to use road transport in circumstances in which they were previously required to use rail. Effective from 1 November 1983.

(2) The Transport Amendment Act (No 3) 1983. Allowing the Court to make an order requiring a person, convicted twice or more in a five year period of specific alcohol or drug related traffic offences, to attend an Assessment Centre and for disqualification from holding or obtaining a driver's licence until the Secretary for Transport makes an order removing that disqualification. Effective from December 1983.

1984 (1) Regulations governing the approval and use of child restraints introduced.

1985 (1) The Open Road Speed Limit was increased from 80km/h to 100 km/h for all vehicles except Heavy Motor Vehicles (speed limit now 90km/h), articulated vehicles (90km/h) and vehicles towing trailers (80km/h). Effective from 1 July 1985.

1986 **(1)** Staggered relicensing of motor vehicles and provision for lifetime drivers' licences introduced.

(2) Strict liability for carriage of insecure loads came into effect (1 February).

1987 **(1)** Increased powers of arrest for traffic officers, new driving hours and logbook requirements for professional drivers, graduated licensing system and increased penalties for unlicensed driving introduced (1 August).

1988 **(1)** Lowering of legal breath alcohol level from 500 g/l to 400 g/l and the removal of the officers' right to require a blood sample in certain circumstances. Increased maximum monetary penalty for serious traffic offences and an increase in the level of infringement fees payable for a number of offences. Introduction of community based sentences as a substitute for disqualification. Increased powers for enforcement officers dealing with offenders who fail to stop.

(2) Introduction of class C roads and the removal of the class II road classification. Revised maximum weights for heavy motor vehicles.

1989 **(1)** Introduction of the Transit New Zealand Act.

(2) Introduction of the Transport Services Licensing Act.

(3) Introduction of a new schedule of infringement fees to cover a wide range of minor offences and road users charges infringements. Increased fees for speeding infringements.

(4) Traffic enforcement officers given power of entry onto private property for the purposes of undertaking drink driving procedures.

(5) Assumption of national traffic enforcement control by the Ministry of Transport.

(6) Introduction of new regulations governing the transport of hazardous substances.

1990 **(1)** Amendment made to the Transport Act to validate the breath test notice in its existing form.

(2) Introduction of the Transport (Vehicle Standards) Regulations 1990.

1991 **(1)** There was a change in the driver licence regulations to allow the introduction of the 'scratch' driver licence testing forms.

1992 **(1)** The merger of the Traffic Safety Service Branch of Ministry of Transport with the NZ Police was implemented 1 July.

(2) Amendments made to the Transport Act to allow for compulsory breath testing, reducing alcohol limits for under 20 year olds, extended owner liability regime and reducing driving hours regime – all to be brought in over 1993.

(3) Amendments made to the Transport Licensing Act to allow for area knowledge for taxi drivers, the licensing of rail services, 5 year id cards and tighter controls over taxi organisations- all to be implemented during 1993.

(4) Amendments made to T (V & DR & L) Act to implement the new MVR system in 1994.

(5) New Railway Safety and Corridor Management Act to come into force over 1993.

(6) Amendments made to the Transport Accident Investigation Commission Act to include rail accidents.

(7) Amendments made to the Local Government Act to simplify procedures for removing abandoned vehicles.

(8) Amendments made to the Road User Charges Act to implement new RUC system over 1993.

1993 **(1)** Compulsory Breath Testing commenced April 93.

(2) Speed cameras operational October 93.

(3) Changes to demerit point system, including application from date of offence and graduated points for speeding offences.

(4) Introduction of VIN system for vehicle identification purposes.

(5) Land Transport Act 1993 created the Land Transport Safety Authority and authorised the making of Rules.

1994 (1) Compulsory cycle helmet wearing implemented on 1 January.

(2) Compulsory child restraints for 0-2 year olds from 1 April.

1995 (1) Compulsory child restraints for 3-5 year olds from 1 April.

(2) Traffic Regulations 1976 amended to provide for reintroduction of light rail/tram services (effective from 20 January 1995).

(3) Clarification of colours for use in personalised registration plates, new range of numbers for trailers, and new combined trade plate and licence introduced from 1 July 1995.

(4) Land Transport Amendment Act 1995 introduced new National Land Transport Strategy and Regional Land Transport Strategy, with effect from 1 July 1996.

(5) Transit NZ Amendment Act 1995 provides for new road funding body, Transfund New Zealand, and revised Safety (Administration) and Roading Programmes regime, from 1 July 1996.

(6) Clarification of vehicle inspection certificate regime's application to registration, licensing and change of ownership of motor vehicles.

(7) Clarification of Police enforcement powers in respect of heavy vehicles and Road User Charges.

(8) Amendment to Transport (Vehicle and Driver Registration and Licensing) Act to provide for continuous licensing of motor vehicles (brought into force with effect from 1 September 1997).

1996 (1) Transfund was created as a new crown entity on 1 July 1996 with the principal objective of allocating resources to achieve a safe efficient roading system.

(2) The Glazing Rule was gazetted in 1996 to come into effect on 1 January 1997. The rule established minimum standards to ensure safe levels of visibility and structural strength for automotive glazing.

1997 (1) Six vehicle standards rules for impact protection were signed into law in August 1997 to come into effect on 1 January 1998.

1998 (1) The Land Transport Act 1998 was passed. The Act carried forward the administrative structures and law making processes of the 1993 Act. It incorporates and updates other transport legislation, and makes substantive changes to parts of transport law such as driver licensing, including provision for photographic licences.

(2) Vehicle Compliance and Repair Rules were signed into law to come into effect in January 1999.

Activity 3: *Calculating Reaction time*

Explanation

This activity can be used for statistics, investigation work and/or problem-solving.

Curriculum Links

Mathematics in the New Zealand Curriculum

Number:	Level 5	Objective 2: Round numbers sensibly.
Measurement:	Level 4	Objective 1: Carry out a measuring task.
	Level 4	Objective 5: Make calculations involving time.
Statistics	Level 5	Objective 5: Collect and display comparative samples in appropriate displays.
Algebra	Level 6	Objective 6: Substitute values into formulae.

Equipment

Metre rules

Calculators

Copysheet 9 A-B **Reaction Time Statistics Exercise** pages 28 - 29

Copysheet 10 **Data Sheet – Adult Reaction Times** page 30

Teaching

1 Students work in pairs for this activity which involves calculating reaction time.

It is best to measure the distance the metre rule falls three times and take the median of the three measurements.

Step 1	Student 1 rests their arm on the desk so that their hand is over the edge of the desk in a position that enables them to grasp the ruler as it falls.
Step 2	Student 2 places the metre ruler in position, hanging between, but not touching, the fingers and thumb of Student 1. Student 2 takes note of what measurement is at the position of the fingers.
Step 3	Without warning, Student 2 drops the ruler. Student 1 reacts by grasping it. This is repeated three times.
Step 4	The pair swap roles and repeat the exercise.
Step 5	The students calculate their reaction time to 2dp (2sf).

They use the formula $\mathbf{t} = \sqrt{\frac{\mathbf{d}}{\mathbf{4.9}}}$ **t** is in seconds **d** is in metres

Step 6 Data from all the pairs is collected on to a Data Sheet like the one in Copysheet 10.

Comment

Teachers may wish to discuss:

a) The formula is from $\mathbf{t} = \sqrt{\frac{\mathbf{d}}{\mathbf{4.9}}}$

b) Average – we used median, not mean. Why?

2 You may like to repeat Steps 1-6 while playing loud pop music (students' choice) to see if it has any effect on reaction time. Discuss the effect that playing the car stereo very loudly might have on drivers.

3 Hand out Copysheets 9 and 10. Working individually, students complete these activities.

Reaction Time – Statistics Exercise

Equipment

Calculators

Data from Reaction Time Activity

Copysheet 10 **Data Sheet – Adult Reaction Times** page 30

1 Copy and complete the frequency tables shown below, using the adult reaction times (given on Copysheet 10) and the student reaction times (collected earlier from all the pairs in class).

Adult Reaction Times (sec)	**Tally**	**Frequency**
0.12 -		0
0.14 -	1	1
0.16 -	11	2
0.18 -		
0.20 -		
0.22 -		
0.24 -		
0.26 – 0.28		

Total 24

Student Reaction times (sec)	**Tally**	**Frequency**
0.12 -		
0.14 -		

2 Draw histograms for each set of data.

3 Calculate the following statistics for each set of data

a) median

b) mean

c) mode

d) upper and lower quartile

e) the interquartile range

4 Draw box and whisker graphs for each set of data.

Draw them together so they can be compared.

5 Use your graphs and statistics to:

a) Comment on each set of data.

b) Compare the results to look for similarities and differences in each set of data.

6 Write a list of the factors that might affect the reaction time of people.

7 Why are reaction times important for all road users, especially drivers?

Data sheet – Adult Reaction Times

This data has been collected from 24 adults ranging in age from 23 to 55.

The data is recorded in the order it was collected.

Remember the formula: $\mathbf{t} = \sqrt{\frac{\mathbf{d}}{\mathbf{4.9}}}$

t = reaction time in seconds **d** = reaction distance in metres

	Measurements from ruler			Median Distance	Reaction Time
1	0.10	0.16	0.19	0.16m	0.18secs
2	0.23	0.17	0.21	0.21m	0.21secs (2dp)
3	0.38	0.21	0.18		
4	0.26	0.27	0.31		
5	0.35	0.21	0.32		
6	0.14	0.22	0.25		
7	0.09	0.29	0.10		
8	0.23	0.23	0.18		
9	0.18	0.20	0.21		
10	0.28	0.19	0.19		
11	0.18	0.08	0.24		
12	0.24	0.21	0.14		
13	0.22	0.13	0.21		
14	0.21	0.17	0.14		
15	0.16	0.19	0.39		
16	0.32	0.23	0.40		
17	0.27	0.57	0.36		
18	0.32	0.18	0.22		
19	0.19	0.12	0.22		
20	0.26	0.27	0.19		
21	0.14	0.14	0.10		
22	0.29	0.15	0.18		
23	0.40	0.23	0.23		
24	0.18	0.19	0.14		

Activity 4: *Stopping Distances for Cars*

Explanation

In this activity, students are calculating total stopping distances of cars travelling at different speeds, modelling the results on graphs and considering factors other than speed and weather conditions that may affect stopping distances.

Curriculum Links

Mathematics in the New Zealand Curriculum

Algebra:	Level 5	Objective 3:	Sketch and interpret linear graphs which represent everyday situations.
	Level 6	Objective 4:	Graph quadratic functions.
Number:	Level 5	Objective 2:	Round numbers sensibly (dp + sf).
Problem-solving:	Level 5	Objective 4, 5:	Use a mathematical model as a problem-solving strategy.

Equipment

Calculator

Squared paper

Copysheet 11 A-C **Stopping Distances for Cars pages 33 - 35**

Teaching

Students work individually on this activity, using Copysheet 11.

Teacher Notes

Graph Types

Expect a linear pattern for reaction distance, quadratic patterns for braking and stopping distances.

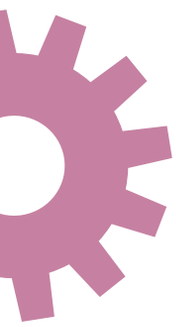
Reaction Time

The reaction times calculated in Activity 3 average close to 0.25 seconds. This experiment measured only the time taken to execute a reaction of the fingers for alert individuals. Reaction times for a leg (accelerator to brake) are longer - longer still if individuals tested are not alert.

There are 5 factors that affect reaction time in stopping vehicles:

- Perception of a hazard
- Identification of the nature of a hazard
- Consideration of response options
- Choice of response
- Execution of choice

In this exercise a conservative reaction time of 1 second is used for an alert person to react to a hazard AND to get one's foot to the brake pedal. The Land Transport Safety Authority (LTSA) advise that reaction times are variable and can be significantly longer if a hazard is not perceived immediately and if the cognitive process leading up to the actual execution of the choice option is slow.



Other Factors that Could Affect Stopping Distances

Towards the end of this activity students are invited to consider/brainstorm other factors that could impact on stopping distances by affecting **reaction time** (eg. Distraction, loud stereo in car, number of passengers, alcohol, tiredness, experience, age...) and **braking distance** (eg. road surface, speed, condition of tyres, gradient of road, ABS brakes..)

Stopping Distances for Cars

– An Exercise in Graphical Modelling

Equipment

Calculator

Squared paper

In this activity you will calculate total stopping distances of cars travelling at different speeds, model the results on graphs and consider factors, other than speed and weather conditions, that may affect stopping distances.

Note 1 - Reaction Time

The average time taken for an alert person to start reacting to a hazard has been measured as close to 0.25 seconds.

In this exercise, a conservative reaction time of 1 second is used as the average time taken to react to a hazard AND to get one's foot to the pedal brake. The Land Transport Safety Authority (LTSA) advise that reaction times are often longer than this when danger is not immediately expected.

Note 2 - Converting Km/h to m/s

60 km/h	*= 60,000m/h*	*(x1000)*
	= 1000m/min	*(÷60)*
	= 16.67m/sec (2dp)	*(÷60)*

1 Calculating Reaction Time

Reaction distance is the distance a car travels in the 1 second it takes for an alert person to get their foot to the brake when reacting to a hazard.

Copy and complete this table to calculate reaction distances.

Speed (Km/h)	Speed (m/s)	Reaction distance (m)	Reaction distance (nearest m)
30 Km/h	$8.\dot{3}$	$8.\dot{3} \times 1.0 = 8.\dot{3}$	8
50 Km/h	$13.\dot{8}$		
70 Km/h			
80 Km/h			
100 Km/h			
115 Km/h			

2 Graphing Reaction Distances

Carefully draw a graph showing the relationship between speed and reaction distance. (Label the horizontal axis **Speed** and the vertical axis **Metres Travelled**).

Plot the points from your table.

Draw the line of best fit through these points.

What type of graph is this?

3 Graph Interpretation

Answer these questions from the graph you have just drawn.

(a) What distance will you travel before your foot gets to the brake as a child steps out onto the road in front of you, while you are travelling at:

(i) 50 km/h **(ii)** 60 km/h **(iii)** 90 km/h

(b) On the open road a car speeds at 130 km/h. The driver suddenly notices a speed camera ahead. How far has the car travelled before the speeding driver is able to brake?

(c) Find the speed at which a car will be travelling if the reaction distance travelled is measured at:

(i) 19m **(ii)** 26m

(d) A bystander notices a cat run onto the road in front of a car passing directly opposite her. The car driver brakes and skids into a stationary vehicle. Skid marks indicate where the driver started to brake.

If the skid mark begins 13m from where the bystander was standing, at what speed was the car travelling prior to braking?

4 Calculating Stopping Distances

Land Transport Safety Authority (LTSA) analysis provides statistics for Braking Distances. These are shown on the table below.

Copy the table below and transfer Reaction Distance data from your table in Question 1. To calculate **Total Dry Stopping Distance** add **Reaction Distance** and **Dry Braking Distance**.

Note: Total Stopping Distance = Reaction Distance + Braking Distance

Speed (km/h)	Reaction Distance (m)	Dry Braking Distance (m)	Total Dry Stopping Distance (m)	Wet Braking Distance (m)	Total Wet Stopping Distance (m)	Difference between Wet & Dry Stopping Distances (m)
30		6		8		2m
50		16		28		12m
70		32		62		30m
80		43		84		41m
100		69		136		67m
115		96		180		84m

5 Graphing Stopping Distances

Carefully draw a grid to graph Total Stopping Distances.

Label your horizontal axis **Speed** with a scale from 0 to 125 km/h.

Label your vertical axis **Distance** in metres from 0 to 200.

(a) Plot the points for Total Dry Stopping Distances from your table.
Carefully draw a smooth line of best fit through these points.
Label this line **Total Dry Stopping.**

(b) On the same grid, plot the points for Total Wet Stopping Distances from your table.
Carefully draw a line of best fit through these points.
Label this line **Total Wet Stopping Distance.**

(c) On the same grid, plot the points for difference between Wet and Dry Stopping Distances. Carefully draw a smooth line of best fit through these points. Label this line appropriately.

(d) What do you notice about these graphs? (speed, shape, characteristics..)

6 Graph Interpretation

Answer these questions from the graphs on your grid.

(a) What is the total stopping distance on a dry road at:
(i) 40km/h **(ii)** 60km/h **(iii)** 90km/h **(iv)**125 km/h

(b) What is the total stopping distance on a wet road at:
(i) 40km/h **(ii)** 60km/h **(iii)** 90km/h **(iv)**125km/h

(c) If a child steps out onto the road in front of your car, what distance will you travel before you stop if you are travelling at:
(i) 50km/h in dry conditions **(ii)** 70km/h in wet conditions

(d) You are travelling on the open road in good conditions. You turn a corner and notice a crash in front of you.
(i) You are travelling at 95km/h.
How far from the crash will you need to be to avoid collision?
(ii) The distance between the crash and you is 60 metres.
Below what speed would you need to be travelling to avoid collision?

(e) In dry conditions, a car travelling at 70km/h can stop in 32 metres. In wet conditions, at what speed would you need to be travelling to stop in the same distance?

Exploring Further

(a) Explore the effect of different reaction times (eg 1.5s, 2s. etc) on stopping distances.

(b) Explore other factors that could influence stopping distance by affecting:
(i) Reaction time **(ii)** Braking distance

7 Advice

What advice would you give drivers about:

a) Driving in wet conditions

b) Watching for hazards

c) Following distances?

Activity 5 - *Stopping Distances for Cars*

An Exercise in Modelling by Formula

Explanation

In this activity, students are using formulae derived from physical laws of energy and motion to model and calculate braking distances and total stopping distances for cars travelling at different speeds and on different road surfaces. The calculated data will be used to investigate the relationship between speed, road surface conditions and stopping distances for a car.

Curriculum Links

Mathematics in the New Zealand Curriculum

Problem-solving:		Objectives 4,5:	Use a mathematical model as a problem-solving strategy.
Measurement:	Level 6	Objective 4:	Use information about rates numerically and in tables.
Algebra:	Level 6	Objective 6:	Substitute values into formulae.
	Level 4	Objective 2:	Use a rule to make predictions.
Developing Logic and Reasoning:		Objective 3:	Interpret information and results in context.
Number:	Level 5	Objective 2:	Round numbers sensibly.

Equipment

Calculator

Squared paper

Copysheet 12 A-E - **Stopping Distances for Cars** pages 38 - 42

Teaching

Students can work individually or in groups on this activity, using Copysheet 12.

Teacher Notes

Slide to Stop Formulae

If a car slides to a complete stop on full brake lock, the amount of work done in stopping the car *(Work = Fd)* will be equal to the amount of kinetic energy **(**$KE = \frac{1}{2}mv^2$**)** that the car initially had.

The braking distance will be proportional to the square of velocity and dependent also upon road surface conditions (f).

The principle of Conservation of Energy and related physical laws generate the formulae below.

1. $v = \sqrt{254fd}$

v = velocity (km/h)

f = coefficient of friction for the road surface

d = braking distance (m) – i.e. length of Tyre Friction Mark (TFM)

2. $d = \frac{v^2}{254f}$ by rearrangement of formula 1 above

In this activity only the second formula is supplied to the students to find braking distances given initial velocity and a friction coefficient. It can still be used in later questions where initial velocities are required to be found, given braking distance and friction coefficients. It is left to the judgement of the teacher whether or not the first form of the formula is introduced to students for use in these questions.

Friction Coefficient (f)

The calculations performed using the Slide to Stop model assume:

- Flat straight surfaces (no bends, no gradient).
- A full brake-locked skid where the vehicle comes to rest without hitting anything.
- A constant coefficient of friction for a particular road surface.

The Friction coefficient does in fact vary according to the speed of a vehicle on any given surface. In general, the greater the speed, the less friction there will be operating between the car and the road. To illustrate, a surface with a friction coefficient of $f = 0.8$ at 25 km/h has been measured to have the following friction coefficients at different speeds:

50 km/h ($f = 0.7$); 75 km/h ($f = 0.6$); 100 km/h ($f = 0.55$)

It is beyond the sophistication of this activity to build this factor into our model. It does indicate further steps that need to be taken to fine-tune this model, and it does suggest that our calculations will be on the conservative side for higher speeds.

Derivation of the Slide to Stop Formulae

Work done to stop Car = Initial kinetic energy of Car

Hence $Fd = \frac{1}{2}mv^2$ F = force of friction between tyres & road (*Newtons*)

d = braking distance (m)

m = mass (Kg)

v = velocity (m/s)

= $wfd = \frac{1}{2}mv^2$ force = weight x coefficient of friction

$= wf$

= $mgfd = \frac{1}{2}mv^2$ weight = mass x gravity

$= mg$

= $gfd = \frac{1}{2}v^2$

= $2gfd = v^2$

= $\sqrt{2gfd} = v$

= $3.6\sqrt{2gfd} = v$ convert m/s to km/h

= $\sqrt{2(3.6)^2gfd} = v$

= $\sqrt{2(3.6)^2(9.81)fd} = v$ g = *gravity* = $9.81m/s^2$

= $\sqrt{254fd} = v$

Stopping Distances for Cars

An Exercise in Modelling by Formula

Equipment

Calculator

Squared paper

In this activity you will use formulae to calculate stopping distances for cars travelling at different speeds and on different road surfaces. This data will be used to investigate the relationship between speed, road surface conditions and stopping distances for a car.

Note 1 – Reaction Distance

Reaction Distance is the distance a car travels in the 1 second (Reaction Time) it takes for alert drivers to get their foot to the brake when reacting to a hazard.

The Land Transport Safety Authority (LTSA) advise that reaction times are often longer than 1 second when danger is not immediately expected.

Note 2 – Braking Distance

***Braking Distance** is the distance it takes a car to slide to a complete stop on full brake-lock.*

***Note 3 – Total Stopping Distance** = Reaction Distance + Braking Distance*

Part A Calculating the Data

1. Copy this table and calculate the remaining **Reaction Distances.**
Follow the method set out below. Round all distances to the nearest metre.

Speed km/h	20	30	40	50	60	70	80	90	100	110	120
Reaction Distance (m)	6	8	11	14	17	19					

e.g. For 60 km/h: 60 km/h = 60000 m/h (x 1000)

= 16.67 m/s (÷ 3600)

So, Reaction Distance = 16.67 m/s x 1.0 s

= 17m (nearest metre)

2. Copy the table on the following page and calculate the **Braking Distances** for the different road surfaces. Follow the method set out beneath the table and round to the nearest metre.

Note 1 – The "Slide to Stop" Formula

*The Braking Distance of a car will be affected by its **speed** and the condition of the **road surface.***

The formula $d = \frac{v^2}{254f}$ *has been derived from Physics where:*

d = *Braking Distance (metres)*

v = *The Speed of the car (km/h)*

f = *the coefficient of friction or "grip" factor for the road surface.*

Braking Distance (metres)				
Speed (km/h)	**Bitumen Smooth Top (Dry)**	**Common NZ Chip Seal (Dry)**	**Gravel (Dry)**	**Wet Surface**
	***f* = 0.75**	***f* = 0.6**	***f* = 0.45**	***f* = 0.35**
20 km/h				
30 km/h				
40 km/h				
50 km/h				
60 km/h	19	24	31	40
70 km/h				
80 km/h				
90 km/h				
100 km/h				
110 km/h				
120 km/h				

e.g., For a car travelling at 60 Km/hr on Common NZ Chip Seal in dry conditions:

Braking Distance $= d = \frac{60^2}{254 \times 0.6}$ ($v = 60$ & $f = 0.6$)

$= 23.62$ m (2dp)

$= 24$m (nearest metre)

3. The table below lists **Total Stopping Distances** for different road surfaces. Check that your calculations for *Reaction Distance* and *Braking Distance* add to give the below figures listed

Total Stopping Distance (metres)				
Speed (km/h)	**Bitumen Smooth Top (Dry)**	**Common NZ Chip Seal (Dry)**	**Gravel (Dry)**	**Wet Surface**
20 km/h	8	9	9	10
30 km/h	13	14	16	18
40 km/h	19	21	25	29
50 km/h	27	30	36	42
60 km/h	36	41	48	57
70 km/h	45	51	62	74
80 km/h	56	64	78	94
90 km/h	68	78	96	116
100 km/h	80	94	115	140
110 km/h	95	110	137	167
120 km/h	109	127	159	195

Part B Interpreting the Data

1. It takes longer to stop than most people think. To assist in getting a feel for distances, the lengths of some common playing fields are listed below.

Badminton Court (13.4m)	**Cricket Wicket (20m)**
Tennis Court (23.8m)	**Basketball Court (28m)**
Netball Court (30.5m)	**Hockey Field (90m)**
Soccer Field (90m – 120m)	**Rugby Field (100m)**

(a) Choose an appropriate playing field to represent the distance a car will travel before the foot of an alert driver will get to the brake when reacting to a hazard at:

(i) 50 km/h **(ii)** 70 km/h **(iii)** 100 km/h **(iv)** 120 km/h

(b) In comparison to any of the playing fields listed above, approximately how long does it take to stop on Common NZ Chip Seal in *dry* conditions at:

(i) 50 km/h **(ii)** 70 km/h **(iii)** 100 km/h **(iv)** 120 km/h?

(c) Approximately how many rugby fields does it take to stop in *wet* conditions at:

(i) 50 km/h **(ii)** 70 km/h **(iii)** 100 km/h **(iv)** 120 km/h?

2. Calculate the difference in **braking distance** between:

(a) travelling at 70 km/h on Bitumen in dry conditions and travelling at 70 km/h on Bitumen in wet conditions.

(b) travelling at 100 km/h on Chip Seal in dry conditions and travelling at 100 km/h on Chip Seal in wet conditions.

(c) travelling at 50 km/h and 100 km/h on Bitumen in dry conditions.

(d) travelling at 50 km/h and 100 km/h on Gravel in dry conditions.

3. Consider the following statements.

"If you double your speed, you must allow four times the braking distance".

"In wet conditions, braking distance doubles".

"As a general rule, if you allow 50 metres stopping distance you will be safe".

Select one of these statements and investigate whether it is true or not. Your conclusions should take the form of an article in a community newspaper on safety issues. Your article should be at least half a page in length and should include relevant data from your calculations to back up your argument.

Part C Crash Analysis and the "Slide to Stop" Formula.

1. You are a road accident analyst who has been required by the court to investigate three separate cases. In each case you must advise the court whether there is enough evidence to charge the driver with speeding, giving your reasons. Each situation is described below.

(a) The first incident involves a driver who has knocked over a pedestrian in a 50 km/h speed zone. In trying to avoid the pedestrian, the driver skidded to a full stop. At the scene of the accident, you measure the length of the car's skid mark at 19 metres. You also measure the friction coefficient (f) of the road surface to be 0.55.

(b) The second case was in a 70 km/h speed zone. The driver being investigated braked hard to avoid a car pulling out from a side street but was unable to stop before hitting the other car causing minor damage. You measure the length of the car's skid mark at 56 metres and the friction coefficient (f) of the road surface at 0.55.

(c) The third incident was on the open road which has a speed limit of 100 km/h. A driver slammed on the brakes when a flying stone shattered his windscreen. He slid to a full stop but in doing so crossed into the oncoming lane. While he did not hit anything, two oncoming cars had to take evasive action and ended up crashing through a fence into an adjacent field. Only minor injuries resulted.
You measure the length of the car's skid mark at 66 metres and the friction coefficient (f) of the road surface at 0.65.

2. Frequently a vehicle slides over a variety of surfaces before coming to a halt. By measuring the length of a car's skid mark on each surface, and the friction coefficient (f) for each surface, a reliable assessment of the car's initial speed can be made by using the formula below.

Formula for "Slide to Stop" over Different Surfaces

It can be shown that $v = \sqrt{254 f_1 d_1 + 254 f_2 d_2 + 254 f_3 d_3 + \ldots}$ depending upon how many surfaces a car slides across, and where:

v = Initial Speed (km/h)

f_1, f_2, f_3 etc = the friction coefficients of each surface

d_1, d_2, d_3 etc = the length of the skid mark on each surface

(a) A car takes 17 metres to slide to a halt on the flat. The first 6 metres of the skid mark was on tar seal and the remaining 11 metres of the skid mark was on loose gravel. The friction coefficient (f) for the tar seal was measured at 0.65 and at 0.4 for the gravel. Give a reliable assessment of the car's initial speed.

(b) Residents of a quiet street were upset at an accident they believed to be the result of too much speed. A car swerved and braked hard to avoid Mavis Brown's cat. The car then slid 10 metres on the tar seal, 8 metres across the grass verge, 4 metres along the concrete footpath, then 6 more metres across Beverly Green's recently mown lawn.

While apologetic, the driver strenuously denied travelling beyond the 50 km/h speed limit. You have been called to investigate the situation.

You measure the coefficients of friction for the different surfaces and find for the tar seal f= 0.7, for the wet and longish grass verge f= 0.4; for the concrete f= 0.8 and for Beverly Green's short cropped lawn f= 0.5.

(i) Is there evidence that the car was speeding?

(ii) What do you estimate the speed of the car to be prior to braking?