# Physics ATAR - Year 12

# Gravity and Motion
# Test 1
# 2019

| Name: **SOLUTIONS** | Mark: / 59<br>= % |
|---|---|

Teacher:
(please circle)

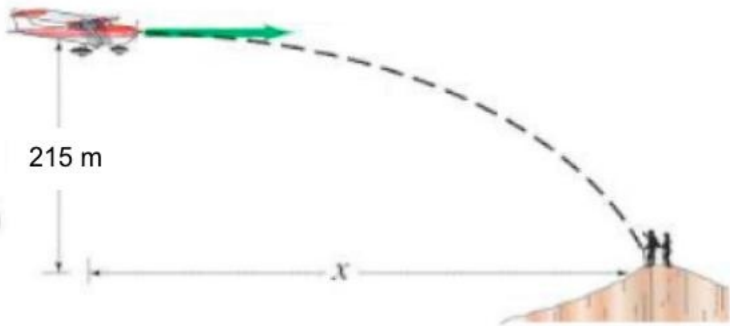
Time Allowed: 50 Minutes

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** **(9 marks)**

A rescue plan wants to drop supplies to isolated mountain climbers on a rocky ridge 215 m below. The plane is travelling at 72.4 ms$^{-1}$ horizontally.




(a) Calculate the distance 'x' that that plane must drop the supplies in advance in order for them to reach the climbers.

(4 marks)

Find t from sy

$s = ut + ½ at^2$ (½)

$= ½ at^2$

$t = \sqrt{\frac{2s}{a}}$

$= \sqrt{\frac{2(-215)}{-9.8}}$ (½)

= 6.62 s (1)

$s_x = u_x.t$ (½)

= 72.4 x 6.62 (½)

= 479 m (1)

(b) Suppose instead, the plane (while still travelling 72.4 ms$^{-1}$ horizontally) releases the supplies a horizontal distance of 425 m in advance of the climbers. Calculate the vertical velocity (up or down) that the supplies should be given in order for them to reach the climbers.

(5 marks)

from x

$t = \frac{s_x}{ux}$ (½) $= \frac{425}{72.4}$ (½)

= 5.87 s (1)

from y

$s = u\sin\theta t + ½ at^2$ (½)

$-215 = u\sin\theta\ (5.87) + (1/2)(-9.8)(5.87)^2$ (1.5)

$u\sin\theta = \frac{-215 + (4.9)(5.87)^2}{5.87}$

= 7.86 ms$^{-1}$ downwards (1)

**Question 2** **(8 marks)**

A “fuzzy dice” is hanging by a string from the rearview mirror of a car. The car enters a corner and travels at a constant speed of 20.0 ms$^{-1}$ throughout. The driver observes that the string makes an angle of 10.0° to the vertical.

(a) Calculate the radius of curvature of the corner.

(5 marks)

$\sum F_x = F_C = \frac{mv^2}{r} = T\sin\theta$

$T = \frac{mv^2}{r\sin\theta}$ (1)

$\sum F_y = W + N\cos\theta = 0$

$T = \frac{-mg}{\cos\theta}$ (1)

$\frac{mv^2}{r\sin\theta} = \frac{-mg}{\cos\theta}$ (1)

$\frac{v^2}{rg} = \tan\theta$

$r = \frac{v^2}{g\tan\theta}$ (1)

$= \frac{20^2}{9.8\tan 10}$

$= 231m$ (1)

(b) Calculate the centripetal acceleration of the car as it turns the corner.

(3 marks)

$a = \frac{v^2}{r}$ (1)

$= \frac{20^2}{231}$ (1)

OR

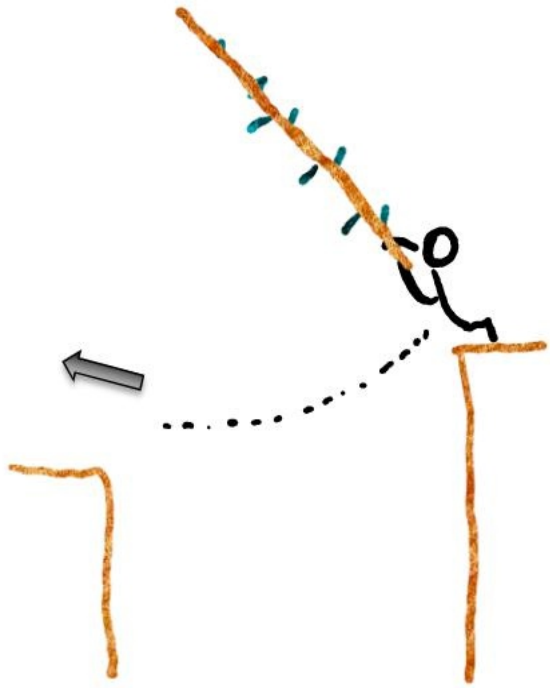
$= \frac{rg\tan\theta}{r} = g\tan\theta$

$= 9.8\tan 10.0$

$= 1.73\ ms^2$ towards centre of curvature (1)

**Question 3** **(7 marks)**

Tarzan plans to cross a gorge by swinging in an arc from a 7.40 m hanging vine. The tension in the vine can withstand a maximum force of 1400 N before it breaks and his mass is 85.0 kg.



(a) Calculate the maximum speed the vine can support at the lowest point of his swing.

(4 marks)

$\sum F_y = F_C = \frac{mv^2}{r} = -W + T$ (1)

= -85.0(9.8) +1400 (1)

= +567 N

$v = \sqrt{\frac{567 \times 7.40}{85}}$ (1)

= 7.03 $ms^{-1}$ (1)

*Students do not need to evaluate the net force = +567 numerically, but for two marks full working out and rearrangement must be shown.

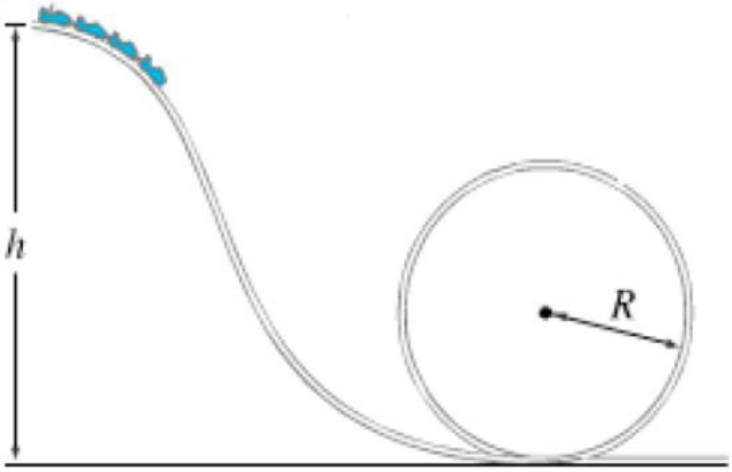
(b) Explain the effect (if any) that shortening the vine would have on the maximum speed that Tarzan could swing at the lowest point.

(4 marks)

- Since T is constant and Weight is constant, the maximum Centripetal Force is a constant.
- As Fc = $mv^2$ / r , as mass is constant, $v^2$/r is also constant (or $v^2$ proportional to r)
- From this, if we decrease r, $v^2$ must also decrease.
- Hence the maximum speed decreases.

**Question 4** **(9 marks)**

A roller coaster of mass 1250 kg falls from point A with an initial speed of 4.00 $ms^{-1}$. It falls from an initial height '$h_i$' and then enters a loop of radius 'R'.




(a) Using concepts of conservation of energy, produce an equation for the total mechanical energy in terms of '$h_i$'. (3 marks)

½ ½

$E_T = E_p + E_k$   $E_p = mgh$   $E_k = ½mv^2$

$E_T = mgh_i + ½ mu^2$ 1

$= 1250(9.8)hi + ½(1250)(4^2)$

$= 12{,}250h_i + 10{,}000$ 1

(b) Given that h = 13.0 m and R = 4.40 m, Calculate the speed of the rollercoaster as it reaches the top of the loop. (3 marks)

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

$= 4^2 + 2(-9.8)(13-2x4.4)$ 1

$= 4^2 + 2(-9.8)(-4.2)$

$v = 9.92\ ms^{-1}$ 1

OR: $\Sigma E_f = \Sigma E_i$

$½mv^2 + mgh_f = mgh_i + ½mu^2$

$½(1250)v^2 + 1250(9.8)*8.8 = 1250(9.8)*13 + ½(1250)4^2$

$v = \sqrt{\frac{2(61450)}{1250}} = 9.92\ ms^{-1}$

(c) Hence, calculate the reaction force that the track exerts on the rollercoaster. (If you could not complete (b), use v = 11.0 $ms^{-1}$) (3 marks)

$$\sum F_y = F_C = \frac{-mv^2}{r} = -W + N$$ 1

½

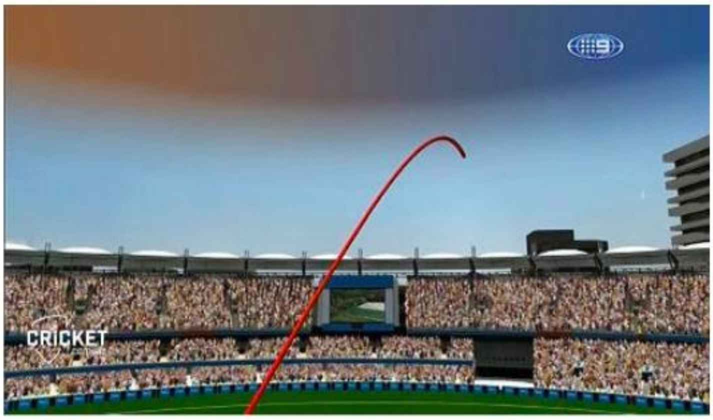
$$-\frac{1250(9.92)^2}{4.40} = -1250(9.80) + N$$ 1

$-27{,}956 = -12{,}250 + N$

$N = 15.7\ x10^3$ N Downwards 1   ($22.1x10^3$ N if v = 11.0 used)

**Question 5** **(7 marks)**

A recent addition to the Big Bash League Cricket commentary is to discuss the "air time" of a big hit. Commentators in the 2018/19 season have commented the longest "air-time" of a 6 (where the ball is struck out of the field) was 5.50 seconds. The ball was struck at an angle of 60.0 degrees above horizontal and a height of 1.10 m above the ground, it was caught by a lucky fan in the crowd a height of 8.50 m above the ground.




*Wide World of Sports, Channel 9 Australia*

(a) Calculate the velocity that the ball leaves the cricket bat with if the ball had an air time of 5.50 seconds.

(4 marks)

$s = ut + \frac{1}{2}at^2$ (½)

$\Delta s = 8.50 - 1.10$

$= 7.40$ m (1)

must show working for $s = +7.40$ m

$7.40 = u\sin(60.0)(5.50) + \left(\frac{1}{2}\right)(-9.8)(5.50^2)$

$7.40 = 4.76u - 148.2$ (1.5)

$u = 32.7\ ms^{-1}$ at 60.0 degrees above the horizontal (1)

-1/2 marks if direction not provided.

(b) Calculate the horizontal distance the lucky fan is from the batsman.

(3 marks)

$S_x = u_x.t$ (1)

$= 32.7\cos(60).5.5$ (1)

$= 89.9$m (1)

**Question 6** **(9 marks)**

A cannon ball is fired at 102 $ms^{-1}$ at an angle of 46.0° above the horizontal towards a tall vertical cliff-face located horizontally 839 meters away.

(a) Calculate the time taken for the cannon ball to strike the cliff.

(3 marks)

From x

$$t = \frac{s_x}{u\cos\theta}$$ (1)

$$= \frac{839}{102\cos 46.0}$$ (1)

= 11.8 s (1)

(b) Calculate the distance up the cliff-face that the cannon ball strikes.

(3 marks)

$s = u\sin\theta t + \frac{1}{2}at^2$ (1)

$= 102\sin 46.0(11.8) + (1/2)(-9.8)(11.8)^2$ (1)

= 184 m (1)

(c) Show, via a suitable equation, whether the cannonball strikes the cliff-face travelling in an upwards direction or a downwards direction.

(3 marks)

$v_y = u_y + a_y t$ (1)

$= 102\sin 46 - 9.8(11.8)$ (1)

$= -42.3\ ms^{-1}$ hence downwards. (1)

or turning point $= \frac{-u\sin\theta}{g}$

$= \frac{-102\sin(46)}{-9.8}$

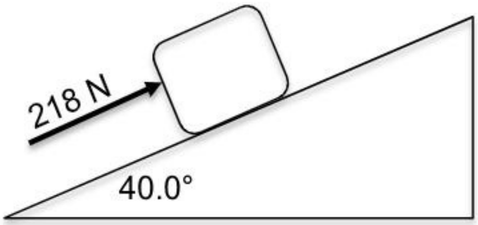
= 7.49 s

Since t > turning point, object must be travelling downwards.

*note: solving for max height and comparing to 184 m does not prove direction as cannon ball can be travelling up or down at 184m.

**Question 7** **(5 marks)**

A force of 218 N is applied to a 25.0 kg box up an incline of 40.0°, as shown in the diagram. The acceleration of the box is measured to be 0.750 ms$^{-2}$ up the incline. Calculate the co-efficient of kinetic friction between the box and the slope given that $F_F = \mu_k F_N$.




$\sum F = ma$ ½

$\sum F_{\perp} = F_N - mg\cos\theta = 0$ ½

$\sum F_{\parallel} = F_A - mg\sin\theta - F_F = ma$ ½

$\sum F_{\parallel} = 218 - (25(9.8)\sin 40) - F_F = (25)(0.750)$ ½

$F_f = 218 - 25(0.750) - (25(9.8)\sin 40)$

$= 41.8$ N 1

$F_F = \mu_k F_N$

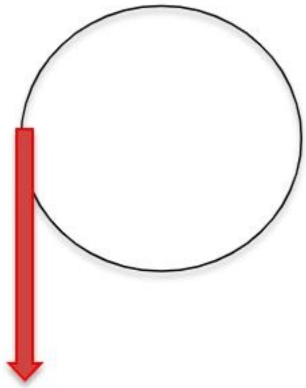
$\mu_k = \frac{F_F}{mg\cos\theta}$ ½

$= \frac{41.8}{25(9.8)\cos 40}$ ½

$= 0.223$ 1

**Question 8** **(5 marks)**

Two children are playing on a piece of playground equipment which rotates in a counter clockwise direction when viewed from above. As the equipment rotates, the child on the left of the diagram lets go.



(a) On the overhead view to the right, sketch the horizontal path of the child after she lets go. (1 mark)

(b) Ignoring any vertical effects due to gravity, explain why the child takes this path. (4 marks)

- Newton's 1st Law states that an object will continue in uniform, straight line motion unless acted upon by a net external force.
- When the child lets go, there is no net external force
- Pulling the child towards the centre of curvature.
- The child then moves in a straight line path, tangential to the path of curvature.

**END OF TEST**

**Acknowledgments:**

Cricket.com.au
https://www.cricket.com.au/video/brett-lee-biggest-six-ever-at-the-gabba/2014-12-18

Belson Outdoors
http://www.belson.com/Hurricane-Spinner-Playground-Component