Name: ____________________ /50

Yr 12 Physics Motion & Forces Test 2020

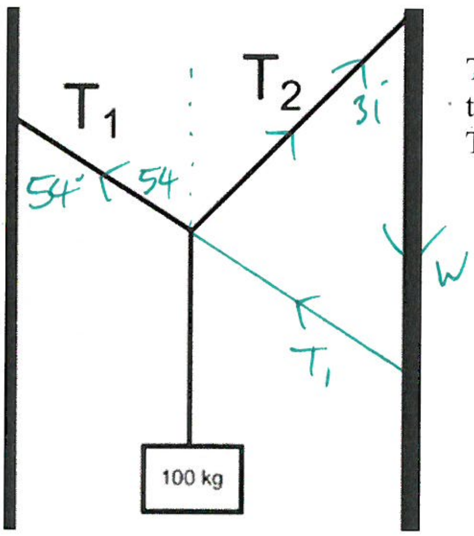
(50 minutes working time)

Instructions

1. Answer all questions in the spaces provided.
2. Give all numerical answers to three significant figures, except when you are required to estimate values where two significant figures will be appropriate.
3. Show all working – marks may be awarded for logical working even when an incorrect final answer is arrived at.
4. If you require extra working space, indicate this to your teacher who will give you some lined paper. Be sure to write your name on top and staple it to your test.

50 marks for answering the questions
Up to 4 marks maybe deducted for incorrect units and significant figures

QUESTION ONE **(4 marks)**



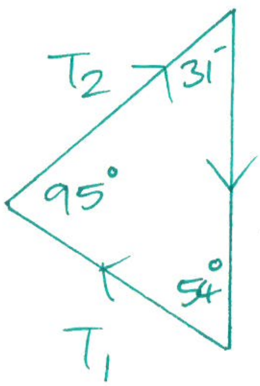
The diagram on the left shows a box of mass 100.0kg suspended by two cables. T1 is attached to a vertical wall at angle of 54.0^0, while T2 is attached to another vertical wall at angle of 31.0^0.

a) Sketch a vector diagram of the situation (2 marks)

b) Determine the tension T1 and T2 in the two cables (2 marks)

$180 - (31 + 54) = 95°$

(a)



$100 \times 9.8 = 980N$

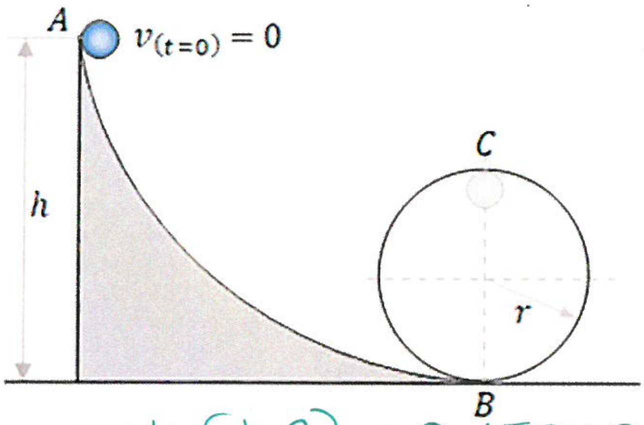
(−1 anything wrong / missing)

(b) $\frac{T_1}{\sin 31} = \frac{980}{\sin 95}$

ie $T_1 = \frac{980 \times \sin 31}{\sin 95} = 506.6... = 507N$ (1)

$T_2 = \frac{980 \times \sin 54}{\sin 95} = 795.8... = 796N$ (1)

QUESTION TWO **(5 marks)**



The diagram on the left shows a ball of mass 0.156 kg held h metres above the ground. If h = 1.25m, determine the largest value of the radius, r, that the ball will successfully negotiate the loop without falling off (ie while maintaining circular motion).

Assume friction is negligible.

$E_{TOTAL} = mgh$ (at A) $= 0.156 \times 9.8 \times 1.25 = 1.911$ J (1)

At top of circle (at C): $mgh + \frac{1}{2}mv^2 = 1.911$ J

ie $mg2r + \frac{1}{2}mv^2 = 1.911$ (1)

ie $2gr + \frac{1}{2}v^2 = 1.911 \div 0.156 = 12.25$

Also at C: minimum v (ie max r) when $\frac{mv^2}{r} = mg$

ie $v^2 = rg$. (1)

SUBSTITUTING: (ie $v^2 = rg$)

then $2gr + \frac{1}{2}v^2 = 2gr + \frac{1}{2}rg = 12.25$ (1)

ie $2.5r = 12.25 \div 9.8 = 1.25$

$\therefore r = \frac{1.25}{2.5} = 0.500$m. (1)

QUESTION THREE **(4 marks)**

By showing appropriate calculations, **explain** why NASA has found it impossible to place a satellite in geostationary orbit around the moon (1 Moon day is equivalent to 27 Earth days).

$M_M = 7.35 \times 10^{22}$ kg

$T_M = (27 \times T_E)$

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$R_{GS} = ?$

$T_M = 27 \times (24 \times 60 \times 60)$

$= 2\,332\,800$ s

Using Kepler's 3rd Law:

$T^2 = \frac{4\pi^2 r^3}{GM}$ (1)

ie $r^3 = \frac{GMT^2}{4\pi^2}$

$= \frac{6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times (2.3328 \times 10^6)^2}{4 \times \pi \times \pi}$ (1)

$= 6.757... \times 10^{23}$ m^3

$r = \sqrt[3]{6.757 \times 10^{23}}$

(1) $= 8.78 \times 10^7$ m ← This distance means a satellite would be pulled * out of G.S. orbit by the Earth's gravitational field. (1)

QUESTION FOUR **(6 marks)**

a) A cyclist of mass 74.5 kg is riding a bicycle of 14.0 kg around a corner that is part of a circular road of radius 27.8 m. Determine the frictional force required for the rider to safely (ie no sliding) negotiate the corner at 31.5 km/h. (2 marks)

$F_{FRICTION} = F_{CENT} = \frac{mv^2}{r} = \frac{(74.5+14) \times \left(\frac{31.5}{3.6}\right)^2}{27.8}$ (1)

(flat road) no bank

$= 243.733...$

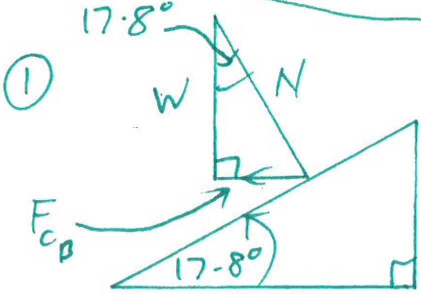
$= 244\ N$ (1)

(towards the circle's centre)

b) Determine the new top speed that the same rider could safely negotiate the same corner at if it was banked at an angle of 17.8^0 to the horizontal **and** the same **surface** friction as calculated in (a) is also available. (4 marks)
(If you didn't get an answer for (a) then use 2.50×10^2 N)

STEPS : ① Determine $F_{CENT\ BANK}$ and $Friction_{Hor.}$

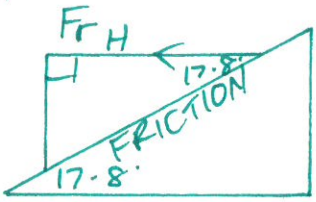
② Add $F_{CENT\ BANK}$ and Fr_H. ③ Rearrange for v.

① 

ie $\tan 17.8° = \frac{F_{C_B}}{W}$ ∴ $F_{C_B} = W \times \tan 17.8°$ (1)

$= 88.5 \times 9.8 \times \tan 17.8$

$= 278.45...\ N$



(1)

(1) ② ADD

$\cos 17.8° = \frac{Fr_H}{243.7...}$ (from (a)) ∴ $Fr_H = 243.7 \times \cos 17.8 = 232.06..\ N$

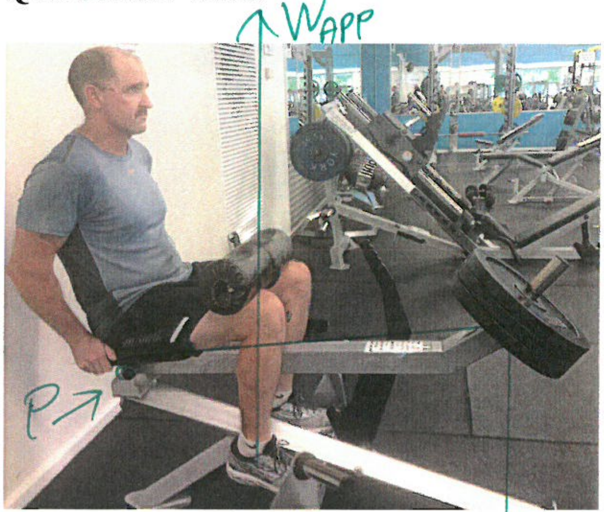
③ $F_{CENT\ TOTAL} = 510.52..\ N = \frac{mv^2}{r}$

∴ $v = \sqrt{\frac{510.5.. \times r}{m}} = \sqrt{\frac{510.5.. \times 27.8}{88.5}}$ (1)

$= 12.66.. = 12.7\ ms^{-1}$

(45.6 km/h)

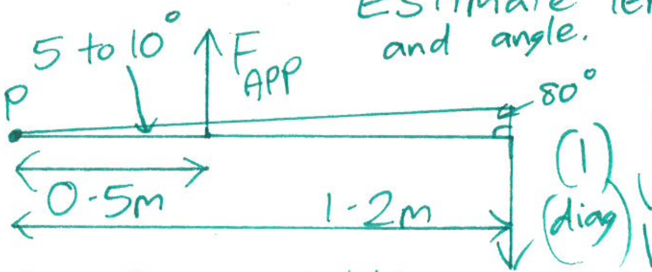
QUESTION FIVE **(5 ~~(4~~ marks)**



The photo on the left shows a man training his calf muscles. There is a 60.0kg load on the right side end of a metal beam, which is hinged under the seat of the device. The load is lifted by the lower legs via two pads, one on each knee. By making appropriate estimations, determine the magnitude of the force exerted by **each** calf to support the 60.0kg load.

(Assume: weight of beam & knee pads are negligent; both the beam and the feet are horizontal; the lower legs are vertical.

Estimate lengths and angle.



(2 for suitable estimations)

$W = 60 \times 9.8 = 588N$

Taking moments about P:

$\Sigma M = 0$

ie $\Sigma M_{ACW} \text{(legs)} = \Sigma M_{CW} \text{(LOAD)}$ (1)

ie $0.5 \times 2F = 1.2 \times 588 \times \sin 80°$

ie $F_{\text{Each leg}} = 694.8... N$

$= 700 N$ (1sf) or $690 N$ (2sf) (1)

QUESTION SIX **(~~5~~ 3 marks)**

Ganymede is the ninth largest object in the solar system and is the largest moon of Jupiter. It orbits at an average distance of 1.07 x 10^6km from Jupiter. Use the Formulae and Data booklet and the data in the table on the right to determine the strength of Jupiter's gravitational field where Ganymede orbits.

Planet	Mass (Earth masses)
Mercury	0.0550
Venus	0.815
Earth	1.000
Mars	0.107
Jupiter	318
Saturn	95.0
Uranus	14.5
Neptune	17.2
Pluto	0.00200

$g = ?$

$G = 6.67 \times 10^{-11} N m^2 kg^{-2}$

$R_G = 1.07 \times 10^9 m$

$M_J = 318 M_E$

$= 318 \times 5.97 \times 10^{24}$

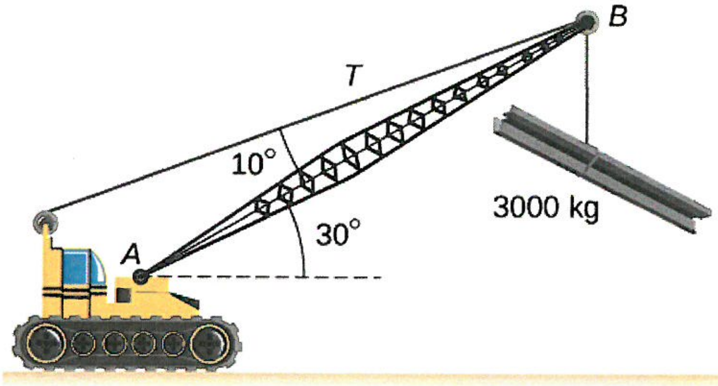
$= 1.89846 \times 10^{27} kg$ (1)

$g = \frac{GM}{r^2}$ (1)

$= \frac{6.67 \times 10^{-11} \times 1.89846 \times 10^{27}}{(1.07 \times 10^9)^2}$ (1)

$= 0.1106... = 1.11 \times 10^{-1} N kg^{-1}$

QUESTION SEVEN **(~~9~~ 10 marks)**



A 12.0m boom, AB, of a crane supporting a 3.00×10^3 kg load is shown on the left. The centre of mass of the boom is at its geometric centre, and the mass of the boom is 1.00×10^3 kg. Assume the two angles shown are 10.0^0 and 30.0^0.

For the position shown, calculate

a) The tension T in the cable (~~4~~ 5 marks)

Taking moments about A : (1)

$\Sigma M = 0$; ie $\Sigma M_{ACW} = \Sigma M_{CW}$
(cable) Load + Boom

ie $12 \times T \times \sin 10^\circ$ (1) $= (12 \times 3000 \times 9.8 \times \sin 60) + (6 \times 1000 \times 9.8 \times \sin 60)$ (1)

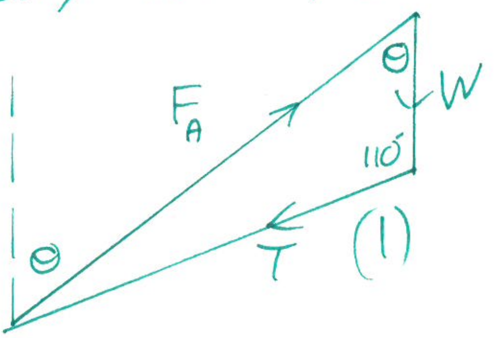
ie $2.083\ldots T = 305\,533.7\ldots + 50\,922.2\ldots$

ie $T = \dfrac{356\,456.0\ldots}{2.083\ldots} = 171\,062.3846$ N (1)

$= 1.71 \times 10^5$ N (1)

b) the force ~~at the axle A~~ of the axle on the boom. (5 marks)

Using vectors/cosine rule :



$F_A = \sqrt{W^2 + T^2 - 2WT\cos 110^\circ}$ (1)

$= \sqrt{(39200)^2 + (171062.3..)^2 - 2 \times 39200 \times 171062.3.. \times \cos 110}$

$= 188\,111.4326$

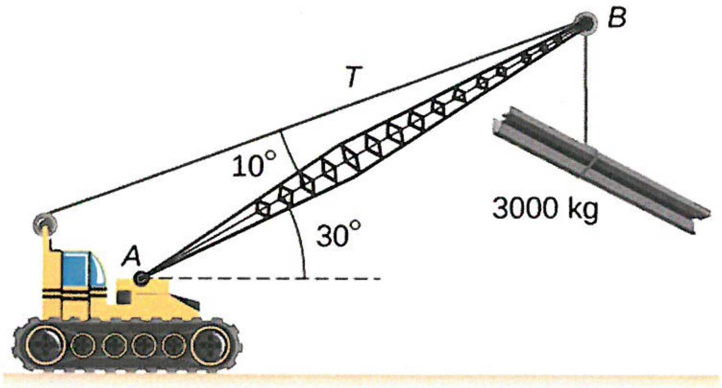
$= 1.88 \times 10^5$ N (1)

FOR θ : $\dfrac{171\,062.3\ldots}{\sin\theta^\circ} = \dfrac{188\,111.4\ldots}{\sin 110^\circ}$ (1)

ie $\sin\theta = \dfrac{171062.3.. \times \sin 110^\circ}{188111.4\ldots} = 0.854\ldots$

ie $\theta = 58.7^\circ$ ∴ Force of A on Boom is 1.88×10^5 N up to the right at 58.7° down from the vertical. (1)

QUESTION SEVEN **(9 marks)**



A 12.0m boom, AB, of a crane supporting a 3.00×10^3 kg load is shown on the left. The centre of mass of the boom is at its geometric centre, and the mass of the boom is 1.00×10^3 kg. Assume the two angles shown are 10.0^0 and 30.0^0.

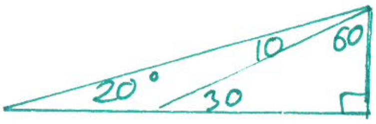
For the position shown, calculate

a) The tension T in the cable (4 marks)

b) the force ~~at~~ of the axle A on the boom (5 marks)

USING COMPONENTS.

① $F_{LEFT} = F_{RIGHT}$ ie $F_{HOR.} = F_{H\,TENSION}$ (1)



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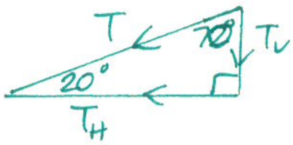


$\sin 70 = \frac{T_H}{T}$ (1)

ie $T_H = T\sin 70 = 171062.3... \times \sin 70$

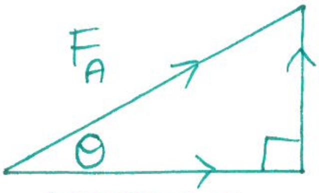
$= 160746.0605N$

② $F_{UP} = F_{DOWN} = W_{BOOM} + W_{LOAD} + T_V$ (1)

$= (1000 \times 9.8) + (3000 \times 9.8) + T \times \cos 70^\circ$

$= 9800 + 29400 + 58506.78... = 97706.7813N$

③



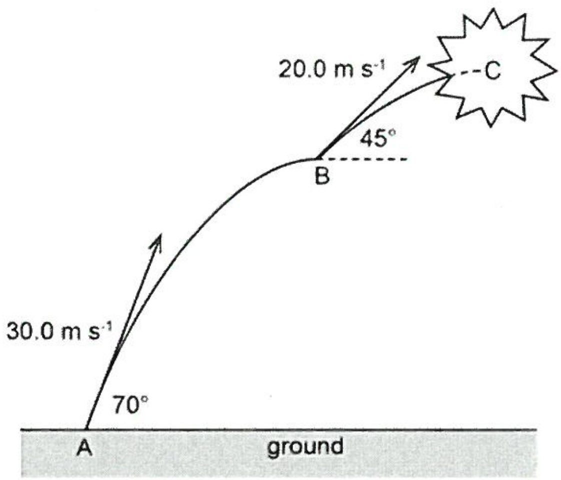
$\therefore F_A = \sqrt{97706.7...^2 + 160746.0...^2}$

$= 1.88 \times 10^5 N$ (1)

$\theta = TAN^{-1}\ 97706.7.. \div 160746.0... = 31.3^\circ$

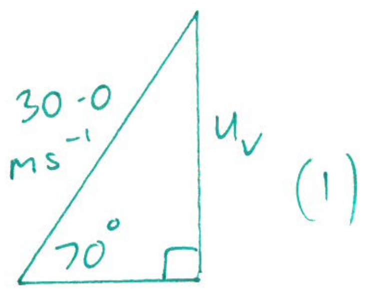
$\therefore F_A = 1.88 \times 10^5 N$ up to the right at 31.3° above the horizontal. (1)

QUESTION EIGHT **(13 marks)**



A firework rocket was launched into the air from the ground at point A with an initial velocity of 30.0 m s^{-1} at an angle of 70.0° to the horizontal. When the firework rocket reached its initial maximum height at point B, there was a second explosion that further propelled the upper part of the firework rocket with a new velocity of 20.0 m s^{-1} at an angle of 45.0° to the horizontal. This upper part of the firework rocket was propelled to a new maximum height at point C where the firework rocket exploded. Ignore all effects due to air resistance.

(a) Determine the initial vertical velocity of the firework rocket. (2 marks)



$u_v = 30 \times \sin 70°$

$= 28.19...$ (1)

$= 28.2 \text{ ms}^{-1}$ up

(b) Calculate the height of point B (3 marks)

$s_v = h = ?$

$u_v = 28.1... \text{ ms}^{-1}$ up

$v_v = 0$

$a_v = 9.8 \text{ ms}^{-2}$ down

Let down be −ve

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

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

$= \frac{0^2 - 28.1...^2}{2 \times -9.8}$ (1)

$= 40.54693...$

$= 40.5 \text{ m}$ (above ground)

(1)

(c) Calculate the total time it takes for the firework to reach C, from launch. (5 marks)

Total time = TIME TO B + TIME TO C (1)

TIME TO B : $t = \frac{v - u}{a} = \frac{0 - 28.19...}{-9.8} = 2.876...\ s$ (1)

TIME TO C :

$v_v = 0$

$u_v = 20 \times \sin 45$

$t = ?$

$a = -9.8\ ms^{-2}$

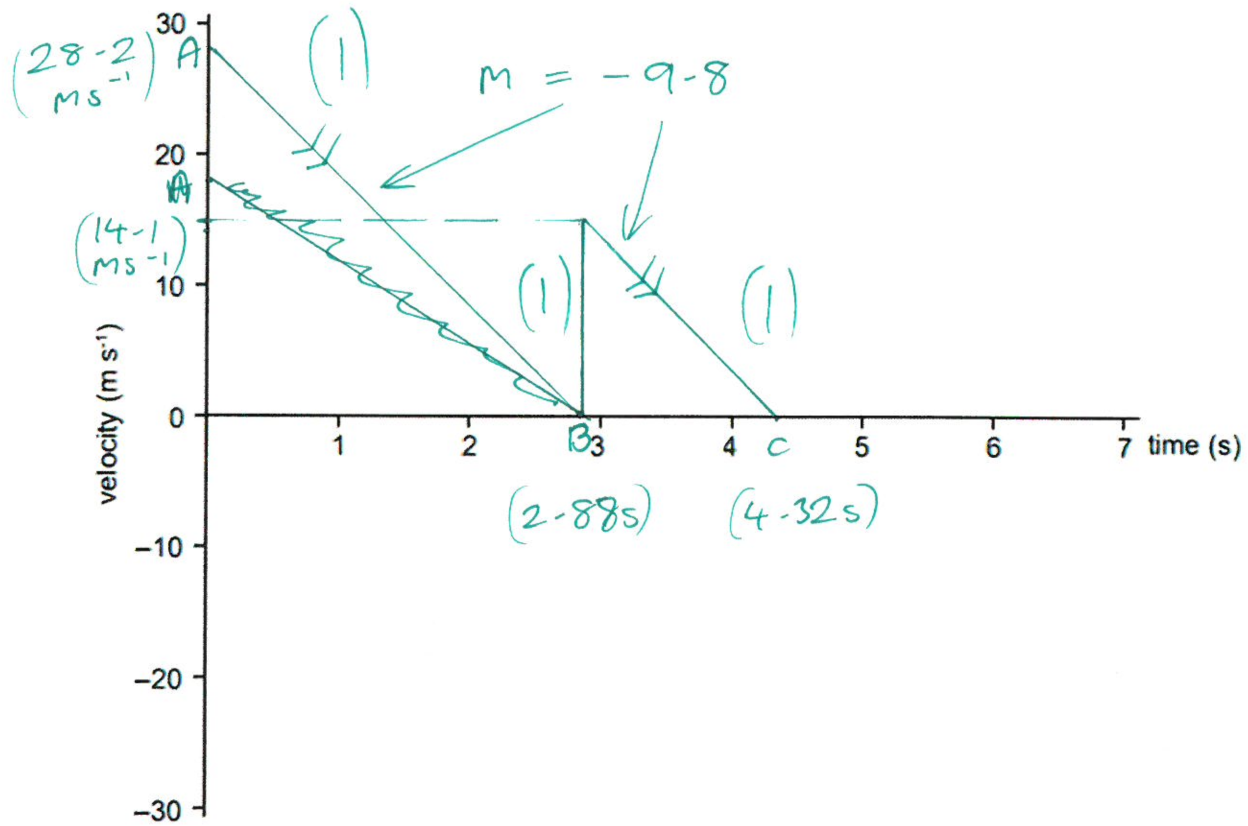
$t = \frac{0 - (20 \times \sin 45)}{-9.8}$ (1)

$= 1.443...$

$t_{total} = 2.876.. + 1.443..$ (1)

$= 4.32\ s$ (1)

(d) Use the axes below to sketch a graph of vertical velocity against time of the firework from immediately after it is launched at point A until it reaches point C. Use appropriate values and ignore all effects due to air resistance. (3 marks)



END OF TEST