Christ Church Grammar School

Science Department
Year 11 2020

ATAR PHYSICS
UNIT 1 – Motion and Forces
TEST 2 2020

SOLUTIONS

Teacher: CJO JRM PCW SA
(Please circle)

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

Instructions to candidates:

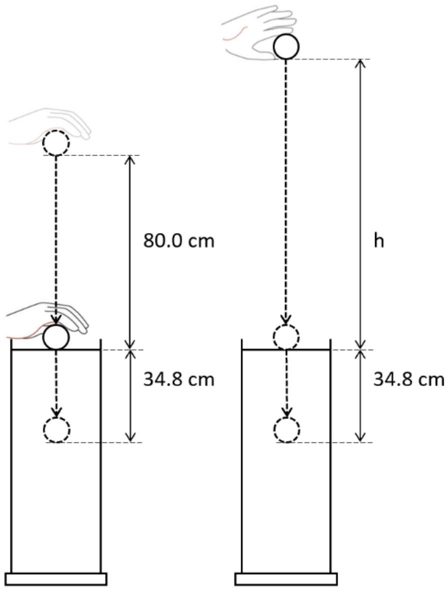
- You must include **all** working to be awarded full marks for a question. Answers should be expressed to an appropriate number of significant figures.
- Follow through marks for working may not be awarded if working is not clear and free body diagrams (if relevant) are not provided.
- Marks will be deducted for incorrect or absent units and / or directions.
- **No** graphics calculators are permitted – scientific calculators only.

Mark: / 46

= %

Question 1 **(11 marks)**

A year 7 student was carrying out an investigation into the viscosity of an unknown fluid by dropping marbles into large cylinders filled with the fluid. He found his result unsatisfying when a marble, of mass 25.0 g, dropped at the surface only sank a few centimetres before stopping. He decided to alter his experiment and threw the marble with great force directly downwards into the cylinder. This caused the marble to sink 34.8 cm before stopping.



(a) If the student applied a constant **net force of 7.50 N** over a distance of 80.0 cm before releasing the marble, calculate the speed at which the marble was released using energy and work concepts only.

(4 marks)

Description	Marks
W = Fs = (7.50)(0.800) = 6.00 N m	1
$W = \Delta E_K$ $Fs = \frac{1}{2} mv^2$	1
$v = \sqrt{\frac{2Fs}{m}}$ $v = \sqrt{\frac{2(6.00)}{(25 \times 10^{-3})}}$ $v = 21.9 \text{ m s}^{-1}$	2
If SUVAT method maximum 2 marks	
Total	4

(b) Using energy and work concepts, calculate the magnitude of the average braking force applied to the marble once it entered the unknown fluid

(4 marks)

Description	Marks
$W = \Delta E_K + \Delta E_P$ $E_P = mgh$	1
Calculates total energy lost $W = 6.00 + (25 \times 10^{-3})(9.80)(34.8 \times 10^{-2})$ W = 6.09 N m (-2 if not considered Ep, final answer is 17.2 N)	1
$F_{braking} = W/s$ Equates total energy lost to Work done by fluid	1
$F_{braking} = 6.09 / (34.8 \times 10^{-2})$ = 17.5 N	1
If SUVAT method maximum 2 marks	
Total	4

A second student, thinking he was smart, thought that a much easier way to find satisfactory results was to drop the marble from a height above the cylinder. This variable would seemingly be much easier to control and measure.

(c) Using energy and work concepts only, calculate the theoretical height from which the student would need to drop the marble in order for the marble to reach the same 34.8 cm depth.
(If you were unable to answer part (a), assume an entrance velocity of 20.0 m s^{-1})

(3 marks)

Description	Marks
Same depth must mean same amount of energy on entrance. Therefore v = 21.9 ms^{-1}, or E_K = 6.00 J ((E_k = 5.00 J)	1
$E_{Kf} = E_{Pi}$ $E_K = mgh_i$ $h_i = \frac{E_K}{mg}$	1
$= \frac{6.00}{(25.0 \times 10^{-3})(9.80)}$ = 24.5 m (20.4 m)	1
Total	3

Question 2 **(4 marks)**

It is often said that friction is a force that always opposes motion. In the case of boxes being transported on a conveyor belt, friction is the force that drives the boxes forwards when the belt is starting up from rest. Explain this with reference to the relevant Newton's law(s) and state whether the first statement is true or false.

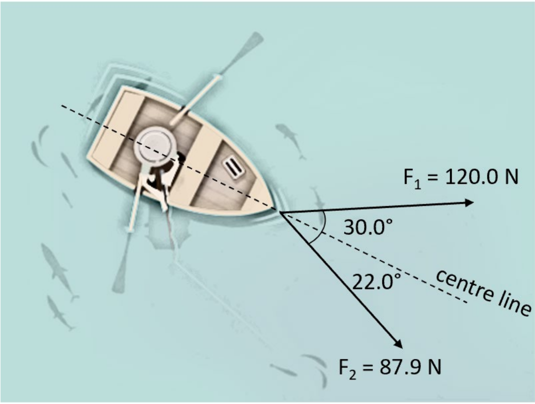
Model Solution

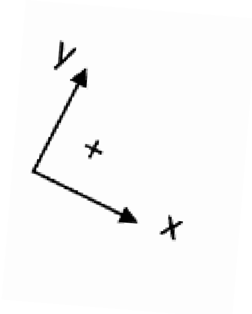
- The boxes were initially at rest, and as they have mass and therefore inertia, according to Newton's first law, they will stay at rest unless an unbalanced force acts upon them.
- If they stayed at rest, relative to the belt which is moving forwards, that would be relative motion between the box and the belt.
- Friction opposes this relative motion, providing the net external force necessary to accelerate the box and therefore maintain equilibrium between the belt and the box.
- The statement is therefore true.

Description	Marks
Define/ link to 1st law with all key terms (mass, inertia and unbalanced / net force)	1
Good physics explanations re relative motion and opposing relative motion	2
Statement is true	1
Total	4

Question 3 **(5 marks)**

Using components, calculate the acceleration with respect to the centreline, of a boat of mass 185 kg subjected to the forces as shown.





Description	Marks
$\sum F_x = ma_x = 120.0\cos(30) + 87.9\cos(22) = 185\ a_x$ $a_x = 1.00\ ms^{-2}$	1.5
$\sum F_y = ma_y\ \ 120.0\sin(30) - 87.9\sin(22) = 185\ a_y$ $a_y = 0.146\ ms^{-2}$	1.5
$a = \sqrt{0.146^2 + 1.00^2} = 1.01\ ms^{-2}$	1
$tan\theta = \frac{0.146}{1.00}\ ,\ \ \theta = 8.30°$	1
$a = 1.01\ ms^{-2} at\ an\ angle\ of\ 8.30°\ from\ its\ current\ course\ (towards\ F_1)$ (no marks attributed to stating solution but -0.5 if missing)	(-0.5)
Must use components. Can resolve x and y components of Force (ΣF = 187N), and use F = ma once net force is resolved for equivalent marks. If student does not analyse forces in y component a = 1.00 maximum 2 marks	
Total	5

Question 4 **(3 marks)**

An overloaded train of mass 850.0 tonnes is struggling to travel up a small incline, while carrying several heavy wagons of ore, managing only 5.20 m s^{-1}. Realising the journey will take too long, a second engine of mass 200.0 tonnes is called in to shunt (push) the train along. The second engine travels at 11.0 m s^{-1} until impact, and then joins to the rear of the first train. Calculate the speed of the assembly immediately after impact.

Description	Marks
$\sum p_i = \sum p_i \qquad\qquad p = mv$	1
$850(5.20) + 200(11.0) = (850 + 200)v$	1
$v = 6.30\ m\ s^{-1}$	1
Total	3

Question 5 **(9 marks)**

An explorer is being lowered down into an abyss by his friend who is slowly feeding a rope through a pulley system. Where the explorer is connected to the rope, there is a force meter which is calibrated to display his mass. He can use this to determine the mass of any treasures he collects and to ensure that he does not exceed the maximum load for the rope.

While being lowered down at constant speed, the force meter reads 82.0 kg.

(a) Calculate the weight of the explorer.

(2 marks)

Description	Marks
W = mg	0.5
W = (82.0)(9.80)	0.5
W = 804 N Down (-0.5 if no direction stated)	1
Total	2

(b) Using energy and work concepts only, calculate the power required to be input to raise the explorer by 10.0 m over a period of 30.0 s

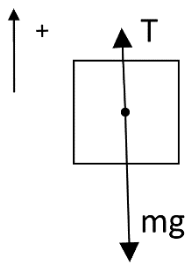
(3 marks)

Description	Marks
$P = \frac{\Delta E}{t}$ $E_P = mgh$ $P = \frac{mgh}{t}$	1
$P = \frac{(82.0)(9.80)(10.0)}{30}$	1
$P = 268\ W$	1
Total	3

While hoisting the explorer up, several of the strands of the rope break after catching on a jagged rock. This causes the explorer to temporarily accelerate downwards at a rate of 7.35 m s^{-2}.

(c) Calculate the mass displayed on the force meter during this descent.

(4 marks)

Description	Marks
$\sum F = ma$ $T - mg = ma$ (a will be negative) $T = m(g + a)$ 	2
$T = 82.0(9.80 - 7.35)$ $T = 201\ N$	1
$\frac{T}{g} = \frac{201}{9.80} = 20.5\ kg$	1
Total	4

Question 6 **(4 marks)**

Explain with reference to the relevant Newton's law(s), why a passenger train is designed to stop over a longer distance than a truck of a comparable mass for any given speed.

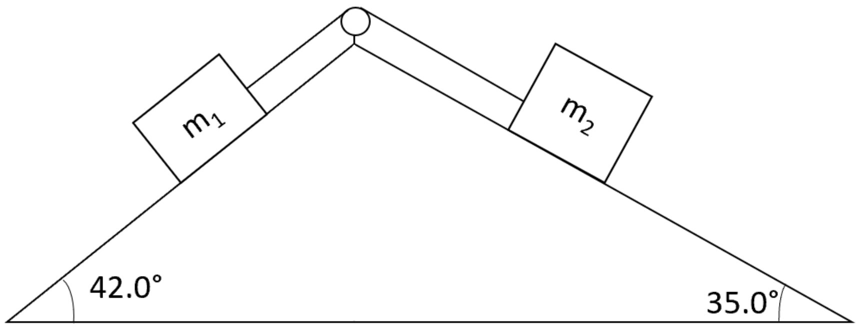
Model solution:

- According to Newton's 1st law, objects with mass have inertia, and will continue in their current state of motion unless acted upon by a net external force.
- By stopping over a greater distance, the train is experiencing a lower acceleration and hence a reduced braking force is required (according to Newton's 2nd law, F = ma)
- People in the passenger train are not rigidly connected to the train, so when the train brakes, the people continue in their state of motion due to their inertia and **appear** to lurch forwards **relative to** the train.
- If the force is reduced, the "lurching" and hence passenger discomfort is reduced. In the truck, passenger comfort is not a consideration.

Description	Marks
Define/ link to 1st law with all key terms (mass, inertia and unbalanced / net force)	1
Link distance with acceleration or force	1
Good physics explanation including all relevant key terms	1
Definitive answer referring to passenger comfort	1
If students state "flying forwards" without mention of "appearing to" or "relative to train's reference frame" maximum 3 marks	
Total	4

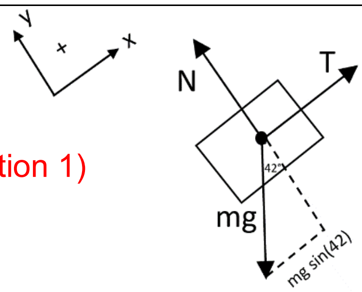
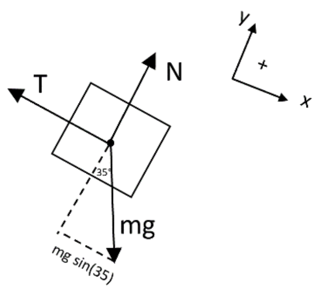
Question 7 **(10 marks)**

A block of unknown mass is connected by a string to a known mass (m_1) of 5.25 kg and suspended on an inclined surface via a frictionless pulley as shown in the diagram. Assume there is no friction between each mass and the surface.



(a) Calculate the mass m_2 if the two masses are stationary and in equilibrium as shown.

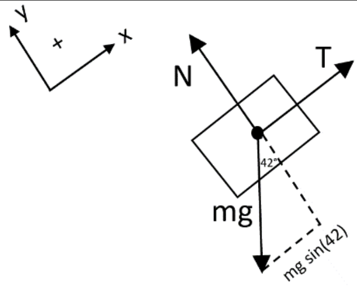
(4 marks)

Description	Marks
Body 1 $\sum F_x = 0$ $T - m_1 g sin\theta_1 = 0$ $T = m_1 g sin\theta_1$ (Equation 1)  	1
Body 2 $\sum F_x = 0$ $-T + m_2 g sin\theta_2 = 0$ $m_2 = \frac{T}{g sin\theta_2}$ (Equation 2)  	1
Sub equation 1 into 2 $m_2 = \frac{m_1 g sin\theta_1}{g sin\theta_2} = \frac{m_1 sin\theta_1}{sin\theta_2}$	1
$m_2 = \frac{5.2 \sin(42)}{\sin(35)}$ $m_2 = 6.12\ kg$	1
Total	4

Now consider another scenario, in which m_2 changes and the two masses are not in equilibrium. The objects are accelerating at a rate of 0.232 m s^{-2} such that m_2 is sliding down the slope

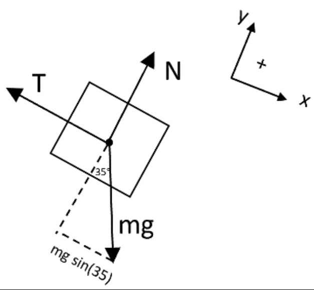
(b) Calculate the magnitude of tension in the rope.

(3 marks)

<table>
<tr><th>Description</th><th>Marks</th></tr>
<tr><td>Body 1
$\sum F_x = m_1 a$
$T - m_1 g sin\theta_1 = m_1 a$

</td><td>1</td></tr>
<tr><td>$T = m_1(g sin\theta_1 + a)$
$T = 5.25(9.80\sin(42) + 0.232)$</td><td>1</td></tr>
<tr><td>$T = 35.6\ N$</td><td>1</td></tr>
<tr><td>Total</td><td>3</td></tr>
</table>

(c) Calculate the mass of m_2. (If you could not solve part (b) use T = 25.4 N)

(3 marks)

<table>
<tr><th>Description</th><th>Marks</th></tr>
<tr><td>Body 2
$\sum F_x = m_2 a$
$-T + m_2 g sin\theta_2 = m_2 a$

</td><td>1</td></tr>
<tr><td>$T = m_2(g sin\theta_2 - a)$
$m_2 = \frac{T}{g sin\theta_2 - a}$</td><td>1</td></tr>
<tr><td>$m_2 = \frac{35.6}{9.80\sin(35) - 0.232}$
$m_2 = 6.61\ kg$ (4.71 kg)</td><td>1</td></tr>
<tr><td>Total</td><td>3</td></tr>
</table>

END OF TEST