HOOKE'S LAW

1. a) $T = \dfrac{\lambda x}{L} = \dfrac{2 \times 1}{4} = 0.5$ M1 A1

[2]

b) When T = 2 $\quad 2 = \dfrac{2(y+1)}{4}$ M1 A1

$y = 3$ A1 cao

[3]

HOOKE'S LAW

2. a) Let extension of AB be x m
Then extension of BC is (2L – x)m — B1

Tension in AB = $\dfrac{2mgx}{L}$ — M1 A1

in BC = $\dfrac{2mg(2L-x)}{L}$ — A1

Resolving vertically at B, and using equilibrium — M1

$\Rightarrow \quad \dfrac{2mg(2L-x)}{L} = mg + \dfrac{2mgx}{L}$

$\Rightarrow \; x = \dfrac{3L}{4}$ — A1 cao

$\therefore$ Height above A is $\dfrac{7L}{4}$ m — A1 ft.

[7]

b) When AB = $\dfrac{3L}{2}$: e.p.e. in AB = $\dfrac{2mg}{2L}\left(\dfrac{L}{4}\right)^2 = \dfrac{mgL}{4}$ — M1 A1

e.p.e. in BC = $\dfrac{2mg}{2L}\left(\dfrac{3L}{2}\right)^2 = \dfrac{9mgL}{4}$ — A1

Taking height $\dfrac{3L}{2}$ above A as zero p.e. level:
p.e. = 0 and k.e. = 0 — B1

When particle risen to equilibrium position :

e.p.e. in AB = $\dfrac{2mg\left(\frac{3L}{4}\right)^2}{2L} = \dfrac{9mgL}{16}$ — B1 f.t.

e.p.e. in BC = $\dfrac{2mg\left(\frac{5L}{4}\right)^2}{2L} = \dfrac{25mgL}{16}$ — B1 f.t.

p.e. = $\dfrac{mgL}{4}$ k.e. = $\dfrac{1}{2}mv^2$ — B1 f.t.

Since gravity is only external force, energy is conserved — M1

So $\dfrac{mgL}{4} + \dfrac{9mgL}{4} = \dfrac{9mgL}{16} + \dfrac{25mgL}{16} + \dfrac{mgL}{4} + \dfrac{1}{2}mv^2$ — M1

$v = \sqrt{\dfrac{gL}{4}} = \dfrac{\sqrt{gL}}{2}$ — A1 c.a.o.

[10]

HOOKE'S LAW

3. When in equilibrium $\frac{4}{AM} = \cos 30^0$	M1
$\Rightarrow AM = \frac{8}{\sqrt{3}}$ (= 4.6188…)	A1
Extension of string = 2AM – 6 = 3.2376	M1 A1 f.t.
Resolving vertically for particle and equilibrium	M1
$\Rightarrow 2T\cos 60 = 5$	A1
$\therefore T = 5$	
Hooke's Law: $T = \frac{\lambda x}{L} \Rightarrow 5 = \frac{3.2376\lambda}{6}$	M1 A1 f.t.
$\lambda = 9.266\ldots = 9.27$ N (3 S.F.)	A1 cao
	[9]

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4. a) If extension of AB is x, then extension of BC is (2L – x)	B1
using $T = \frac{\lambda x}{L}$: For AB: $T_A = \frac{mgx}{L}$	M1 A1
For BC: $T_C = \frac{2mg(2L-x)}{2L}$	A1
$T_A = T_C$	M1
$\frac{mgx}{L} = \frac{mg(2L-x)}{L} \Rightarrow x = L$	A1 cao
$\therefore BC = 3L$	A1 f.t
	[7]
b) Again $T_A = \frac{mgx}{L}$ and $T_C = \frac{2mg(2L-x)}{2L}$	B1
Resolving vertically and using equilibrium $\Rightarrow T_A - mg - T_C = 0$	M1 A1
$\therefore \frac{mgx}{L} - mg - \frac{2mg(2L-x)}{2L}$	M1
$\Rightarrow x - L - (2L - x) = 0$	
$\Rightarrow 2x = 3L \Rightarrow x = \frac{3}{2}L$	A1 cao
$BC = 5L - L - \frac{3}{2}L = \frac{5}{2}L$	A1 f.t
	[6]

HOOKE'S LAW

5. a) When B is vertically below A

$$T = \frac{\lambda x}{L} \Rightarrow \quad T = \frac{2mgx}{L}$$ M1 A1

Equilibrium of particle $\Rightarrow T = mg$

$$\therefore \; mg = \frac{2mgx}{L} \Rightarrow x = \tfrac{1}{2}L$$ M1 A1

[4]

b) When B is in new position $\frac{\frac{3L}{2}}{AB} = \cos\theta$ M1

$\therefore$ AB $= \frac{15}{8}L$ A1 cao

$\therefore$ extension is $\frac{7}{8}L$ A1 ft.

[3]

c) Initial and final k.e. are both zero B1

Since same horizontal level no change in p.e. B1

Initially e.p.e. $= \frac{\lambda x^2}{2L} = \frac{2mg\left(\frac{L}{2}\right)^2}{2L} = \frac{mgL}{4}$ M1 A1

Final e.p.e. $= \frac{2mg\left(\frac{7L}{8}\right)^2}{2L} = \frac{49mgL}{64}$ A1

$\therefore$ Gain in energy $= \frac{49mgL}{64} - \frac{mgL}{4} = \frac{33mgL}{64}$ M1 A1 f.t.

Work done = gain in energy $= \frac{33mgL}{64}$ B1

[8]

HOOKE'S LAW

6. a) Since no external forces other than gravity, energy is conserved
Taking level of A as zero p.e.

Initially p.e. = k.e. = e.p.e. = 0 — B1

When at lowest point, if extension of string is x

p.e. = $-mg(x + L)$ — B1

k.e.= 0 — B1

e.p.e. = $\dfrac{2mgx^2}{2L} = \dfrac{mgx^2}{L}$ — M1 A1

$\therefore\ -mg(x + L) + \dfrac{mgx^2}{L} = 0$ — M1 A1

$x^2 - Lx - L^2 = 0$ — A1 f.t

$x = \left(\dfrac{1 + \sqrt{5}}{2}\right)L$ as $L > 0$ — A1

$x < 2L$ $\therefore$ Does not reach the floor — B1 ft

[10]

b) Taking level of B as zero p.e. level

Initial p.e. = k.e. = 0 — B1

Initial e.p.e. = $\left(\dfrac{2mg \times (2L)^2}{2L}\right)$ = 4mgL — M1 A1

If h= height reached

Final p.e. = mgh — B1

Final e.p.e. = final k.e. = 0 — B1

$\therefore$ mgh = 4 mgL

$\Rightarrow$ reaches height of 4L m above B. — B1

[6]

HOOKE'S LAW

7. a) When gun fired energy is conserved	B1
e.p.e. of spring $= \dfrac{\lambda x^2}{2L} = \dfrac{0.6 \times 0.06^2}{2 \times 0.08}$	M1 A1
$= 0.0135$	A1 cao
k.e. of pellet when it leaves gun $= \frac{1}{2} mv^2$	M1
$= \frac{1}{2} \times 0.001\ v^2$	A1 cao
equating: $0.0135 = 0.0005\ v^2$	M1
$v = 3\sqrt{3}\ \text{ms}^{-1}$ (= 5.20 (3 S.F.))	A1 f.t.
	[8]
b) i) If vertical then after firing, pellet is moving under gravity	B1
When hits ground s = -1 a = -9.8 u = 5.196…	B1
Using $v^2 = u^2 + 2as$	M1
$v^2 = 27 + 2 \times -1 \times -9.8$	
$v = 6.826\ . = 6.83$ (3 S.F.)	A1 cao
$\therefore$ velocity is $6.83\ \text{ms}^{-1}$ vertically downwards	A1 f.t
	[5]
ii) If horizontal, horizontal velocity remains constant so horizontal velocity = $3\sqrt{3}$	B1
Initial vertical velocity = 0 s = -1 a = -9.8	
$\therefore$ using $v^2 = u^2 + 2as$	M1
$v^2 = 2 \times -1 \times -9.8 \quad v = 4.427$	A1
$\therefore$ Speed$^2 = (3\sqrt{3})^2 + (4.427\ldots)^2$	M1
Speed $= 6.83\ \text{ms}^{-1}$ (3 S.F)	A1 cao
Direction θ below horizontal where	
$\tan\theta = \dfrac{4.427}{3\sqrt{3}}$	M1
$\theta = 40.4^0$ (3 S.F.)	A1 cao
	[7]
c) Inside of barrel is smooth Or length of barrel is negligible	
Pellet small enough to be treated as particle	B2 (any two)
Ground is horizontal	
No air resistance	
	[2]

HOOKE'S LAW

8.	Speed $= 60\text{ kmh}^{-1} = \frac{50}{3}\text{ ms}^{-1}$	M1 A1
	Mass $= 40 \times 10^3$ kg	B1
	$\therefore$ k.e. of engine approaching buffers $= \frac{1}{2} \times 40 \times 10^3 \times \left(\frac{50}{3}\right)^2$	M1 A1 cao
	"Extension" of spring = 0.45 m	
	$\therefore$ e.p.e. in one spring $= \dfrac{\lambda(0.45)^2}{2 \times 0.5}$	M1 A1
	Since no external forces, energy conserved	B1
	p.e. stays the same Initial e.p.e. = 0 final k.e. = 0	$\}$ B1
	$20 \times 10^3 \times \left(\frac{50}{3}\right)^2 = 6 \times \lambda\,(0.45)^2$	M1(equating) B1 (6)
	$\lambda = 4570000$ N (3 S.F.)	A1 cao
		[12]

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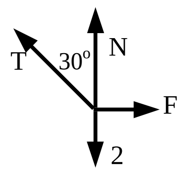
9. a)



For the ring B: resolving horizontally and vertically and equilibrium	M1
$T\cos 30 + N - 2 = 0$	A1
$T\sin 30 = F$ ①	A1
$AB = \dfrac{L\sqrt{3}}{\cos 30^{o}}$ $\therefore AB = 2L$	B1
$\therefore\ T = \dfrac{\lambda L}{L} \Rightarrow T = \lambda$ ②	M1 A1 f.t.
Limiting equilibrium $\Rightarrow F = \mu N$	M1
$\therefore F = \frac{1}{4}N$ ③	A1
①, ②, ③ $\Rightarrow$ $N = 2 - \dfrac{\lambda\sqrt{3}}{2}$; $F = \dfrac{\lambda}{2}$	
$\dfrac{\lambda}{2} = \dfrac{1}{4}\left(2 - \dfrac{\lambda\sqrt{3}}{2}\right)$	M1
$\lambda = \dfrac{4}{4 + \sqrt{3}}$	A1 cao
	[11]

HOOKE'S LAW

10. a) No external force other than gravity $\therefore$ energy conserved — B1

Initial p.e. = mgh = $70 \times 9.8 \times 30 = 20580$ — M1 A1
Initial k.e. = 0   Initial e.p.e. = 0 — B1

Final p.e. = 0

Final e.p.e. = $\dfrac{\lambda x^2}{2L} = \dfrac{900 \times 20^2}{2 \times 10} = 18000$ — M1 A1

Final k.e. = $\frac{1}{2}mv^2 = \frac{1}{2} \times 70v^2 = 35v^2$ — M1 A1

Conservation of energy $\Rightarrow 20580 = 18000 + 35v^2 \quad \Rightarrow v = 8.59$ (3 S.F.) — M1 A1 cao
[10]

b) Impulsive force = change in momentum — M1
$\therefore$ Magnitude of impulse $= 30 \times 8.585.$
$= 258$ — A1 f.t.
$\therefore$ Impulsive force is 258 Ns vertically down — A1 cao
[3]

c) Man treated as a particle
Velocity of man before he falls disregarded
No air resistance — B3 (any 3)
Elastic limit of rope not reached
Man brought to rest by the impact with the ground
[3]

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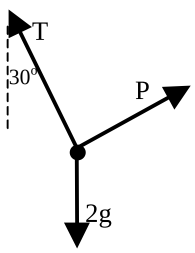
11. a) Resolving vertically and equilibrium gives T = 2g — M1 A1

$T = \dfrac{\lambda x}{L} \Rightarrow 2g = \dfrac{6gx}{3}$ — M1

x = 1 metre — A1
[4]

b)



Resolving — M1
Horizontally: $T\sin 30 = P\cos 30$ ① — A1
Vertically: $T\cos 30 + P\sin 30 = 2g$ ② — A1

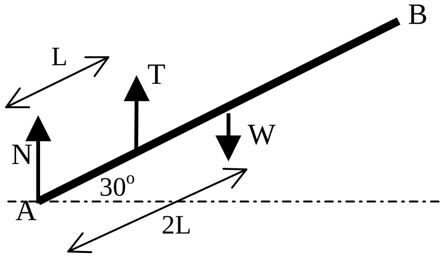
① $\Rightarrow T = P\sqrt{3}$ — M1
② $\Rightarrow 2P = 2g$ so $P = g$ — A1

$T = g\sqrt{3}$, so $g\sqrt{3} = \dfrac{6gx}{3} \Rightarrow x = \dfrac{\sqrt{3}}{2}$ — M1 A1

[7]

HOOKE'S LAW

12.a)



Taking moments about A:	M1
$T\times L\cos 30 - W\times 2L\cos 30 = 0$	A1
$\Rightarrow T = 2W$	A1
	[3]
b) Length of spring = $L\sin 30 = \frac{1}{2}L$	M1 A1
So compression is $\frac{1}{2}L$	B1
Thrust = $\frac{\lambda x}{L}$	M1
$\Rightarrow 2W = \frac{\frac{1}{2}L\lambda}{L} \Rightarrow \lambda = 4W$	A1 f.t.

13.a) Only gravity is acting on "frog", so energy conserved	B1
Initial k.e. = initial p.e. = 0	B1
Initial e.p.e. $= \frac{\lambda x^2}{2L} = \frac{\lambda 0.03^2}{2\times 0.05}$	M1 A1
$= 0.009\lambda$	A1
Final k.e. = final e.p.e. = 0	B1
Final p.e. = $0.05g \times 0.08$	B1
So $0.009\lambda = 0.004g \Rightarrow \lambda = 4.36$ N (3 S.F.)	M1 A1
	[9]
b) Work done in compressing spring = $0.009\lambda = 0.0392$	M1 A1 f.t.
So force $\times$ distance = 0.0392	M1
So force = $\frac{0.0392}{0.03} = 1.31$N	A1 f.t.
	[4]
