Christ Church Grammar School

Science Department
Year 12 2020

ATAR PHYSICS
UNIT 3: MOTION AND FORCES
TEST 2 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:	/ 51
=	%

Question 1 **(3 marks)**

Two 2.00 kg crystal balls are 1.00 m apart. Calculate the net force between the crystal balls.

Description	Marks
$F_g = G\frac{m_1 m_2}{r^2}$	1
$F_g = (6.67\ x\ 10^{-11})\frac{(2.00)(2.00)}{(1)^2}$	1
= 2.67 x 10^{-10} N attraction -0.5 marks if direction not stated	1
Total	3

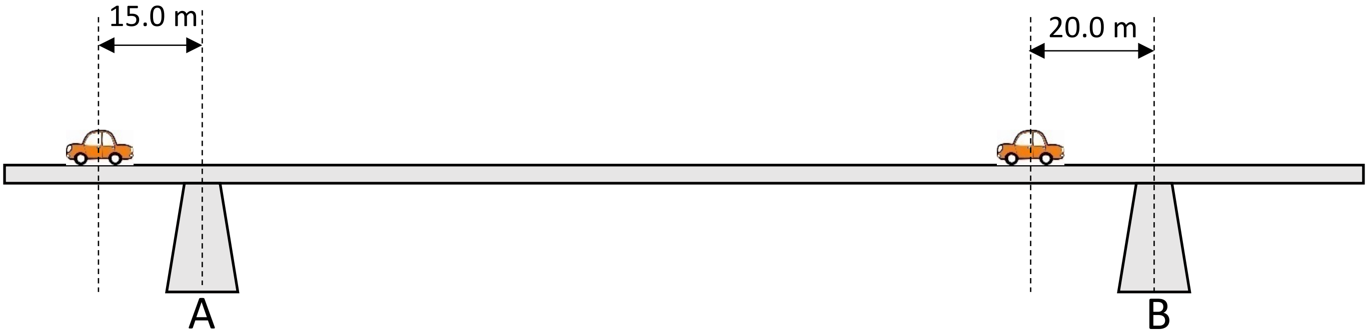
Question 2 **(3 marks)**

Astronauts orbiting in a satellite 300.0 km above the surface of the Earth experience weightlessness which can lead to a range of health problems – including early onset osteoporosis (a reduction in bone density). Explain why the astronauts, who are still within the Earth's gravitational field, experience weightlessness.

Description	Marks
The astronauts are moving in a circular path around the Earth with the acceleration vector towards the centre of the Earth	1
The astronauts and satellite are accelerating towards the Earth at the same rate	1
This means they are never in contact, so there is no Normal force acting on the astronauts.	1
Total	3

Question 3 **(7 marks)**

The uniform bridge shown in the diagram below is 120.0 m long and has a weight of 20.0 kN. The support pillars (A and B) are 70.0 m apart.



(a) Calculate the magnitude of the force that pillar A exerts on the bridge when the two 8.00 kN cars are located at the positions shown.

(4 marks)

Description	Marks
$\Sigma\tau = 0$, $\tau = rF\sin\theta$ Taking Pillar B as the pivot	1
$\Sigma\tau_{cw} = 70F_A$ $\Sigma\tau_{ccw} = (20)(8,000) + 35(20,000) + (70+15)(8000)$	2
$70F_A = (20)(8,000) + 35(20,000) + (70+15)(8000)$ $F_A = 22.0$ kN	1
Total	4

(b) Calculate the magnitude of the force that pillar B exerts on the bridge when the two 8.00 kN cars are located at the positions shown. (If you could not complete part (a), use $F_A = 20.0$ kN)

(3 marks)

Description	Marks
$\Sigma F = F_A + F_B - 8000 - 8000 - 20000 = 0$	1
$F_A = 8000+8000+20000-22{,}000$	2
$F_B = 14.0$ kN (16.0 kN)	1
Total	4

Question 4 **(8 marks)**

Uranus has a moon, Umbriel, whose mean orbital radius is 2.67×10^8 m and whose period is 3.58×10^5 s.

(a) Calculate the mass of Uranus. Include a full derivation of Kepler's Third Law in your response.

(6 marks)

Description	Marks
$F_g = G\frac{m_1 m_2}{r^2}$, $F_c = \frac{mv^2}{r}$	1
$v = \frac{2\pi r}{T}$	0.5
$F_g = F_c$	0.5
$G\frac{m_1 m_2}{r^2} = \frac{m_1(\frac{2\pi r}{T})^2}{r}$	1
$Gm_2T^2 = 4\pi^2 r^3$	1
$(6.67 \times 10^{-11})(M_U)(3.58 \times 10^5)^2 = (4\pi^2)(2.67 \times 10^8)^3$	1
$M_U = 8.79 \times 10^{25}$ kg	1
Total	6

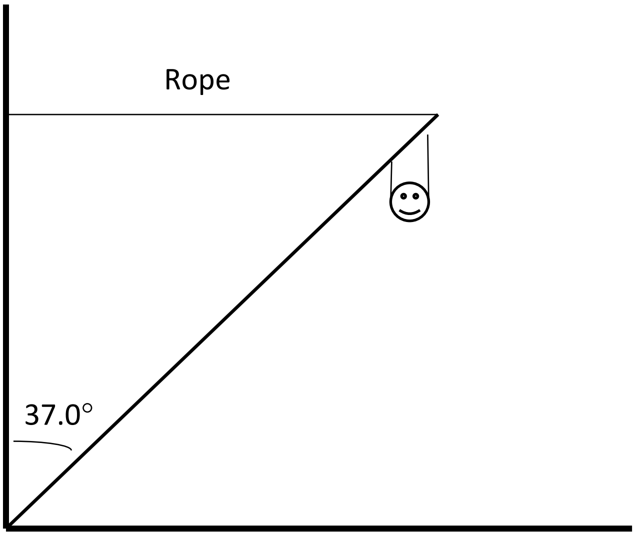
(b) Calculate the period of another of Uranus's moons, Oberon, whose mean orbital radius is 5.86×10^8 m.

(2 marks)

Description	Marks
$Gm_2T^2 = 4\pi^2 r^3$	
$(6.67 \times 10^{-11})(8.79 \times 10^{25})(T)^2 = (4\pi^2)(5.86 \times 10^8)^3$	1
$T = 1.16 \times 10^6$ s (or can use ratio of r^3 to T^2)	1
Total	2

Question 5 **(17 marks)**

The base of a non-uniform ladder rests against a wall and is held in place by a rope, as shown in the diagram below. The ladder is 7.00 m long and has a mass of 10.2 kg. Its centre of gravity is 0.400 of its length from the base. A 150.0 N child hangs from the ladder 0.200 of its length from the top.



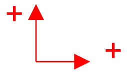
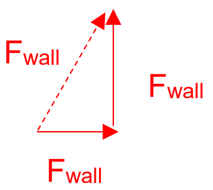
(a) Calculate the magnitude of the tension in the rope

(5 marks)

Description	Marks
$\Sigma\tau = 0$, $\tau = rF\sin\theta$	1
Taking left-hand base as the pivot $\Sigma\tau_{cw}$ = (0.4)(7)(10.2 x 9.8)(sin37) + (0.8)(7)(150)(sin37) $\Sigma\tau_{ccw}$ = (7)(T)(sin53)	3
(0.4)(7)(10.2 x 9.8)(sin37) + (0.8)(7)(150)(sin37) = (7)(T)(sin53) T = 121 N	1
Total	5
If working out for r = 2.4 m or 5.6 m not shown -1 mark	

(b) Calculate the force exerted on the base of the ladder. (If you could not complete part (a) use T = 110 N.)

(6 marks)

Description	Marks
$\Sigma F = 0$ Show convention 	0.5
$\Sigma F_V = F_{wallV} - m_{ladder}g - m_{boy}g = 0$ $\Sigma F_H = F_{wallH} - T = 0$	2
$F_{wallV} = (10.2 \times 9.8) + 150$ $= 250$ N	1
$F_{wallH} = T$ $=121$ N	0.5
 $tan\theta = \frac{opp}{adj} = \frac{250}{121}$ $\theta = 64.2°$ (66.3°) $\|F_{wall}\| = \sqrt{121^2 + 250^2}$ $\|F_{wall}\| = 278\ N$ (273 N)	1
$F_{base} = 278$ N at 64.2° above the floor to the right	1
Total	6

(c) Explain, making reference to any appropriate formulae, how the horizontal and vertical components of the force on the base of the ladder would change as the child moves back down the ladder towards the base.

(6 marks)

Description	Marks
As the child moves back down the ladder, the system remains in static equilibrium, So $\Sigma F=0$ and $\Sigma\tau=0$	1
Taking the pivot as the base of the ladder, as the child moves closer to the base, the radius at which their weight force is acting from the pivot decreases	1
As $\tau=rF\sin\theta$, as the **force is constant** (weight of child), **the angle between the force and radius is constant**, if r decreases, then the torque in the clockwise direction will decrease (clockwise torque due to ladder will not change).	1
To maintain static equilibrium, if the clockwise torque decrease, so must the counter-clockwise torque.	1
As the counterclockwise torque is to decrease, as **r and θ do not change**, the tension in the rope must decrease. This means that the horizontal component of the net force on the base will decrease	1
The vertical component on the force on the base of the ladder will not change, as there is no net change in the force in the vertical direction (ie the mass of the ladder nor the mass of the child are changing).	1
Total	6

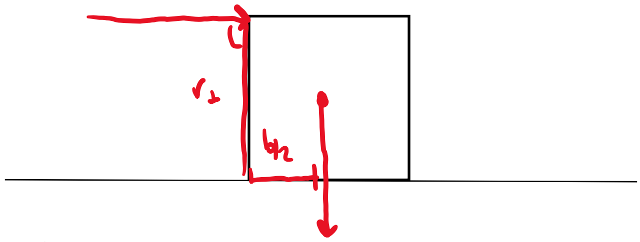
Question 6 **(4 marks)**

Mars has a mass of 0.107 M_{Earth} and a radius of 0.533 R_{Earth}. Calculate the acceleration due to gravity on the surface of Mars.

Description	Marks
$g = G\frac{M}{r^2}$	1
$= (6.67\ x\ 10^{-11})(\frac{(0.107)(5.97\ x\ 10^{24})}{((0.533)(6.37\ x\ 10^{6}))^2})$	2
= 3.70 ms^{-2} or 3.69 ms^{-2} if formula and ratio of 9.80 ms^{-2} used	1
Total	4

Question 7 **(4 marks)**

A square box of side length 20.0 cm and mass 15.0 kg sits on a table, as shown in the diagram below. It can be assumed that there is a sufficiently large static friction force between the box and table, that the box will not slip.

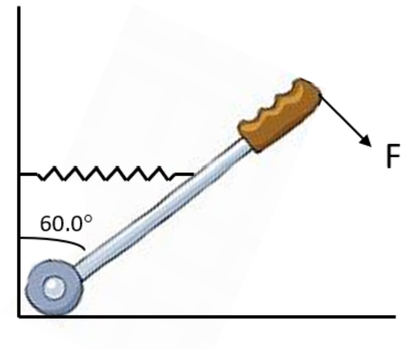


Calculate the minimum horizontal force that must be applied to the box to make it start to tip to the left.

Description	Marks
Box will start to tip when $\Sigma\tau_{ccw} < \Sigma\tau_{cw}$, $\tau = rF\sin\theta$	1
Take lower left corner as pivot $\Sigma\tau_{ccw} = (0.2)(F)$ $\Sigma\tau_{cw} = (\frac{0.2}{2})(15 \times 9.8)$	2
(0.2)(F) = (0.1)(147) F > 73.5 N -0.5 marks if = sign stated	1
Total	4

Question 8 **(5 marks)**

A person is pulling down on a 1.20 m long lever that is connected to the wall by a spring, as shown in the diagram below. In the diagram, the hand exerts a 200.0 N force, perpendicularly, at the end of the lever. The spring, which is connected to the midpoint of the lever, pulls back with a horizontal force of 80.0 N. Calculate the net torque acting on the lever about the pivot.



Description	Marks
$\tau = rF\sin\theta$	1
Taking lower left hand corner as the pivot $\Sigma\tau_{cw} = (1.20)(200)(\sin 90)$ $\Sigma\tau_{ccw} = (\frac{1.20}{2})(80)(\sin 30)$	2
$\Sigma\tau = (1.20)(200)(\sin 90) - (\frac{1.20}{2})(80)(\sin 30)$	1
$\Sigma\tau =$ 216 Nm Clockwise (-0.5 if direction missing)	1
Total	5