Physics ATAR - Year 11

Motion and Forces
Test 2
2018

Mark: / 51

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Name: SOLUTIONS

Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(8 marks)**

A car travelling at 27.0 ms^{-1} West crashes and activates its airbags. The 90.0 kg driver comes to a stop in 40.0 milliseconds.

(a) Calculate the initial momentum of the driver.

(2 marks)

$p = mv$ ½

$= 90 \times 27$ ½

$= 2.43 \times 10^3$ $kgms^{-1}$ West 1

(b) Calculate the impulse experienced by the driver.

(3 marks)

$I = F\Delta t = \Delta p = mv - mu$ 1

$= 90(0) - (90)(-27)$ 1

$= 2.43 \times 10^3$ $kgms^{-1}$ East 1

- ⟷ +
west east

(b) Calculate the average force experienced by the driver.

(3 marks)

$I = F = \dfrac{\Delta p}{\Delta t}$ 1

$= \dfrac{2.43 \times 10^3}{40 \times 10^{-3}}$ 1

$= 6.08 \times 10^4$ N East 1

- ⟷ +
west east

Question 2 **(9 marks)**

A rocket has an initial total mass of 5.00 x10^4 kg, which includes 3.00 x10^4 kg of fuel. It expels exhaust from its engines at a velocity of 5.00 x10^3 ms^{-1} (relative to the rocket) at a constant rate of 175.0 kg/s until its fuel supply is exhausted. Assume that the rocket is in space and not significantly influenced by gravitational fields.

(a) Calculate the average force exerted on the rocket during the time of engine operation.

(3 marks)

$$I = F = \frac{\Delta p}{\Delta t} = \frac{mv - mu}{\Delta t} \quad 1$$

$$= \frac{175\,(5000)}{1} \quad 1$$

$$= 875{,}000 \text{ N} \quad 1$$

(b) Calculate the initial acceleration of the rocket during the time of engine operation. If you could not complete (a), use F = 500,000 N

(3 marks)

½ ½

$$\Sigma F = ma \qquad a = \frac{\Sigma F}{m}$$

$$= \frac{875{,}000}{50{,}000} \quad 1$$

$$= 17.5 \text{ ms}^{-2} \text{ forwards} \quad 1$$

Runs out of fuel

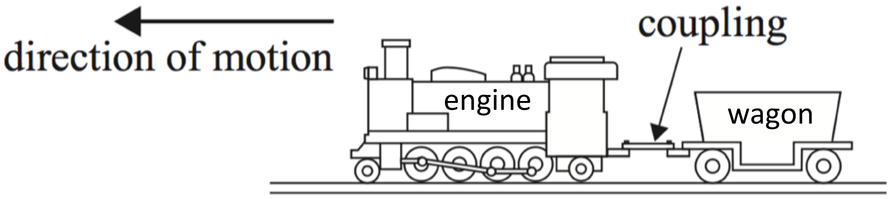
(c) State and explain (using your knowledge of Newton's Laws of motion) what happens to the acceleration of the rocket as it exhausts its fuel supply. (3 marks)

- As the fuel exhausts it's supply, it can no longer produce an unbalanced external force on the rocket
- Newton's 1st law states that an object in motion will continue in a straight line motion unless acted upon by an unbalanced external force.
- The rocket will travel in a straight line / with a constant velocity.

(Note: If student interpret question as "while fuel is being exhausted/ejected" and uses Newton's 2nd Law, maximum 2 marks awarded)

Question 3 **(9 marks)**

A train consists of an engine of mass 21.2 x10^3 kg towing one wagon of mass 13.5 x10^3 kg, as shown in the diagram. The train accelerates from rest with a constant acceleration of 0.100 ms^{-2}.



(a) The wagon has a frictional resistance of 2.00 kN. Calculate the tension in the coupling between the engine and the wagon.

(3 marks)

Consider forces acting on wagon

$\Sigma F = ma = T + F_F$ 1

$= 13{,}500(0.100) = T + (-2000)$ 1

$1{,}350 = T - 2000$

$T = 3350$ N 1

In another (completely different) situation, the engine, moving at 3.00 ms^{-1} West, collides with another stationary wagon of mass 15.4 x10^3 kg and couples with it.

(b) Calculate the speed of the train (engine and wagon) after the collision.

(3 marks)

m1u1 + m2u2 = mcvc 1

- ← → +
west east

$21200(-3) + 15400(0) = (21200 + 15400)\ v_c$ 1

$v_c = -1.74$

$= 1.74\ ms^{-1}$ 1

(c) Determine whether the collision shown in (b) was elastic or inelastic, including a calculation to support your answer. (if you could not complete (b), use vc = 1.60 ms^{-1}).

(3 marks)

Does $\Sigma E_i = \Sigma E_f$ ½

$½\, m_1 u_1^2 = ½(m1+m2)v_c^2$ ½

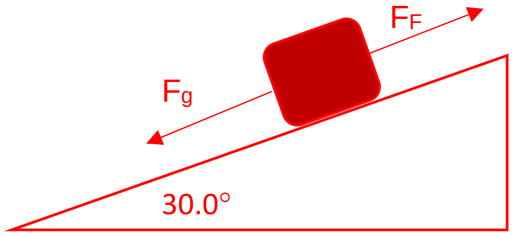
$½\,(21200)(3^2) = ½\,(21200+15400)(1.74^2)$ 1

95,500 J $\neq$ 55,405 J

Hence inelastic. 1

Question 4 **(3 marks)**

An object rests on an inclined plane that is at an angle of 30.0° to the horizontal. The friction between the object and the surface of the plane is a maximum 15.0 N. What would be the minimum mass of the box for it to slide down the plane? Include a diagram in your response.



$\Sigma F > 0 = F_g + F_F$ 1

$mg\sin\theta > 15$ 1

$m > 15 / (9.8.\sin 30)$

$m > 3.06$ kg 1

Question 5 **(9 marks)**

Students set up an experiment as shown below. M_1, of mass 4.00 kg, is connected by a light string (assume it has no mass) to a hanging mass, M_2, of 1.00 kg. The system is initially at rest. Ignore the mass of string and friction.

(a) Calculate the acceleration of M_1

(3 marks)

1 $\Sigma F_S = (m1+m2)a_S = m_2g$

$a_s = \dfrac{m_2 g}{(m_1+m_2)} = \dfrac{1(9.8)}{5} = 1.96\ ms^{-2}$ Left

1 1

OR

$T = m_1a_1$

$m_2g - T = m_2a_2$ $T = m_2g - m_2a_2$

$m_1a_1 = m_2g - m_2a_2$

$m_1a_1 + m_2a_2 = m_2g$

$(m_1+m_2)a = m_2g$ $a = 9.8/5 = 1.96$

(b) Calculate the magnitude of the tension in the string as the masses accelerate.

(3 marks)

$\Sigma F_1 = T = m_1a_1$ 1

$= 4.00(1.96)$ 1

$= 7.84$ N 1

(c) State whether the tension in the string changes if the masses had an initial motion. Include an explanation in your response.

(3 marks)

- No
- as the Tension is only dependent on the acceleration of the system
- which is only dependent on m_1 m_2 and g, (not v or u)

Question 6 **(13 marks)**

A large electromagnet in a scrap metal yard is used to pick up and move pieces of metal. A large metal bar of mass 605 kg is raised through a height of 4.00 m.

(a) Calculate the work done on the metal bar.

(3 marks)

$W = \Delta E = mg\Delta h$ 1

$= 605 \times 9.8 \times 4.00$ 1

$= 2.37 \times 10^4$ J 1

(b) The electromagnet is switched off and the bar falls to the ground. **Using the concept of conservation of energy**, calculate the speed of the bar as it hits the ground.

(3 marks)

$E_T = \cancel{E_{ki}}^{0} + E_{pi} = E_{kf} - \cancel{E_{pf}}^{0}$ ½

$mgh = \frac{1}{2}mv^2$ ½

$v = \sqrt{2gh}$ 1

$= \sqrt{2 \times 9.8 \times 4.00}$

$= 8.85$ ms^{-1} 1

(c) The electromagnet has an input power rating of 4.50 kW. Calculate the height it could lift the bar if it runs for 15.0 s?

(4 marks)

$P = \frac{E}{t} = \frac{mgh}{t}$ 1

$h = \frac{Pt}{mg}$ 1

$= \frac{4.5 \times 10^3 (15)}{605(9.8)}$ 1

$= 11.4$ m 1

(d) State the primary assumption made in (c) and explain in reality, how the actual height would compare to (c).

(3 marks)

- Assumption is energy transformation is 100% efficient.
- In reality, some energy input would be lost to heat/sound
- resulting in less output energy, hence lower height.

END OF TEST