Christ Church
Grammar School

Science Department
Year 11 2021

ATAR PHYSICS
UNIT 1 MOTION AND FORCES
TEST 2 2021

Student Name:

SOLUTIONS

Teacher: JRM PCW CJO
(Please circle)

Time allowed for this paper
Working time for paper: 50 minutes.

Instructions to candidates:

- You must include **all** working to be awarded full marks for a question.
- Answers should be expressed to 3 significant figures unless otherwise indicated.
- Marks may be deducted if diagrams are not drawn neatly with a ruler and to scale (if specified).
- Marks will be deducted for incorrect or absent units.
- **No** graphics calculators are permitted – scientific calculators only.

Mark:	/ 51
=	%

Question 1 **(6 marks)**

A car of mass 1250 kg is travelling along the freeway at a velocity of 95.0 km h^{-1} South. The driver spots a hazard ahead and applies a steady braking force over 85.0 m, bringing the car to rest.

(a) Using the concepts of work and energy, calculate the average force required to bring the car to rest.

(4 marks)

Description		Marks
u = 95.0 / 3.6 = 26.4 m s^{-1}		1
W = F x s = E_f - E_i		1
85F = 0 – ½(1250)(26.4^2)		1
F = 5,120 N North	(-1/2 mark for absent unit or direction)	1
	Total	4
If student uses accelerated motion equations; maximum 2 marks		

(b) Explain what would happen to the impulse if the driver applied a smaller braking force to bring the car to rest.

(2 marks)

Description	Marks
There were be no change	1
Impulse is the change in momentum which remains constant no matter how slowly the car is brought to rest.	1
Total	2

Question 2 **(2 marks)**

In the table below, state which of Newton's Laws applies **predominantly** in the scenario stated.

Scenario	Newton's Law
Getting thick liquids like tomato sauce out of a bottle can be difficult. Two methods work to solve the problem. You can bang the bottom of the upturned bottle **or** you can give it a sharp jerk downward.	1^{st}
After kicking a football outside with his mate without out shoes on, Jack notices that his foot has become pink and painful.	3^{rd}
Kim is pleased that next year at the Inters Athletics carnival he will still be using the same mass shot for the shot-put event. He plans on training hard over the year so he will be stronger and will be able to accelerate the put by a larger amount and hence, throw it further.	2^{nd}
Jack entered the train carriage to get to school one morning and stood by the door as all of the seats were taken. He was so preoccupied with his phone that he did not notice the train begin to accelerate, and promptly fell over.	1^{st}

Question 3 **(7 marks)**

A lift of mass 455 kg is designed to reach its top speed of 3.50 m s^{-1} at a uniform rate in 2.00 seconds and to carry no more than 10 people at a time.

(a) If the average mass of a person is taken to be 75.0 kg, calculate the magnitude of the tension (force) on the cable when the lift is fully loaded and stationary.

(3 marks)

Description	Marks
ΣF = 0 = W + T	1
0 = (455 +10 x 75)(-9.80) + T	1
T = 11,800 N	1
Total	3

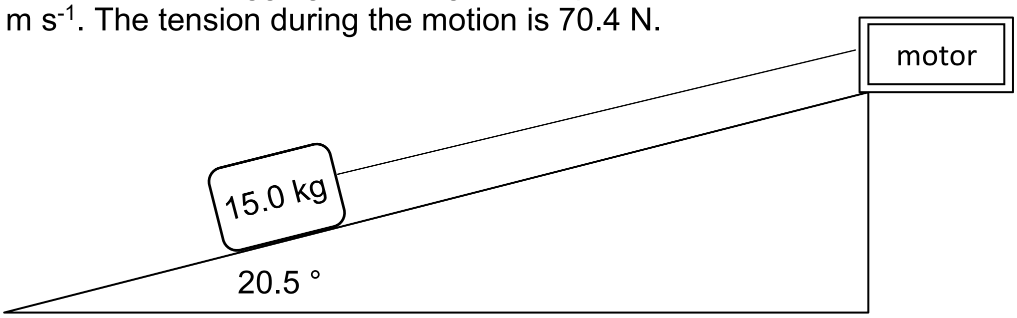
(b) Calculate the maximum magnitude of tension that the cable experiences when accelerating the lift upwards.

(4 marks)

Description	Marks
a = v – u /t = 3.50 – 0 / 2 = +1.75	1
ΣF = ma = W + T	1
(75x10+455)(+1.75) = -11,800 + T	1
T = 13,900 N	1
Total	4

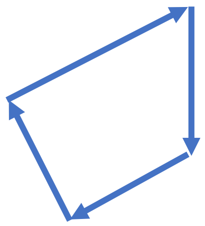
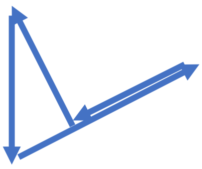
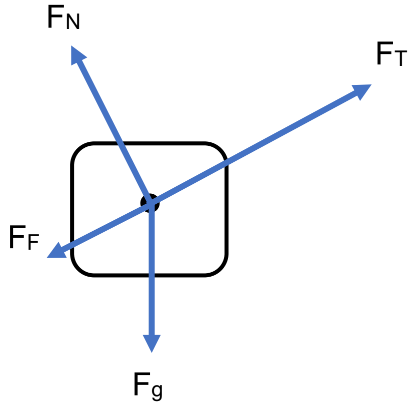
Question 4 **(13 marks)**

An electric motor is dragging a 15.0 kg mass up an incline of 20.5 ° at a constant speed of 0.500 m s^{-1}. The tension during the motion is 70.4 N.



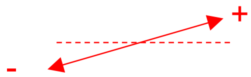
(a) In the space below, draw a vector diagram and a free body diagram of the forces acting on the mass while it is being dragged up the incline.

(2 marks)

Vector Diagram	Free body diagram
Eg: $F_T + F_G + F_F + F_N$  $F_N + F_G + F_T + F_F$ 	

(b) Calculate the normal force and the frictional force acting on the mass while it is being dragged up the incline.

(4 marks)

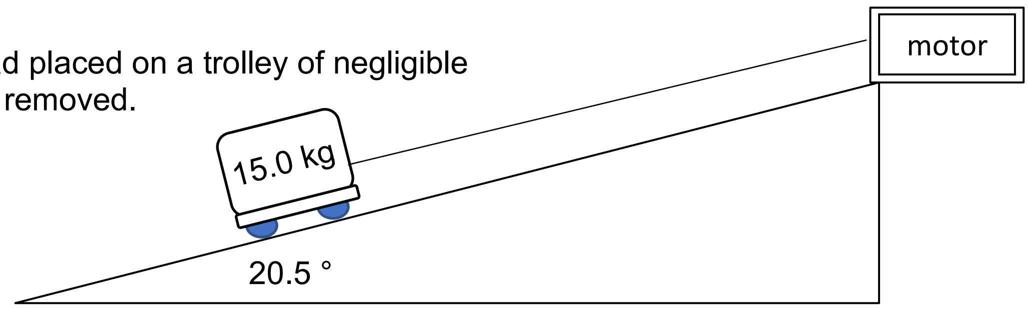
Description	Marks
$F_N = mg\cos\theta$ $= 15 \times 9.8 \cos(20.5)$	1
$= 138$ N up 20.5° left	1
$F_{II} = 0 = mg\sin\theta + F_F + T$  $0 = 15 \times -9.80\sin(20.5) + F_F + 70.4$	1
$F_F = 18.9$ N down the incline	1
Total	4

(c) Show via calculation that power output of the motor while the mass is being raised is 35.2 W.

(3 marks)

Description	Marks
$P = \frac{W}{t} = \frac{F \times s}{t} = F.v$	1
$= 70.4 \times 0.5$	1
$= 35.2$ W	1
Total	3
Note; more complicated methods are possible: $= \frac{mgs.\sin\theta + F_F xs}{t}$ etc etc	

Suppose the mass was instead placed on a trolley of negligible mass such that friction is now removed.



(d) Calculate the rate that the **vertical height** changes providing the power output remains constant.

(4 marks)

Description	Marks
$P = \frac{E_p}{t} = \frac{mgh}{t}$	1
$P = mg \cdot \frac{h}{t}$	1
35.2 = (15*9.8) h/t	1
$h/t = 0.239 \text{ m s}^{-1}$	1
Total	4

Question 6 **(12 marks)**

SoftStop® is a safety barrier designed to reduce the injuries suffered by drivers who are unfortunate enough to experience a head on collision with the end of the barrier. The vertical metal piece (with the black and yellow signage) is attached to anchor points in the ground but are designed to travel back along the length of the barrier to reduce the injuries that drivers would receive in a collision.

Figure 1: SoftStop® Barrier

Figure 2: After a collision

A deceleration of 40.0 g's (392 m s^{-2}) provided by a collision with a rigid barrier would cause serious internal injury while a SoftStop® collision can reduce the impact to 20.0 g's; resulting in far less chance of significant injuries.

(a) Explain how the SoftStop® is able to reduce the injuries experienced by drivers in a collision.

(3 marks)

Description	Marks
$F = ma = m\frac{(v-u)}{t}$ hence $F \propto \frac{1}{t}$	1
Increasing the time taken to decelerate reduces the average force acting on the drivers.	1
OR	
Increasing distance reduces the acceleration as per $a = v^2 - u^2 / 2s$	1
Since F = ma, decreasing a decreases F	1
Hence reducing the injuries experienced.	1
Total	3

Consider a 65.0 kg occupant initially travelling at 15.0 m s^{-1} East who is brought to rest by a SoftStop® barrier.

(b) Calculate the impulse of the occupant involved in a collision with a SoftStop® barrier.

(3 marks)

Description	Marks
$I = m\Delta v$	1
I = 65(0-15) = -975	1
= 975 kg m s^{-1} West (- ½ mark for absent unit or direction)	1
Total	3

(c) Calculate the maximum time taken for the occupant to come to rest with the two possible decelerations provided.

(2 marks)

Description	Marks
a = (20 x 9.8) = -196	1
$t = \frac{v - u}{a}$ $= \frac{0 - 15}{196}$ = 0.0765 s	1
Total	2

(d) Hence, calculate the average Force exerted on the occupant.

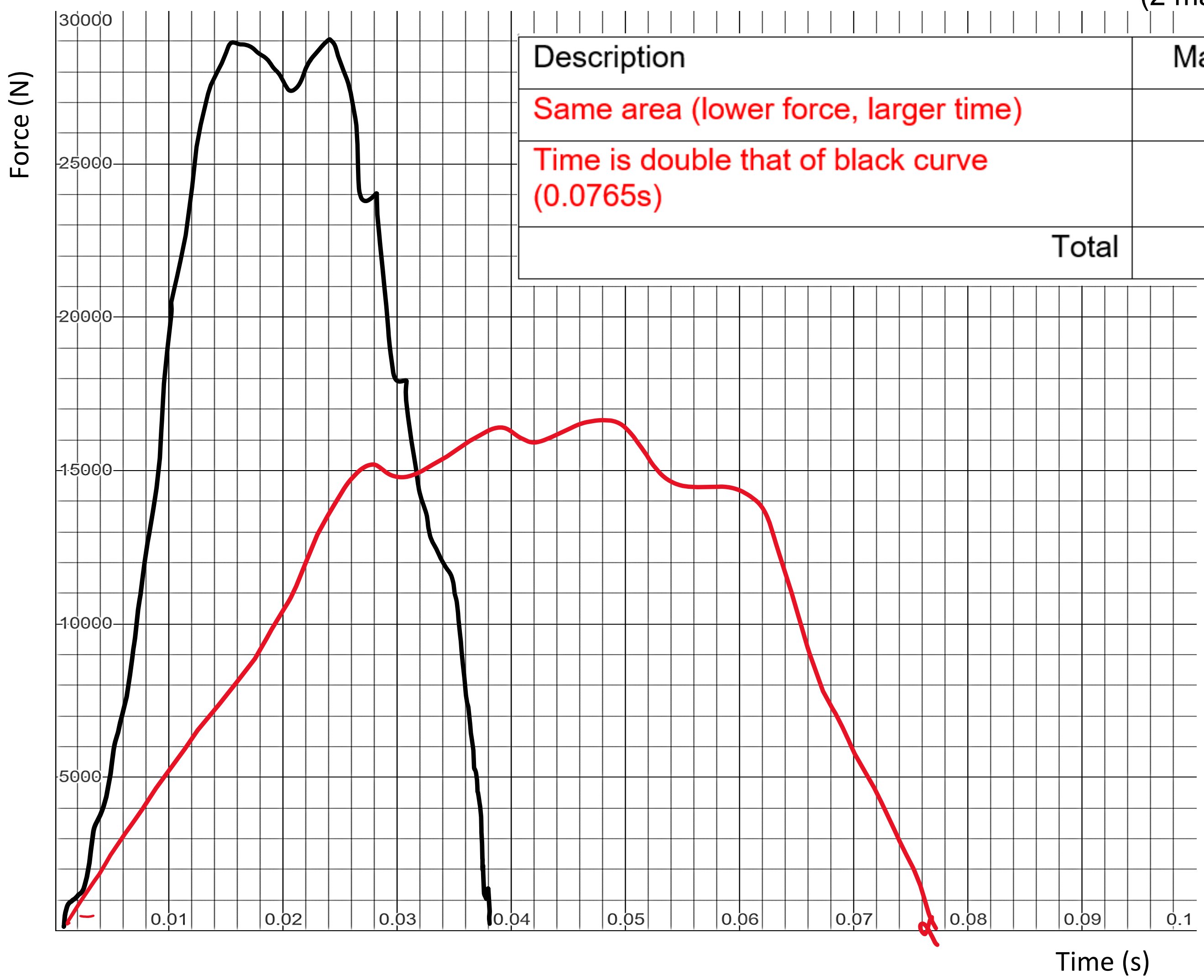
(2 marks)

Description	Marks
F = ma = 65 x 196	1
= 12,700 N West	1
Total	2

The graph below shows the Force-time curve for a collision with a rigid barrier.

(e) On the graph below, sketch a Force-time graph of a collision with a SoftStop® Barrier.

(2 marks)



Description	Marks
Same area (lower force, larger time)	1
Time is double that of black curve (0.0765s)	1
Total	2

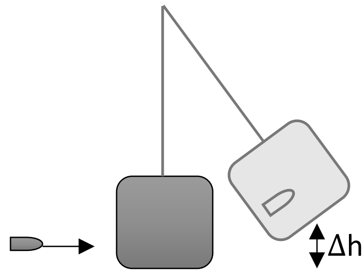
Question 5 **(11 marks)**

A 0.0500 kg bullet is fired at a speed of 145 m s^{-1} and is embedded into a stationary ballistics block of mass 2.20 kg (an example of a coupled collision).

(a) Using concepts of conservation of momentum, calculate the combined speed of the ballistics block (with bullet embedded).

(3 marks)

Description	Marks
$\Sigma p_i = \Sigma p_f$ $m_1u_1 = (m1+m_2)v$	1
$0.05(145) = (2.20+0.05)\ v$	1
$v = 3.22$ m s^{-1}	1
Total	3



(b) Show via calculation that the collision above is an inelastic one and determine how much energy was converted to heat and sound. (If you could not complete (a), use v = 6.00 m s^{-1})

(3 marks)

Description	Marks
$\Sigma E_i = ½m_1u_1^2$ $= ½\ (0.050)(145^2)$ $= 526$ J	1
$\Sigma E_f = ½m_cv_c^2$ $= ½\ (2.25)(3.22^2)$ $= 11.7$ J (40.5 J)	1
$E_L = E_i - E_f$ $= 526 – 11.7$ $= 514$ J Lost (485 J)	1
Total	3

In a separate experiment a different 0.0600 kg bullet was fired at another similar stationary ballistics block of the same mass and it was observed to rise to a maximum vertical height of 0.430 m.

(c) Calculate, using concepts of conservation of energy and momentum, the initial speed of the bullet.

(5 marks)

Description	Marks
$\Sigma E_i = \Sigma E_f$ $½mu^2 = mgh_f$	1
$½\ (2.2+0.06)\ u^2 = (2.2+0.06)(9.8)(0.430)$	1
$u = 2.90$ m s^{-1} (if $u = \sqrt{2gh}$ without derivation from energy concepts, -1 mark)	1
$m_1u_1 = m_cv_c$ $v_c = 2.90$ $0.06u = (2.26)(2.90)$	1
$u = 109$ m s^{-1}	1
Total	5
If u = 17.8: maximum 1 mark.	