Christ Church Grammar School

Science Department
Year 12 2020

ATAR PHYSICS
UNIT 3: MOTION AND FORCES
TEST 1 2020

SOLUTIONS

Teacher: JRM HKR
(Please circle)

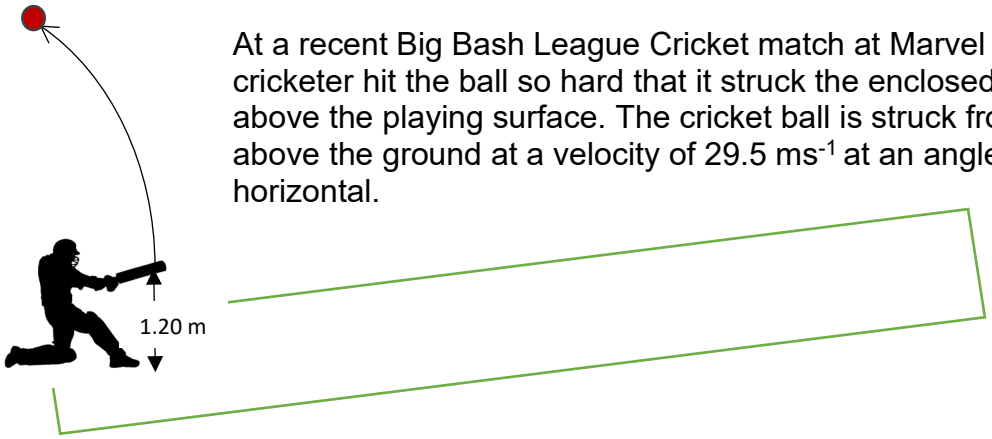
Time allowed for this paper
Working time for paper: 50 minutes.

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:	/ 56
=	%

Question 1 **(14 marks)**



At a recent Big Bash League Cricket match at Marvel Stadium in Melbourne, a cricketer hit the ball so hard that it struck the enclosed roof; a height of 38.0 m above the playing surface. The cricket ball is struck from a height of 1.20 m above the ground at a velocity of 29.5 ms^{-1} at an angle of 75.0° to the horizontal.

(a) Calculate the velocity of the ball when it strikes the enclosed roof.

(5 marks)

Description	Marks
$v_y^2 = u_y^2 + 2a_y s$ Show convention + ↑ → +	1
$= (29.5\sin 75)^2 + 2(-9.80)(38.0-1.20)$ (-0.5 marks if s = + 36.8 not shown) $= +9.52$ m s^{-1}	1
$v = \sqrt{9.52^2 + (29.5\cos 75)^2}$ $= 12.2$ ms^{-1}	1
$\theta = \tan^{-1}\frac{9.52}{12.2}$ $= 51.3°$	1
v = 12.2 m s^{-1} at 51.3° above horizontal	1
Total	5

(b) Calculate the time taken for the cricket ball to strike the enclosed roof.

(3 marks)

Description	Marks
$v = u + at$, $t = \frac{v - u}{a}$	1
$= \frac{9.52 - 29.5\sin(75)}{-9.8}$	1
$= 1.94$ s	1
Total	3

Question 1 continued

The ruling in the Big Bash League is if the cricket ball is to strike any part of the stadium, it is instantly deemed to be a "six"; the number of runs awarded if the cricket ball were to land over the field boundary on the first bounce. At Marvel Stadium, the boundary is 67.0 m from where the ball was struck. The fielding team argued that this ball would never have been a "six" as it was never going to cross the boundary.

(c) Determine via suitable calculation, whether the fielding opposition have a valid argument, ie: that the ball would not have landed over the boundary.

(6 marks)

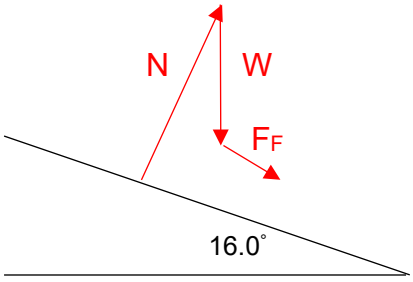
Description	Marks
$s = ut + \frac{1}{2} at^2$ $-1.20 = 28.5.t + (1/2)(-9.8).t^2$	1
$= \frac{-28.5 \pm \sqrt{28.5^2 + 2(-9.8)(-1.2)}}{-9.8}$ $= \frac{-28.5 \pm 28.9}{-9.8}$	1
$= 5.86$ s	1
$s_x = u_x.t$ $= 29.5\cos(75)(5.86)$	1
$= 44.8$	1
As $44.8 < 67.0$, would not reach boundary	1
Total	6

Question 2 **(8 marks)**

A motorbike is travelling on a 16.0° banked curve, making a horizontal turn with a 63.2 m radius at 60.0 km h^{-1}. While the road supplies a normal force of 1280 N, the wheels of the motorbike supply an additional 185 N frictional force, down the plane of the surface, to assist the motor bike in completing the turn without slipping.

(a) Draw a vector diagram which shows all the physical forces acting on the motorbike in this scenario.

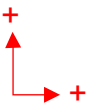
(2 marks)



Description	Marks
All three correct size and direction	1
Arranged such that ΣF is horizontal	1
Total	2

(b) Calculate the mass of the motorbike.

(3 marks)

Description	Marks
Show convention $\sum F_y = ma = 0 = -W + N_y - F_{Fy}$ 	1
0 = -m(9.8) + 1280cos16 + (-185sin16) m = $\frac{-1280\cos(16) + 185\sin(16)}{-9.8}$	1
m = 1.20 x10^2 kg	1
Total	3
If m = 126 kg, F_{Fy} not considered, maximum 1 mark If m = 131 kg, sign convention incorrect, maximum 2 marks	

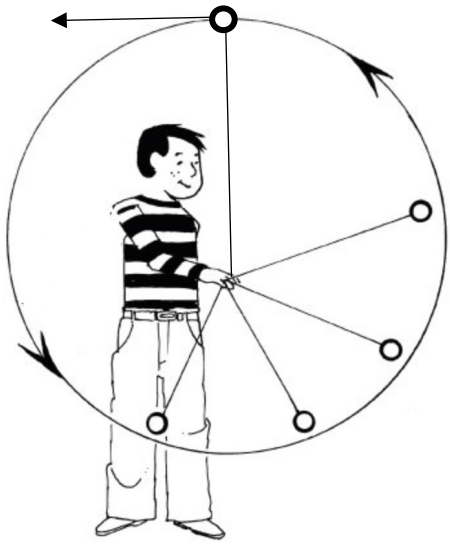
(c) Calculate the centripetal force acting on the motorbike.

(3 marks)

Description	Marks
$\sum F_x = F_C = N_x + F_{Fx}$ or $\sum F_x = F_C = \frac{mv^2}{r}$	1
= 1280sin(16) + 185cos(16) $= \frac{130(16.7)^2}{63.2}$	1
= 5.30 x10^2 N towards centre of curvature.	1
Total	3
If Fc = 599 N, incorrect mass has been used and F_{Fx} not considered max 1 mark	

Question 3 **(5 marks)**

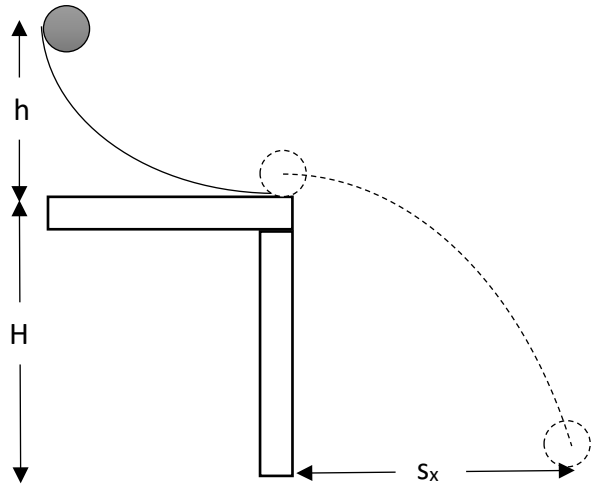
A ball of mass 0.455 kg is being swung in a vertical circular path, attached to the end of a light string of negligible mass as shown in the diagram. The string has a constant radius of 1.12m and at its highest point it is travelling with a speed of 4.50 m s^{-1}. The ball is then allowed to fall under the influence of gravity. Calculate the magnitude of the tension in the string when the ball is at its lowest point of its path.



Description	Marks
Show convention +  + $v^2 = u^2 + 2as$ $v = \sqrt{4.50^2 2(-9.8)(2 \times -1.12)}$	1
= 8.01 ms^{-1}	1
$\sum F_y = Fc = \frac{mv^2}{r} = T - W$	1
$\frac{(0.455)(8.01)^2}{1.12}$ = -(0.455 x 9.8) + T T = 26.1 + 4.46	1
= 30.6 N	1
Total	5
If T = 12.7 N, u = 4.50 m s^{-1} was used, maximum 3 marks.	

Question 4 **(10 marks)**

A ball is rolled from rest down a curved slope, across a flat smooth table horizontally and falling to the floor. H = 1.00 m and h = 0.40 m



(a) Using concepts of conservation of energy, calculate the speed with which the ball leaves the table. Assume no energy is lost to friction or air resistance or transferred to rotational energy.

(3 marks)

Description	Marks
$\Sigma E_i = \Sigma E_f$ $E_k = \frac{1}{2}mv^2$, $E_p = mgh$ $mgh_i = mv^2/2$	1
$v = \sqrt{2gh}$ $= \sqrt{2(9.8)(0.4)}$	1
$= 2.80$ m s^{-1}	1
Total	3

(b) Calculate the time taken for the ball to strike the ground.

(3 marks)

Description	Marks
$s_y = u_y t + \frac{1}{2}a_y t^2$ $u_y = 0$ $s_y = \frac{1}{2}a_y t^2$	1
$t = \sqrt{\frac{2H}{a_y}}$ $= \sqrt{\frac{2(-1.00)}{-9.8}}$	1
$= 0.452$ s	1
Total	3
If student uses entire "h+H" to fall vertically, t = 0.535 = maximum 2 marks	

Question 4 continued

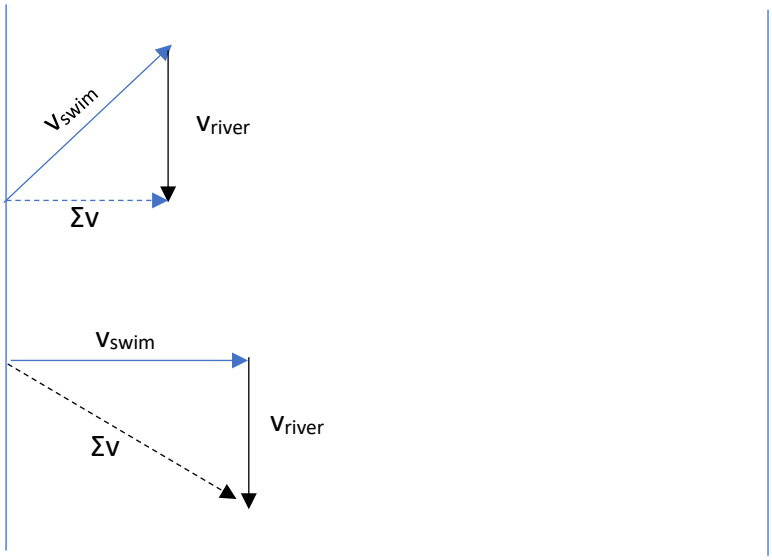
(c) Derive an expression for s_x in terms of h and H only. (Note: you can include numbers)

(4 marks)

Description	Marks
$v_H = \sqrt{2gh}$	1
$t = \sqrt{\frac{2H}{a_y}}$	1
Sx = ux.t $= \sqrt{2a_y h}$ x $\sqrt{\frac{2H}{a_y}}$	1
$= 2\sqrt{Hh}$ (students must square and simplify to receive full marks)	1
Total	4

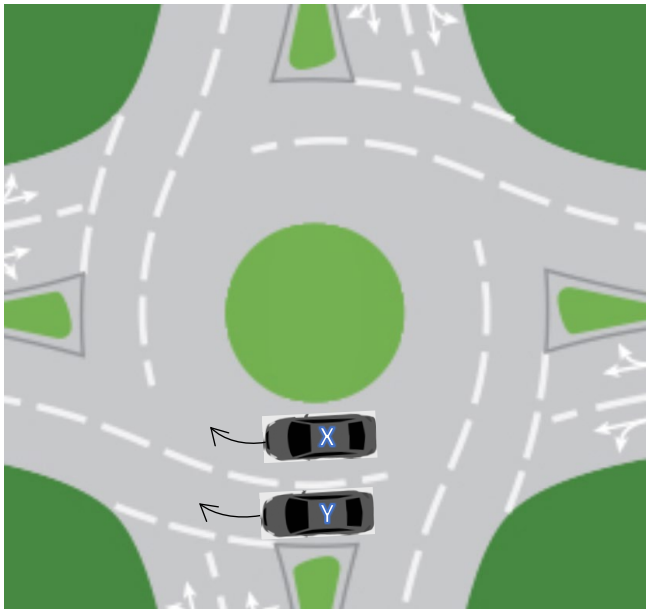
Question 5 **(4 marks)**

Two rowers, who can row at the same speed in still water, set off across a river at the same time. One heads straight across and is pulled downstream somewhat by the river's current. The other one heads upstream at an angle so as to arrive at a point opposite the starting point. Explain which rower, if any, reaches the opposite side first. Include a detailed diagram in your response.

Description	Marks
The rower that rows upstream will reduce his horizontal velocity component by $\cos(\theta)$	1
The rower that rows straight across will maintain his horizontal velocity component.	1
Since $t = s_x/u_x$ and sx (remaining constant) the rower that rows straight across will reach the opposite side first.	1
	1
Total	4

Question 6 **(7 marks)**

Cars X and Y are moving in a circle around a horizontal dual lane round about at a constant speed of 11.0 m s^{-1} as shown in the diagram (not to scale).



(a) Making reference to an appropriate equation, compare the acceleration of cars X and Y.

(3 marks)

Description	Marks
Given the equation $a_c = \frac{v^2}{r}$	1
as v is constant then $a_c \propto \frac{1}{r}$	1
as r_Y is greater than r_X a_{cY} is less than a_{cX}	1
Total	3

The roundabout currently has a maximum speed limit of 12.0 m s^{-1} to enable cars to travel safely. Engineers have been asked to redesign the roundabout so as to increase the safe speed limit to 16.0 m s^{-1}, while still maintaining the inner and outer radius.

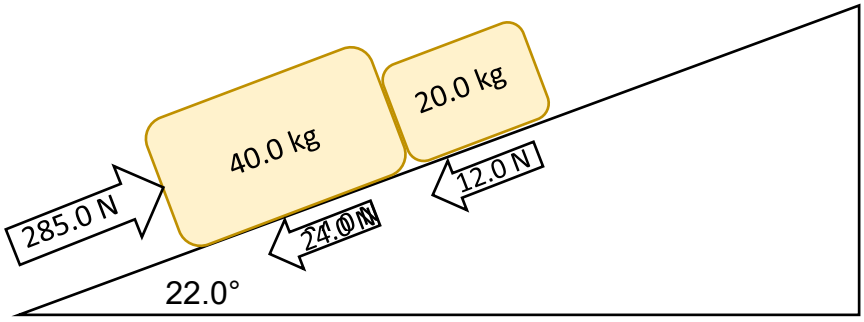
(b) Explain how the roundabout can be redesigned to enable cars to travel safely at higher speeds.

(4 marks)

Description	Marks
At higher speeds, $Fc = \frac{mv^2}{r}$ for a constant m and r, a greater centripetal force is required to maintain circular motion.	1
so…	
the roundabout will need to be banked/inclined plane	1
this means that the normal force can provide a horizontal component inward which contributes to the centripetal force required	1
thus the friction force needed can stay within the limits of the car. (On a horizontal track, friction is the only force providing centripetal force.)	1
OR	
make the surface rougher	1
this will increase friction	1
thus the friction force is larger and can stay within the limits of the car. (On a horizontal track, friction is the only force providing centripetal force.)	1
Total	4

Question 7 **(8 marks)**

Two crates, of mass 20.0 kg and 40.0 kg are in contact and at rest on an incline of angle 22.0°. A friction force of 12.0 N and 24.0 N (respectively) acts between each mass and the incline when a force of 285.0 N acts up the incline as shown in the diagram.



(a) Calculate the acceleration of the system.

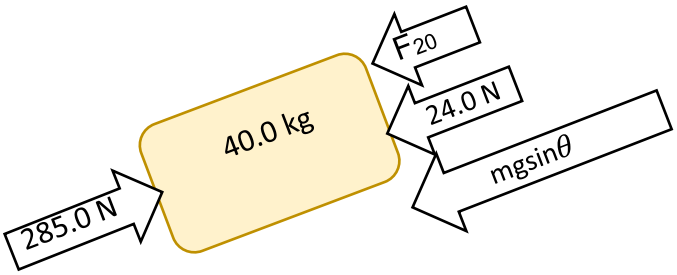
(4 marks)

Description	Marks
$\sum F_{\parallel} = ma_{\parallel} = F_F + F_A + mgsin(\theta)$ Show convention + -	1
60a = -(24+12) + 285 – 60(9.8)sin22	1
= 28.7 N up the incline	1
a = $\frac{28.7}{60}$ = 0.478 ms^{-2} up the incline	1
Total	4
If student omits F_g = mgsinθ, a = 4.15 = maximum 3 marks	

(b) Calculate the reaction force that the 20.0 kg mass applies to the 40.0 kg mass.

(4 marks)

Description	Marks
$\sum F_{40} = ma_{40} = F_{20} + F_A + F_F + mgsin(\theta)$	2
40(0.478) = F_{20} + 285 – 24.0 – 40(9.8)sin22) +19.2 = F_{20} + 114	1
$F_{20} = -94.8$ = 94.8 N down the incline.	1
Total	4
Free body diagram or vector diagram very useful to analyse forces acting on m_{40}	



END OF TEST