Semester 1 Examination, 2012

PHYSICS

Stage 2 2011 ANSWERS

Section One: Short answers 42% (53 Marks)

1. Why is there a rule that university research students are never allowed to eat or drink in a Science laboratory where radioactive isotopes are being used? [3 marks]

Eating in the lab could involve the ingestion of contamination by radioactive materials left there. 1

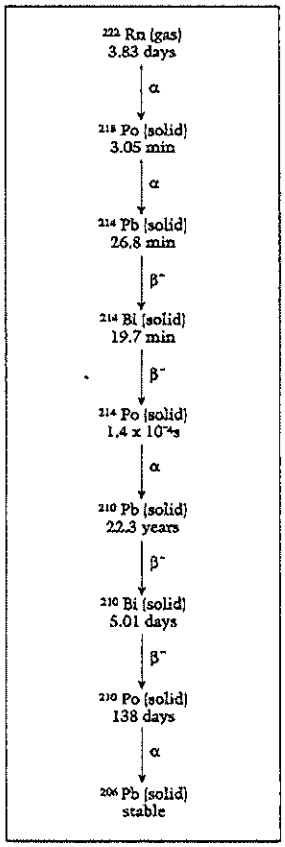
Radioactive materials inside the body are more dangerous 1
as there is direct irradiation of unprotected body cells. 1

3. The diagram below shows part of the decay series for radon 222. The half lives of radon and subsequent daughters is also shown. Use the decay series to write balanced nuclear equations for the following decays:

[4 marks]

(a) Bi 210 decaying to Po – 210

(b) Po 210 decaying to Pb - 206



Radon daughters, their decays and half-lives.

4. Plutonium 94 is an extremely toxic element that would have been present on the Earth's surface when the Earth was first formed about 4.50×10^9 years ago. Explain why uranium is fairly abundant on the Earth today but plutonium-94 cannot be found? [2 marks]

Uranium 238 has a very long half-life (4.5×10^9 y) but plutonium has a fairly short one.

The Earth is about 4×10^9 years old so a lot of uranium would remain but almost all the plutonium would have decayed.

5. a) An atom of helium-4 is made up of 2 protons and 2 neutrons in its nucleus.

The mass of the 2 protons and 2 neutrons, compared with the mass of the helium-4 nucleus would be: (circle the correct answer)

Greater than the nucleus

Less than the nucleus

Same as the nucleus

[1 mark]

b) Explain your answer to part a). [3 marks]

The mass of the nucleus is less than the sum of its particles because some of the mass has been converted to Binding Energy. 1

Binding Energy is used to hold the nucleons together in the nucleus 1

according to Einstein's formula $E = mc^2$. 1

6. a) A car of mass 1.50×10^3 kg is at rest when the driver accelerates so that the impulse produced by the engine is 2.00×10^4 Ns. What would be the value of the velocity of the car after this initial acceleration?

[3 marks]

Impulse = momentum change = mv 1

$2 \times 10^4 = 1500v$ 1

$v = 13.3\ ms^{-1}$ 1

b) Calculate the kinetic energy of the car after the impulse from the engine has been applied. (If you couldn't do part a of this question, use a value of 12.0 ms^{-1} for the car's velocity). [2 marks]

$E_K = \frac{1}{2} mv^2 = \frac{1}{2} \times 1500 \times 13.3^2$ 1

$E_K = 1.33 \times 10^5$ J

($E_K = 1.08 \times 10^5$ J if 12.0 ms^{-1} is used) 1

7. In a football match, a player kicks a stationary football of mass 0.440 kg and gives it a speed of 32.0 m s^{-1}.

a) The contact time between the football and the footballer's boot was 9.20 ms. Calculate the average force of impact on the football.

[2 marks]

$F = m(v-u)/t = 0.440\ (32.0 - 0) / 0.092$ 1

$= 1.53 \times 10^3$ N 1

b) A video recording showed that the toe of the boot was moving along the straight line of the impact force when it struck the football. The force of the impact slowed the 1.60 kg boot down from a speed of 24.0 ms^{-1} to a speed of 15.0 ms^{-1}. Calculate the change of momentum of the boot.

[2 marks]

$\Delta p = m(v-u) = 1.6\ (15 - 24) = -14.4\ kgm\ s^{-1}$

1 for answer 1 for negative or "opposite direction to kick"

8. World champion 200 metre bicycle sprinters can develop enormous power in their legs whilst maintaining a top speed of around 78.0 km h^{-1}.

a) If a 70.0 kg rider maintains a constant force on his bike from his legs of 1.25 x 10^2 N over the whole 200 m track at a speed of 78.0 km h^{-1}, calculate a value for the power output of his legs.

[2 marks]

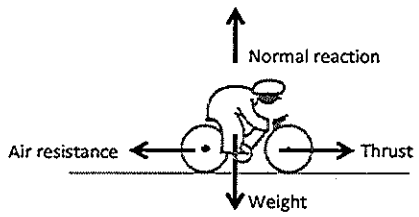
$v = \frac{78}{3.6} = 21.66\ m\ s^{-1}$

$P = Fv = 1.25 \times 10^2 \times 21.66 = 2.71 \times 10^3\ W$ (or W=Fs, then P=W/t)

b) Draw and label all the vectors representing the forces acting on the cyclist below when moving at a constant velocity.

[4 marks]

(1/2 mark for each arrow and label)



9. In a game of football, a ball travelling at 5.00 m s^{-1} struck the moving head of a player and rebounded at 6.00 m s^{-1} into the goal. The angle between the initial and final directions of the ball was 90°.

a) Calculate the **change in velocity** of the ball. [3 marks]

Vector triangle drawn (not shown) 1

Velocity change is given by $R^2 = \sqrt{5^2 + 6^2}$

$\Delta v = 7.81\ ms^{-1}$ 1

TanΘ = 5/6 so $\Theta = 39.8°$ from initial velocity direction 1

b) The mass of the ball is 3.50 x10^2 g and it was in contact with the player's head for 0.200s, during which time its change in velocity was 7.50 m s^{-1}. Calculate the magnitude of the force that the ball exerted on the head of the player during contact time.

[3 marks]

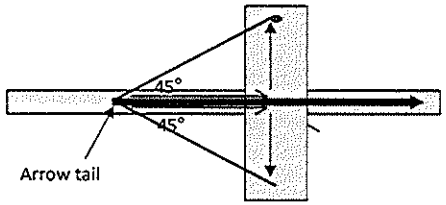
$a = \frac{\Delta v}{\Delta t} = \frac{7.81}{0.2} = 39.05\ m\ s^{-1}$ 1

$F = ma = 0.35 \times 39.05 = 13.7\ N$ 1

at an angle of $(50° + 50.2^2) = 100.2°$ to the horizontal. 1

10. a). The elastic of a child's crossbow is pulled back and held firmly so that it makes an angle of 45.0° with the tail of the arrow. If the tension in each side of the elastic is 65.0 N, (assume a constant value) calculate the total force acting on the arrow at the instant it is released. Give the force's direction.

[3 marks]



Vector triangle drawn 1

$R^2 = \sqrt{65^2 + 65^2}$

R = 91.9 N 1

Direction is straight to the right. 1

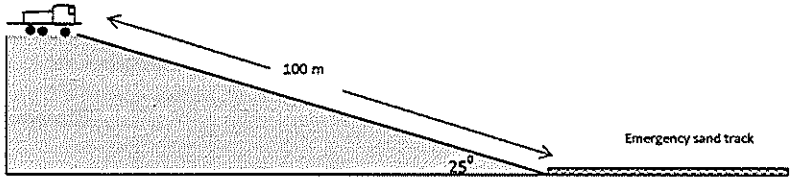
b) If the arrow has a mass of 0.250kg and the acceleration of the arrow by the elastic takes place over a distance of 15.0 cm before leaving the crossbow, calculate the maximum velocity attained by the arrow. (If you couldn't do part a of this question, use a value of 80.0 N for net force). [2 marks]

F = ma, so $a = \frac{F}{m} = \frac{91.9}{0.25} = 367.7\ m\ s^{-1}$ 1

$v^2 = u^2 + 2as = 0 + 2 \times 367.7 \times 0.15 = 110$ 1

$v = 10.5\ ms^{-1}$ ($v = 9.80\ ms^{-1}$ if 80N used)

11. A truck driver on the top of a hill releases the hand brake whilst in neutral gear, so that the truck rolls 100 m down the hill to a level emergency sand track. The hill has a slope of 25.0° to the horizontal and the truck's mass is 6.50 tonnes.



a) Calculate the speed of the truck at the bottom of the hill. [3 marks]

$a = g\sin\Theta = 9.8\sin25° = 4.14\ ms^{-1}$ 1

$v^2 = u^2 + 2as = 0 + 2 \times 4.14 \times 100 = 828$ 1

$v = 28.8\ ms^{-1}$ down the slope 1 (- ½ if no direction)

When the driver reaches the bottom he realizes that his brakes have failed, but luckily there is an emergency track made of sand which has been made to stop runaway trucks coming down the hill.

b) If the sand in the emergency track has a resistive force of 55.0 kN against the wheels of the truck, calculate the distance the truck travels in the sand (in the horizontal direction) before it stops. (If you couldn't do part a of this question, use a value of 30.0 ms^{-1} for the truck's velocity).

[3 marks]

$a = F/m = -55{,}000 / 6500 = -8.46\ ms^{-2}$ 1

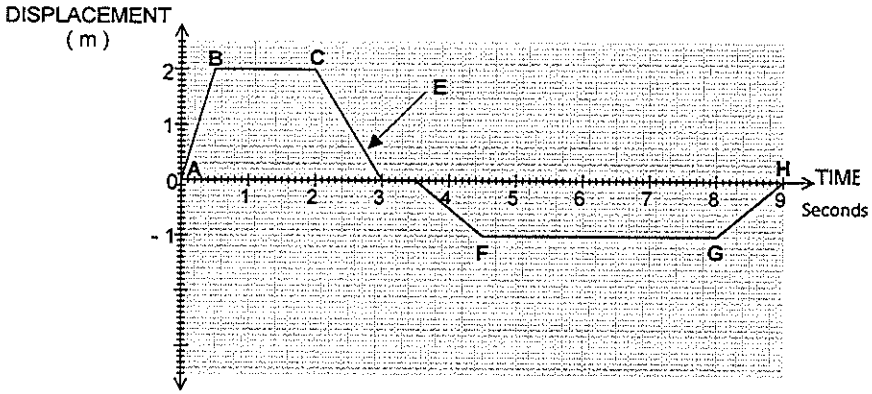
$v^2 = u^2 + 2as$

$28.8^2 = 0 + 2(-8.46)s$ 1

$s = -49.0m$ 1

($s = -53.2m$ if $30.0\ ms^{-1}$ used)

12. The graph below shows how the **displacement** of a toy train moving in a straight line varies over a period of time.



a) What is the maximum speed attained by the train?

(1 sig fig is Ok)

Answer: 4 ms^{-1} [1 mark]

b) Describe the motion of the train in section

(i) BC STATIONARY

(ii) E RETURNING TO START AT CONSTANT VELOCITY

[2 marks]

c) What is the *total length of track* used by the toy train in the above journey as shown by the graph?

Answer: 3m [1 mark]

END OF SECTION 1

Section Two: Problem-solving 46%(57 marks)

This section has **four (4)** questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 70 minutes

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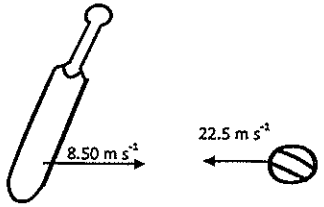
13. *(8 marks total)*

a) Melinda likes playing cricket for her school. During a school match, she swings her new 2.20 kg bat forward to strike a 0.350 kg ball that is being bowled towards her at 22.5 ms^{-1}. Her bat is moving towards the ball at a speed of 8.50 ms^{-1} before it strikes the ball and the bat slows to a speed of 0.300 ms^{-1} forwards after the ball has been hit.



Calculate the speed with which the ball leaves the bat after it has been hit.

[3 marks]

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$2.2 \times 8.50 + 0.350 \times (-22.5) = 2.20 \times 0.300 + 0.35v_2$ 1

$0350v_2 = 10.2$ 1ans

$V_2 = 29.0\ ms^{-1}$ away from the bat 1 direction

b) Jim has a mass of 55.0 kg and jumps down from his garden wall 2.00 m high onto the ground landing safely by bending his knees. What is Jim's momentum just before he lands?

[3 marks]

Equating E_P on the wall to E_K at the ground: ~~55~~ x 9.8 x 2 = ½ x ~~55~~ x v^2

$v^2 = 2 \times 9.8 \times 2 = 39.2$ so $v = 6.26\ m\ s^{-1}$ 2

Momentum $p = mv = 55 \times 6.26 = 3.44 \times 10^2\ kgms^{-1}$ 1

c) Explain, in terms of physics, **how** bending his knees makes the force acting on him smaller whilst his change in momentum remains the same.

[2 marks]

Bending the knees makes the time over which the momentum change occurs longer.

Force on body $F = \frac{\Delta p}{\Delta t}$ so as t becomes larger F becomes smaller.

14. (16 marks total)

(a) In a thermal nuclear reactor, induced fission is caused by the U–235 nucleus capturing a neutron, undergoing fission and producing more neutrons. Which one of the following statements is true? (Circle the correct answer).

A To sustain the reaction a large number of neutrons is required per fission.

B The purpose of the moderator is to absorb all the heat produced.

C The neutrons required for induced fission of U–235 should be slow neutrons.

D The purpose of the control rods is to slow down neutrons to thermal speeds.

[1 mark]

(b) An unstable isotope of uranium may split into a caesium nucleus, a rubidium nucleus and some neutrons in the following process.

$$^{236}_{92}U \Rightarrow ^{137}_{55}Cs + ^{95}_{37}Rb + x\,^{1}_{0}n$$

(i) Determine the value of X, that is, the number of neutrons produced in the above process. 4 [1 mark]

(ii) Calculate the energy, in Mev and in Joules, which is released in the above process, given the following nuclear masses together with data from the *Formula and Constants Sheet.*

NUMER CHANGED IN BC EXAM – AFFECTS RESULTS FOR PART 2 and 3

[5marks]

Mass of a neutron = 1.00867 u

mass of a nucleus of Cs 137 = 136.87688 u

mass of a nucleus of Rb 95 = 94.19481 u

mass of a nucleus of U 236 = 235.4055 u

mass of products = 136.87688 u + 94.19481 u + 4(1.00867 u) 1

= 235.10637 u 1

Mass lost = 235.4055 u - 235.10637 u

= 0.29913 u 1

Energy = 0.29913 u x 931 MeV

= 278.5 MeV = 279MeV 1

= 278.5 MeV x 10^{6} x 1.6 x 10^{-19} J

= 4.47 x 10^{-11} J 1

(iii) If the energy released is shared equally by the neutrons as kinetic energy, at what speed do they travel upon emission?

[3 marks]

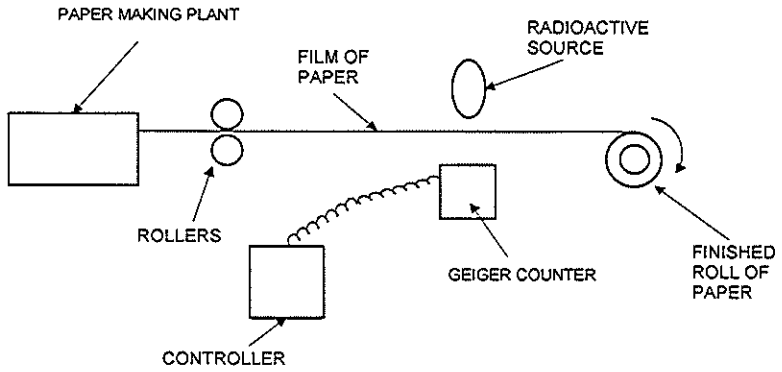
$E = \frac{1}{2} mv^2$

$4.47 \times 10^{-11} \div 4 = \frac{1}{2}(1.67 \times 10^{-27}) v^2$ 1

$v^2 =$

$v =$ 2

(c) A radioactive source is used to test the thickness of paper. The source is put on one side of the paper and the Geiger counter on the other side. The paper travels from the papermaking plant through the rollers as shown.



(i) Why are beta particles more suitable than alpha particles or gamma rays for this job?

[2 marks]

Alpha particles will not penetrate the paper at all

Gamma rays will pass straight through

The table shows the reading on the counter during 70 s.

times in seconds	10	20	30	40	50	60	70
total count since the start	50	100	150	195	235	275	315
count in 10 seconds	50	50	50	45	40	40	40

(ii) Look at the table of results. What happened to the thickness of the paper? Explain.

[2 marks]

Paper is becoming thicker, 1

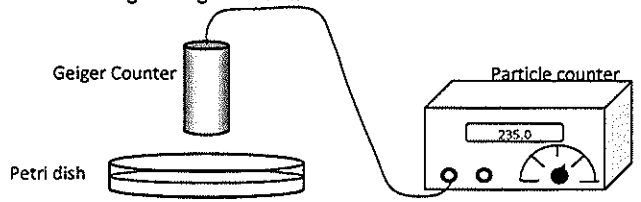
as less beta particles are passing through 1

(iii) The isotope used in the above process has a half life of 5.50 years. If a new sample of the isotope used has a count rate of 1500 counts per minute and is only useful with count rate over 190 counts per minute, approximately how long will the isotope sample last before it needs to be replaced?

[2 marks]

15. *(16 marks total)*

In an experiment to determine the half-life of the element protactinium a small amount of protactinium nitrate solution was placed in a petri dish and the β-particle emission from the liquid was measured using a Geiger Counter.



The Geiger Counter was connected to an electronic particle recorder that displays the **total** number of counts of β-particles coming from the protactinium source, measured every 25 seconds.

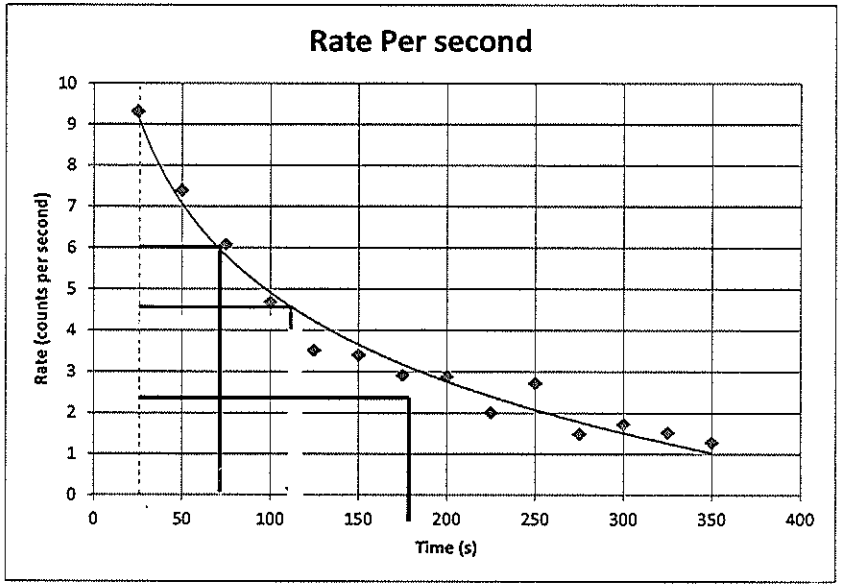
The experimental results are shown in the table below.

Column A	Column B	Column C	Column D
Time (s)	Total Count	Counts for each 25 s	Rate Per second
25	233	*233*	*9.32*
50	418	*185*	*7.40*
75	570	*152*	*6.08*
100	687	*117*	*4.68*
125	775	88	3.52
150	860	85	3.40
175	933	73	2.92
200	1005	72	2.88
225	1055	50	2.00
250	1123	68	2.72
275	1160	37	1.48
300	1203	43	1.72
325	1241	38	1.52
350	1273	32	1.28

a) Complete Columns C and D in the table so that Column C shows the counts recorded in **each** 25 second interval and Column D shows the count rate i.e. the count per second. (The first four have been completed for you.)

[2 marks]

b) Using Columns A and D, construct a graph on the grid below. Plot **Count Rate or Count per second** (y-axis) against **Time** (x-axis). [5 marks]



Title

Labelled axes

Scaling

Points correct

Line of best fit 5 marks

c) using your graph, determine the half life of the protactinium isotope.

Show your working on the graph. 1
[2 marks]

Half Life = 105 - 115 seconds 1

d) **Using your graph**, estimate the elapsed time for the counter to record a rate of two counts per minute.

ANSWER: 255 - 215 seconds [2 marks]

1 method on graph 1 answer

16. (8 marks total)

A traffic police officer discovers a car on the edge of a road where the speed limit is 70 km h^{-1}. He observes a skid mark leading to the car which is 50.0 m long.

The police officer knows that the mass of this car is 1.25 tonnes and that the frictional braking force when skidding was approximately 1.25×10^4 N. From this evidence he is able to estimate the speed of the car immediately before the driver applied the brakes.

a) Assuming a constant braking force, calculate the speed of the car just before the driver applied the brakes. Show your working.

[4 marks]

$a = F/m = -12000 / 1.25 \times 10^3 = -10.0\ ms^{-1}$ 1

$v^2 = u^2 + 2as$

$0 = u^2 + s(-10.0)(50.0)$ 2

$u^2 = 1000$

$u = 31.6\ ms^{-1}$ 1

b) Was the car speeding? Justify your answer. [2 marks]

$u = 31.6\ ms^{-1} = 114\ km\ h^{-1}$ 1

Hence the car was REALLY speeding! 1

c) Calculate how long it would have taken for the car to stop.

[2 marks]

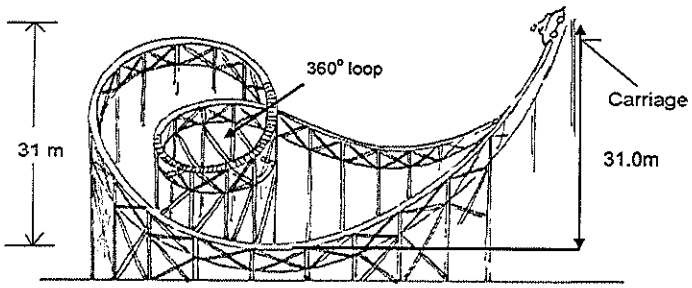
$v = u + at$

$0 = 31.6 + (-10.0)t$ 1

$t = 3.16$ s 1

17. (10 marks total)

A roller coaster at a festival is set up by a carriage being hauled to the top by an electric motor. The total mass of the carriage and the people is 505 kg and the vertical height is 31.0m.



a) Calculate the potential energy of the carriage at the beginning of the ride.

[2 marks]

$Ep = mgh = 505 \times 9.90 \times 31.0 = 1.53 \times 10^5$ J

b) The car is then released and goes down a slope that is 70.0 m long, where the average frictional force is 30.0 N. What is the speed of the carriage when it reaches the bottom? [4 marks]

W done by friction = $Fs = 30.0 \times 70.0 = 2.10 \times 10^4$ J 1

$E_k = E_p$ - Energy loss from friction

$= 1.53 \times 10^5 - 2.10 \times 10^4 = 1.32 \times 10^5$ J 1

$E_k = \frac{1}{2} mv^2$

$1.53 \times 10^5 = \frac{1}{2} 505\ v^2$ 1

$v = 22.9\ ms^{-1}$ 1

c) Calculate the momentum of the carriage at the bottom of the slope.

[2 marks]

$p = mv$

$= 505 \times 22.9 = 1.16 \times 10^4\ kgms^{-1}$

1 1

d) The diagram shows a 360° loop on the ride that is lower in height to the beginning of the ride, where the carriage was released. Briefly explain why this is necessary. [2 marks]

In the real world, there is friction on the rails. If the height of the loop was higher the carriage will not make it to the top and fall off the rails.

END OF SECTION 2

Section Three: Comprehension 12% (15 Marks)

This section contains **one (1)** question. You must answer this question. Write your answers in the spaces provided. You are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and /or numerical results should be included as appropriate.

Suggested working time: 25 minutes.

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18. **Sudden Stop**

(Paragraph 1)
Vehicles are not intrinsically dangerous: let's face it, you are most unlikely to have an accident if your car never leaves your driveway. Which tends to prove that it is the movement that causes all the problems. You see, as soon as your vehicle moves it comes under the influence of a variety of physical forces, some good for you, some bad. Things like momentum, kinetic energy, centripetal force, gravity, drag, directional force, etc.

(Paragraph 2)
The worst of that lot is kinetic energy, a function of the speed and loaded mass of the vehicle. This kinetic energy increases proportionally with the square of your speed. In other words, when you triple your speed (for example when you go from 30 km h^{-1} to 90 km h^{-1}) your kinetic energy increases 9 times (3x3). This is not good because your braking distance will increase 9 times when you increase your speed 3 times. (Please note that I am not talking about the total stopping distance, as this would include the driver's thinking distance).

(Paragraph 3)
You probably realise what this means in practical terms: if you hit at 90 km/h the crash is going to be 9 times worse than it would be at 30 km/h. However if you take this a bit further, you will see that something good comes out of it. If faced with any crisis, wipe as much speed off the car as you can. So, you see that firstly (before taking evasive action with the steering wheel), you have to decrease your speed as much as you can - without locking the wheels - and then you must try to avoid a hard landing. Given a choice, a clump of bushes is preferable to a parked car, and hitting the back of a parked car at 60 km h^{-1} will be pretty much the same as hitting a brick wall at half that speed.

(Paragraph 4)
Above all, never hit a tree!! Trees are the most unforgiving things that you may come up against in anger. There is no "give" in them and you concentrate the whole force on a narrow profile. And of course, make sure that your loads are secure, the baby is in the baby capsule on the back seat, and you and your passengers are all correctly buckled in.

Questions

1. Explain why the sudden stop in the collision is a killer.

(3 marks)

In stopping in a very short time, the change in momentum occurs over a short time so the impulse and hence the impulsive force that the person is subjected to will be very large. The force may be large enough to kill the person. It is the sudden stop that produces a net force.

2. Verify the claim that the "stopping distance increases 9 times when the speed increases 3 times". (Assume that the braking force is constant.)

(2 marks)

$v^2 = u^2 + 2\,a\,s$ (where s is the stopping distance)
For initial speed of 30 km h^{-1}

$0^2 = 30^2 + 2 \times \text{constant} \times s$

$900 = 2 \times \text{constant} \times s$

For initial speed of 90 km h^{-1}

$0^2 = 90^2 + 2 \times \text{constant} \times s$

$8100 = 2 \times \text{constant} \times s$

So ratio of 90 : 30 :: 8100 : 900 which represents a ratio of 9 to 1

3. What does "driver thinking time" have to do with the total stopping distance in a collision?

(2 marks)

While the driver is thinking (reaction time) the vehicle is still travelling at close to its velocity before the driver is aware of the hazard. During this time there is no braking. The faster the vehicle is travelling the further it will travel and hence increase the stopping distance.

4. Why is hitting the back of a parked car at 60 km h^{-1} similar to hitting a brick wall at half the speed?

(3 marks)

The parked car will tend to move forward on impact and so increase the time of impact. The change in momentum is spread over a longer time. This will decrease the impulsive force on the occupant of the car so causing less injury. The parked car may also have a crumple zone which will increase the time of the collision and hence reduce the impulsive force. A brick wall will not "give" as much.

5. Explain the Physics behind the claim that loads should be secured in a moving vehicle. Is this the same reasoning behind the wearing seat belts for people?

(3 marks)

If a load is secured it increases the net mass of the vehicle. The increased mass will reduce the value of the deceleration if the vehicle is involved in a crash. Also – Newton's first law states that bodies in motion remain in motion unless acted upon by an outside force so if the vehicle is stopped suddenly an unsecured load the will continue to travel in the direction the vehicle was travelling. If the load is behind the occupant then it may travel forward and impact on the occupant. Wearing a seat belt is like securing the load. If the vehicle stops suddenly, the occupant is prevented from moving forward and impacting on the steering wheel or dash board.

6. Explain how design features such as "crumple zones" use the concept of impulse to reduce the severity of injury to drivers in the event of a collision.

(4 marks)

$I = F \times t$ (where F is the impulsive force and t is the time taken for an impact)

If the time of impact in a collision can be increased then the impulsive force can be reduced. Crumple zones, padding, seat belts etc all increase the time that two bodies are in contact during a collision. If the impulse remains constant for a given collision and one collision involves a crumple zone and the other does not then the crumple zone will increase the time of collision and hence reduce the impulsive force. Injury to the occupants will be reduced.