

Mechanics Worksheet for KS5

These resources are based on real-life challenges faced daily by HM Coastguard. Each problem has been assigned a coastguard rank according to its challenge level to enable easy differentiation.



Maritime Operations Officer



Senior Maritime Operations Officer



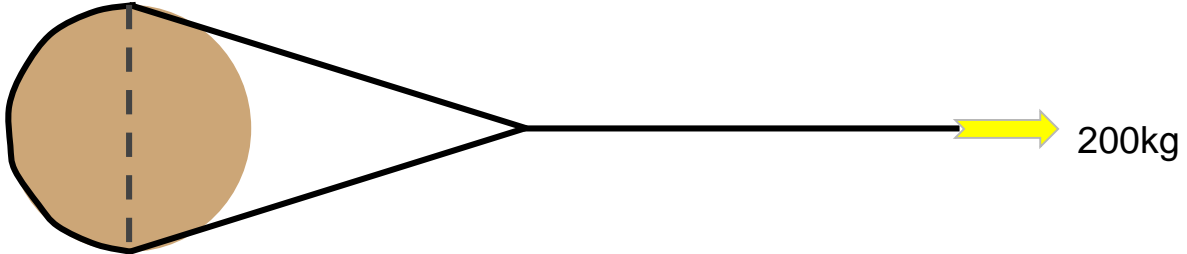
Commander



Chief Coastguard

The four levels vary in terms of scaffolding and challenge, but are all based on the same scenario.

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Bridle Ropes

At a rescue site, the search and rescue team identify a person in distress off a cliff who will need winching up.



They estimate that the combined weight to winch up will be 200kg.

a) Identify the minimum rope diameter to be used to be within the 'safe load'.

The search and rescue team only have 10mm thick rope with them. If the rope is deemed to be unsafe, they try to ensure that the two lengths around the tree have a safe tension.



b) Identify a minimum sling angle to ensure that the lengths of rope around the tree have a safe tension.

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Tensionless hitches

The crew decide that a tensionless hitch might be a quicker way to secure a winch rope.

In order for a tensionless hitch to be secure, the hold tension (T_{hold}) needs to be less than 100g.

What would be the maximum theoretical T_{load} be for a rope with 2 turns around:



- a) a tree with friction coefficient 0.5 b) a lamp post with friction coefficient 0.1

To hold the 200kg load, what is the minimum number of turns required around:



- c) a tree with friction coefficient 0.5 d) a lamp post with friction coefficient 0.1

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Applied Challenge 1

The search and rescue team arrive at a scene and find a sinking speedboat and a man overboard. They need to winch both out of the water as quickly as possible.

The combined rescue weight of the man is expected to be 250kg.

The boat weighs 1,800kg.

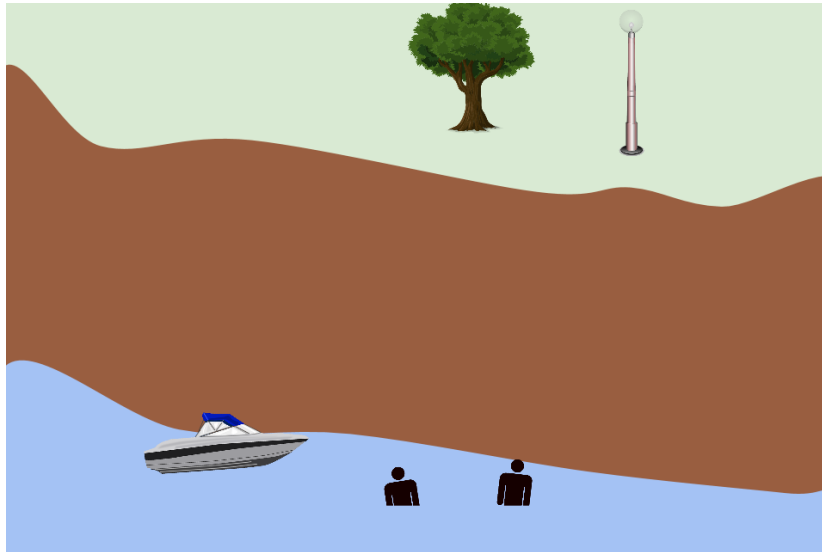
Lamp post coefficient of friction = 0.2, tree coefficient of friction = 0.6.

The team's experience suggest that a bridle rope would be the best rope for winching out the boat.



Plan a full rescue plan including minimum rope thickness, types of hitches and any necessary angles. If any rope is not considered 'safe' (within a factor of 12 of maximum breaking strength), please state its safety factor so that the team know the risk.

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Applied Challenge 2

The search and rescue team arrive at a scene and find a sinking speedboat and 2 men overboard. They need to winch both out of the water as quickly as possible.

The combined rescue weight of each man is expected to be 300kg.

The boat weighs 2,200kg.

Lamp post coefficient of friction = 0.1, tree coefficient of friction = 0.7.



Plan a full rescue plan including minimum rope thickness, types of hitches and any necessary angles. If any rope is not considered 'safe' (within a factor of 12 of maximum breaking strength), please state its safety factor so that the team know the risk.

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References

Rope Strength

$$1\text{kg} = 9.81\text{N} = 0.00981\text{kN}$$

$$1\text{kN} \approx 102\text{kg}$$

Rope Diameter		Minimum Breaking Strength		Safe Load (Safety Factor 12)		Weight	
(in)	(mm)	(lbf)	(kN)	(lbf)	(kN)	(lbm/ft)	(kg/m)
3/16	5	880	3.91	73.3	0.326	0.009	0.013
1/4	6	1486	6.61	124	0.551	0.016	0.023
5/16	8	2295	10.2	191	0.851	0.025	0.036
3/8	10	3240	14.4	270	1.2	0.036	0.053
7/16	11	4320	19.2	360	1.6	0.048	0.071
1/2	12	5670	25.2	473	2.1	0.063	0.094
9/16	14	7200	32	600	2.67	0.08	0.119
5/8	16	8910	39.6	743	3.3	0.099	0.147
3/4	18	12780	56.8	1070	4.76	0.143	0.213

Capstan equation table

$$T_{\text{load}} = T_{\text{hold}} e^{\mu\theta}$$

T: tension

e: e

μ : coefficient of friction

θ : total angle made by rope (radians)

2π radians = 1 full turn

Number of turns	Coefficient of friction μ						
	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	1.9	3.5	6.6	12	23	43	81
2	3.5	12	43	152	535	1881	6661
3	6.6	43	286	1881	12392	81612	437503
4	12	152	1881	23228	286751	3540026	43702631
5	23	535	12392	286751	6635624	153552935	3553321281