Physics ATAR - Year 11

Linear Motion
Unit Test
2017

Name: SOLUTIONS	Mark: / 61 = %

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 **(10 marks)**

The limited-edition hybrid sports car "LaFerrari" has the fastest recorded 0.00 – 100.0 km/h time of 2.30 seconds.

(a) Calculate the average acceleration of the LaFerrari during this time.

(3 marks)

v = 100 / 3.6

= 27.8 m/s (1)

$$a = \frac{v-u}{t}$$ (½)

$$= \frac{27.8-0}{2.30}$$ = 12.1 ms^{-2} in direction of motion

(1) (1)

(b) Calculate the distance travelled during this average acceleration.

(3 marks)

s = ut + ½at^2 (1)

= ½(12.1)(2.3^2) (1)

= 32.0 m (1)

(c) If the LaFerrari has a mass of 1,450 kg, determine the "power-to-mass" (in kW/kg) ratio of the car during its 0.00 – 100.0 km/h acceleration.

(4 marks)

$$P = \frac{W}{t} = \frac{\frac{1}{2}mv^2}{t} = \frac{\frac{1}{2}(1450)(27.8^2)}{2.3}$$

(½) (½) (½)

= 244 kW (1)

$$\frac{P}{m} = \frac{244\ kW}{1450\ kg} = 0.168\ kW/kg$$

(½) (1)

Question 2 **(6 marks)**

A person stand on top of a 3.50 m high balcony and throws a rock downwards with a speed of 4.00 ms^{-1}.

(a) Calculate the velocity of the object as it strikes the ground.

(3 marks)

$v^2 = u^2 + 2as$ (1)

$v = \sqrt{-4^2 + 2(-9.8)(-3.5)}$ (1)

$= 9.20\ ms^{-1}$ Downwards (1)

(b) Calculate the time it takes to strike the ground.

(3 marks)

$t = \frac{v-u}{a}$ (1)

$= \frac{-9.20-(-4)}{-9.8}$ (1)

= 0.531 s (1)

Question 3 **(8 marks)**

A 70.0 kg person stands in a lift on the ground floor of a building and begins to accelerate upwards at a rate of 1.50 ms^{-2}. The elevator reaches its cruising speed of 2.50 ms^{-1} and maintains this speed as it ascends towards level 5 which is 13.0 m above the ground floor.

(a) Calculate the normal force acting on the person as the lift accelerates upwards (3 marks)

$\Sigma F = ma = W + N$ (1)

N = ma - W (½)

= 70(+1.50) – (70x-9.8) (½)

= 791 N Upwards (1)

(b) Calculate the time taken for the elevator to reach level 5 (assuming it continues past without decelerating). (5 marks)

Acceleration

$t = \frac{v-u}{a}$

$t = \frac{2.50-0}{1.5}$

= 1.67 s (1)

Constant Speed

s = $\frac{v^2-u^2}{2a}$

s = $\frac{2.5^2-0^2}{2(1.5)}$

= 2.08 m (1)

s = 13.0 – 2.08

= 10.9 m (1)

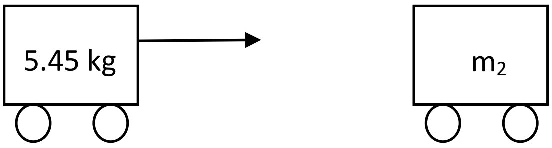
t = $\frac{s}{v} = \frac{10.9}{2.5}$ = 4.36 (1)

t = 1.67 + 4.36

= 6.03 s (1)

Question 4 (10 marks)

A 5.45 kg cart travelling 3.00 ms^{-1} East collides with a stationary cart of mass m_2. The carts then couple and are observed to travel off with velocity 1.20 ms^{-1} East.



(a) Calculate the mass of m_2.

(3 marks)

$\Sigma p_i = \Sigma p_i$ p = mv (½)

$m_1 u_1 = (m_1 + m_2)\, v_c$ (½)

$5.45(+3) = (5.45 + m_2)(+1.2)$ (½)

$= 6.54 + 1.2\, m_2$ (½)

$m_2 = \frac{16.4 - 6.54}{1.2} = 8.18$ kg (1)

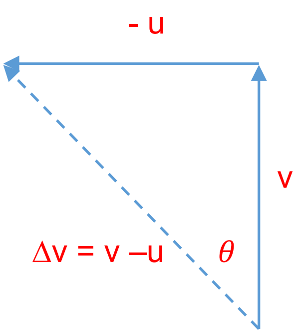
(b) Can the force acting on either cart be determined from the above information. Provide and suitable equation in your explanation.

(3 marks)

- No
- The change in momentum is equal to FΔt.
- Since the time of contact is not given, the magnitude of force cannot be calculated.

(c) In a new scenario, the 5.45 kg cart is travelling with the same initial velocity as (a) and collides with another cart travelling North-West. The final velocity of the 5.45 kg cart is 2.35 ms^{-1} North. Calculate the change in momentum of the 5.45 kg cart.

(4 marks)



$|\Delta v| = \sqrt{3^2 + 2.35^2} = 3.81\ ms^{-1}$ (1)

$\theta = \tan^{-1}(3 / 2.35) = 51.9°$ (1)

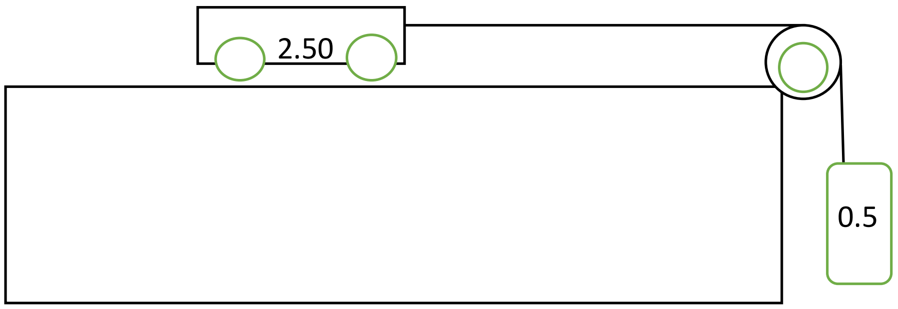
$\Delta p = m\Delta v$ (½)

$= 5.45 \times 3.81$ (½)

$= 20.8$ $kgms^{-1}$ N 51.9° W (1)

Question 5 **(7 marks)**

A frictionless cart of total mass 2.50 kg, is connected by a light thread that passes over a fixed pulley, as shown in the diagram below. A hanging mass of 0.500 kg is attached over the pulley and allowed to fall.



(a) Ignoring friction, calculate the magnitude of the acceleration of the system mass.

(4 marks)

$\Sigma F = m_2 a$ (½)

$= 0.5(9.8)$ (½)

$= 4.90$ N (1)

$a = \frac{\Sigma F}{m_s} = \frac{4.9}{(2.5+0.5)}$ (½) (½)

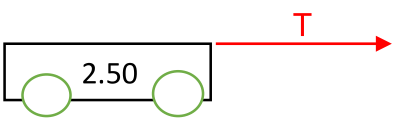
$= 1.63\ ms^{-2}$ (1)

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

(3 marks)

Choose m_1

a = +1.63 →



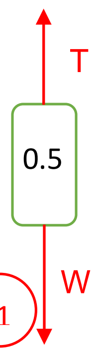
$\Sigma F = m_1 a$ = T (1)

T = 2.5 x 1.63 (1)

= 4.08 N (1)

Choose m2

a = -1.63



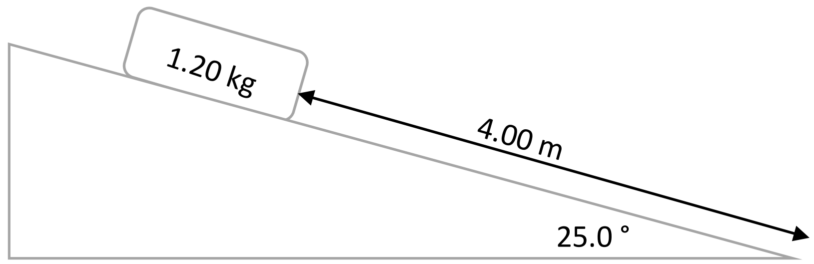
$\Sigma F = m_2 a$ = T + W (1)

T = 0.5(-1.63) – (0.5 x -9.8) (1)

= 4.08 N (1)

Question 6 **(10 marks)**

A 1.20 kg textbook is placed on an incline of 25.0°. It is observed to take 4.00 seconds to slide 4.00 m down the incline.



(a) Calculate average acceleration of the book as it slides down the incline.

(3 marks)

$s = ut + \frac{1}{2}at^2$ (1)

$4 = \frac{1}{2}(a)(4^2)$ (½)

$a = \frac{2(4)}{16} = 0.500\ ms^{-2}$ down the incline

(½) (1)

(b) Calculate the average frictional force that acts while the book is sliding down the incline.

(4 marks)

Down the incline is positive

$\Sigma F = ma = mgsin\theta + F_F$ (1)

$F_f = ma - mgsin\theta$ (1)

$= 1.20(0.500) - (1.2)(9.8)sin25$ (1)

$= 4.37$ N up the incline (1)

(c) Calculate the energy lost to heat as the book slides down the incline.

(3 marks)

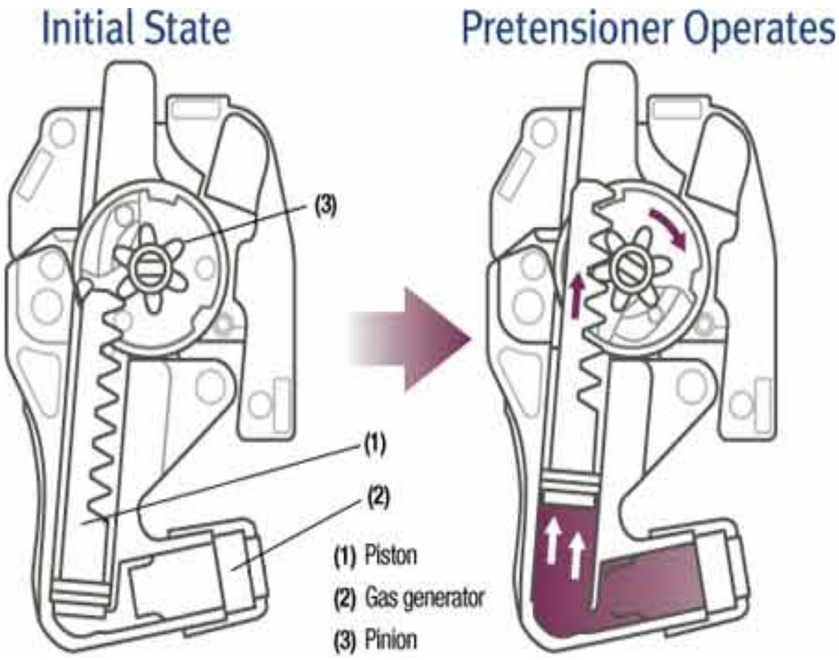
$W = F_f \times s$ (1)

$= 4.37(4)$ (1)

$= 17.5$ J (1)

Question 7 **(10 marks)**

Occupant safety in car design has been a been an important factor in research and manufacturing since the introduction of the “lap-belt” in the mid 1950s. Dr C. Hunter Sheldon published an important paper in the 1955 Journal of the American Medical Association (JAMA) in which he proposed not only a retractable lap-belt, but also recessed steering wheels, reinforced roofs, roll bars, door locks and passive restraints such as the air bag. Subsequently, in 1959, Congress in America passed legislation requiring all automobiles to comply with certain safety standards, including the installation of the lap-belt.



In in the mid 1970s, the lap-belt, which was essentially a single belt fastened across the waist, was replaced with a 3-point harness; a belt across the waist and diagonally across the torso of the occupant. The diagonal section was able to apply a retarding force to the torso of the occupant.

Seatbelts in many newer vehicles are also equipped with "pretensioners" or "web clamps", or both. Pretensioners pre-emptively tighten the belt to prevent the occupant from jerking forward in a crash. Mercedes-Benz first introduced pretensioners on the 1981 S-Class. In the event of a crash, a pretensioner will tighten the belt almost instantaneously. This reduces the motion of the occupant in a violent crash. Like airbags, pretensioners are triggered by sensors in the car's body, and many pretensioners have used explosively expanding gas to drive a piston that retracts the belt.

(a) State which of Newton’s laws applies predominantly to application of pretensioners. (1 mark)

Newton’s 1st Law

(b) Explain, making reference to an appropriate Newton’s law, how the 3-point harness seatbelt provides additional safety to the occupant compared to the lap-belt. (3 marks)

- The occupants torso has inertia and, in the event of a collision, will continue travelling in original direction
- The 3 point harness applies an external unbalanced force to the torso of the occupant
- And decelerate them preventing impact with the dashboard or steering column

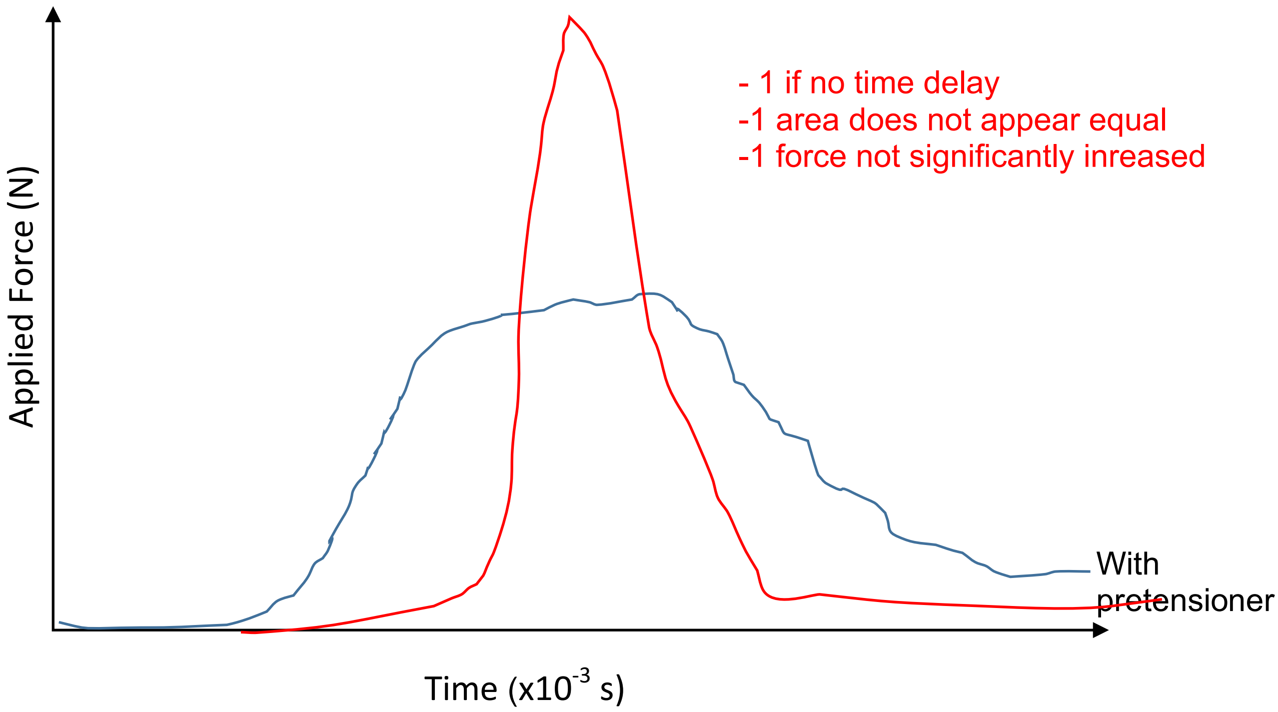
Web clamps clamp the webbing of the seatbelt in the event of an accident, and limit the distance the webbing can spool out (caused by the unused webbing tightening on the central drum of the mechanism). These belts also often incorporate an energy management loop ("rip stitching") in which a section of the webbing is looped and stitched with a special stitching. The function of this is to "rip" at a predetermined load, which reduces the maximum force transmitted through the belt to the occupant during a violent collision.

(c) Explain, making reference to appropriate physics concepts, why the rip stitching reduces injuries to the occupant.

(3 marks)

- By ripping the stitching during collision, the time that the occupant experiences the force is increased
- As the change in momentum is constant and $\Delta p = F\Delta t$
- The force acting on the occupant is reduced which reduces the likelihood of injuries.

The graph below shows the applied force acting on an occupant while in a collision over time.



(d) On the graph above, plot another Force-time curve to represent the applied force on an occupant if the seat belt did not contain a pretensioner.

(1 mark)

(e) State what the area under the curve represents and the units of the quantity.

(2 marks)

Area = [N][s] or [kgms^{-1}]
= Impulse or "change in momentum"