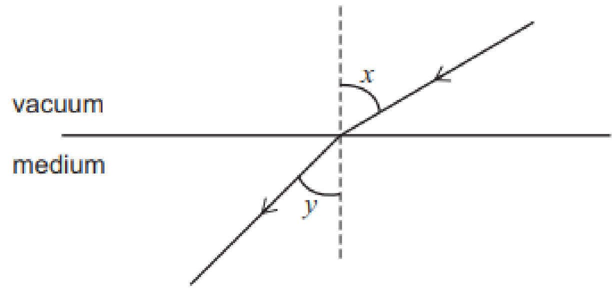
Worked Solutions for ENGAA Past Papers

ENGAA S2 2019 - Question 1

1 The ray diagram shows light passing from a vacuum into a medium.



Two angles, x and y, are shown on the diagram.

When x is 60°, y is 45°.

When x is 45°, what is the value of $\sin y$?

A $\frac{1}{\sqrt{3}}$

B $\frac{2}{\sqrt{3}}$

C 1

D $\frac{\sqrt{3}}{2}$

E $\sqrt{3}$

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ENGAA S2 2019 - Question 1 - Worked Solution

$$\sin sin\, 45 \;=\frac{\sqrt{2}}{2}$$

$$\sin sin\, 60 \;=\frac{\sqrt{3}}{2}$$

$$n \sin sin\, x \;= \sin sin\, y$$

$$n\,.\;\frac{\sqrt{3}}{2}=\frac{\sqrt{2}}{2}$$

$$n \;=\sqrt{\frac{2}{3}}$$

$$n. \sin sin\, 45 \;= \sin sin\, y$$

$$\sin sin\, y \ = \frac{\sqrt{2}}{2} \cdot \frac{\sqrt{2}}{\sqrt{3}}$$

$$\sin sin\, y \ = \frac{1}{\sqrt{3}}$$

Answer is A

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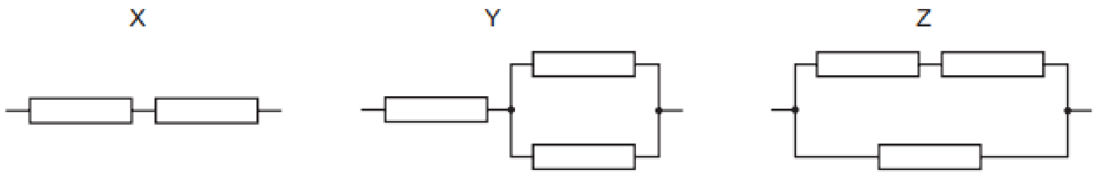
ENGAA S2 2019 - Question 2

2 Identical resistors are used to produce three different arrangements X, Y and Z.



Each arrangement is connected, in turn, across the same battery which has a negligible internal resistance.

The total power developed in each of the arrangements is determined.

What is the order of the arrangements when placed in order of **increasing** power?

A X, Y, Z

B X, Z, Y

C Y, X, Z

D Y, Z, X

E Z, X, Y

F Z, Y, X

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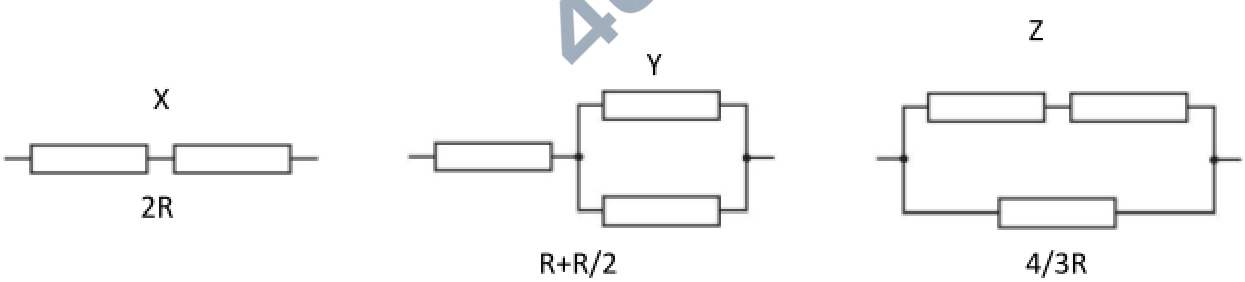
ENGAA S2 2019 - Question 2 - Worked Solution



$$P = IR$$

$$V = IR$$

$$\therefore P = \frac{V^2}{R}$$

We want to rank them

$$lowest\ power \rightarrow highest\ power$$

Thus:

$$highest\ R \rightarrow lowest\ R$$

X , Y , Z

Answer is A

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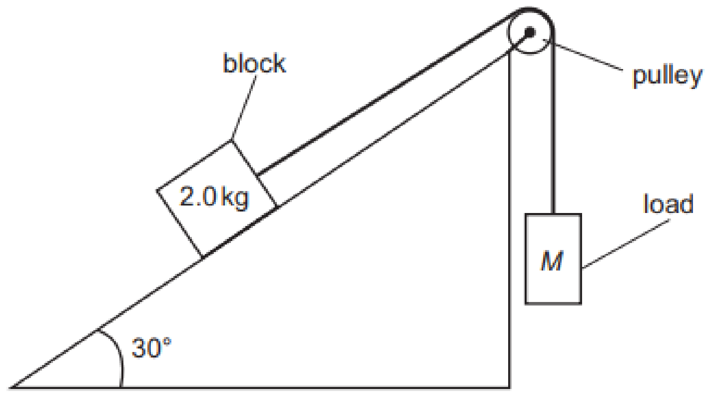
ENGAA S2 2019 - Question 3

3 A block of mass 2.0 kg is on a plane which is inclined to the horizontal at an angle of 30°.

The block is attached to a load of mass M by a light, inextensible string which passes over a smooth pulley.



The load moves downwards at a constant speed.

A constant friction force of 5.0 N acts on the block while it moves.

What is the value of M?

(gravitational field strength = 10 N kg^{-1}; assume that air resistance is negligible)

A 0.50 kg

B 1.0 kg

C 1.5 kg

D 2.5 kg

E 4.0 kg

F 6.0 kg

ENGAA S2 2019 - Question 3 - Worked Solution

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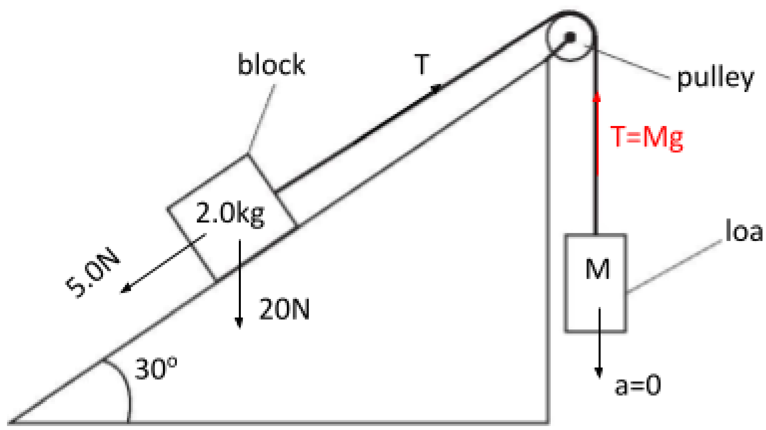

$$wait\ of\ the\ block\ acting\ \ down\ slope:$$

$$w\ =\ mg\sin sin\ \theta$$

$$\therefore T\ =\ mg\sin sin\ \theta\ +\ 5N$$

$$Mg\ =\ 10N\ .\ \ \sin sin\ 30\ °\ +\ 5$$

$$M\ =\ \frac{15}{10}\ =\ 1.5kg$$

Answer is C

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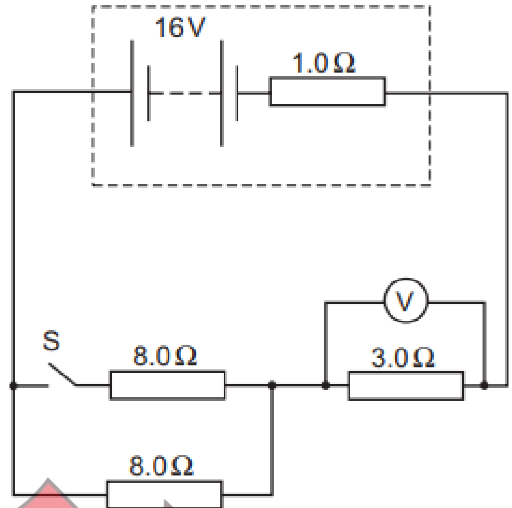
ENGAA S2 2019 - Question 4

4 The battery in the circuit shown has an emf of 16 V and an internal resistance of 1.0 Ω.



Which line in the table gives the voltmeter readings when switch S is in its open and closed states?

	voltmeter reading / V	
	when S is open	*when S is closed*
A	$\frac{4.0}{3.0}$	2.0
B	4.0	6.0
C	4.0	2.4
D	6.0	2.4
E	6.0	4.0
F	$\frac{48}{11}$	$\frac{48}{19}$
G	$\frac{48}{11}$	$\frac{48}{7.0}$
H	$\frac{128}{11}$	$\frac{64}{7.0}$

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ENGAA S2 2019 - Question 4 - Worked Solution

$$V_{measured} = \frac{3}{R_0} \cdot 16V$$

$$V_{open} = \frac{13}{12} \cdot 16 = 4V$$

$$V_{closed} = \frac{3}{8} \cdot 16 = 6V$$

Answer is B

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ENGAA S2 2019 - Question 5

5 A stationary wave is set up in a medium in which the speed of the wave is $3.2\,m\,s^{-1}$.

The stationary wave is formed by the superposition of two longitudinal waves, each of amplitude 1.5 cm, travelling in opposite directions.

The distance between adjacent nodes in the stationary wave is 4.0 cm.

What is the total distance travelled by a particle at an antinode during a time interval of 1.0 minute?

A 0 m

B 72 m

C 144 m

D 192 m

E 288 m

F 576 m

ENGAA S2 2019 - Question 5 - Worked Solution

$f = \frac{3.2ms}{0.08m} = \frac{v}{\lambda}$

$f = 40Hz$

$in\ one\ minute : 40Hz \times 60s = 2400\ waves\ per\ min$

$Amplitude\ at\ antinode\ ,\ where\ opposite\ waves\ superpose:$

$A = 1.5cm \times 2 = 3cm$

$If\ the\ particle\ experiences\ one\ full\ wave\ it\ does\ 4\ amplitue\ distance$

$d = 4A$

Hence:

$d_0 = 3cm \times 4 \times 2400\ min^{-1}$

$= 28800\ cm$

$= 288\ m$

Answer is E

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ENGAA S2 2019 - Question 6

6 A ray of light of single frequency f is travelling in a block of transparent material.

The ray strikes the boundary between the block and air at an angle θ **to the boundary**.

When $\theta = 65°$ the ray is just at the threshold of being totally internally reflected.

Which of the following is an expression for the wavelength of the light in the material?

(The speed of light in air is v_{air}.)

A $\dfrac{v_{air} \times \cos 65°}{f}$

B $\dfrac{v_{air} \times \sin 65°}{f}$

C $\dfrac{f}{v_{air} \times \cos 65°}$

D $\dfrac{f}{v_{air} \times \sin 65°}$

E $\dfrac{v_{air}}{f \times \cos 65°}$

F $\dfrac{v_{air}}{f \times \sin 65°}$

G $\dfrac{f \times \cos 65°}{v_{air}}$

H $\dfrac{f \times \sin 65°}{v_{air}}$

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ENGAA S2 2019 - Question 6 - Worked Solution

$$\varphi = 90 - \theta$$

$$\frac{\sin sin\, 90}{\sin sin\, \varphi} = \frac{n_m}{n_{air}} = \frac{v_{air}}{v_{mat}} \quad by\ defination\ of\ optical\ index$$

$$v_{mat} = v_{air} - \sin sin\, \varphi$$

$$\sin sin\, \varphi = \sin sin\, (90 - \theta) = \cos cos\, \theta$$

$$v_{mat} = v_{air} . \ \cos cos\, 65$$

$$\lambda_{mat} = \frac{v_{air} \cos cos\, 65}{f}$$

Answer is A

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ENGAA S2 2019 - Question 7

7 A solid pyramid of height 140 m has a square base.

The density of the stone from which the pyramid is made is 2100 kg m^{-3}.

Atmospheric pressure is 100 kPa.

What is the average pressure on the ground under the pyramid?

(gravitational field strength = 10 N kg^{-1}; volume of a pyramid = $\frac{1}{3}$ × base area × vertical height)

A 98 kPa

B 108 kPa

C 198 kPa

D 980 kPa

E 1080 kPa

F 2940 kPa

G 3040 kPa

ENGAA S2 2019 - Question 7 - Worked Solution

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$$P_{ground} = P_{atm} + P_{pyramid}$$

$$P_{pyramid} = \frac{weight}{base\ area} = g\times\frac{V\times\rho}{A} = \frac{1}{3}gh\rho \ \ using\ V = \frac{1}{3}Ah$$

$$= 10Nkg^{-1}\times\frac{1}{3}\times 140m\times 2100kgm^{-3}$$

$$= 980,000\ Pa$$

$$\therefore P_{pyramid} = 100kPa + 980kPa$$

$$= 1080\ kPa$$

Answer is E

ENGAA S2 2019 - Question 8

8 The pressure exerted by a gas at constant temperature is directly proportional to its density.

A spherical bubble of gas forms at the bottom of a glass containing a fizzy drink.

The radius of the bubble at the point of formation, at the bottom of the drink, is R.

The depth of the liquid in the glass is h, and the density of the liquid of the drink is ρ.

Atmospheric pressure is P.

As the bubble rises, its radius changes.

Which expression gives the radius of the bubble when it is at a distance x below the surface of the drink?

(gravitational field strength = g; volume of sphere = $\frac{4}{3}\pi r^3$ where r is the radius; the mass and the temperature of the gas in the bubble remain constant)

A $R\left(\frac{h\rho g - P}{x\rho g - P}\right)^{\frac{1}{3}}$

B $R\left(\frac{h}{x}\right)^{\frac{1}{3}}$

C $R\left(\frac{h\rho g + P}{x\rho g + P}\right)^{\frac{1}{3}}$

D $R\left(\frac{x\rho g - P}{h\rho g - P}\right)^{\frac{1}{3}}$

E $R\left(\frac{x}{h}\right)^{\frac{1}{3}}$

F $R\left(\frac{x\rho g + P}{h\rho g + P}\right)^{\frac{1}{3}}$

ENGAA S2 2019 - Question 8 - Worked Solution

$$P.V \text{ is constant}$$

$$(h\rho g + P).4\pi R^3 = (x\rho g + P).\ 4\pi\left(R'\right)^3$$

$$\therefore R' = \left(\frac{h\rho g+P}{x\rho g+P}\right)^{\frac{1}{3}} R$$

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Answer is C

ENGAA S2 2019 - Question 9

9 A block of mass 2.0 kg slides directly down a smooth slope.

The slope is at an angle of 30° to the horizontal.

The block reaches a speed of 8.0 m s^{-1}, at which point the slope becomes rough and the block begins to decelerate.

After travelling a distance of 4.0 m down the rough slope the block comes to rest.

What is the magnitude of the average friction force between the block and the rough slope?

(gravitational field strength = 10 N kg^{-1}; assume that air resistance is negligible)

A 2.0 N

B 6.0 N

C 10 N

D 12 N

E 16 N

F $10\sqrt{3}$ N

G 26 N

H $(16 + 10\sqrt{3})$ N

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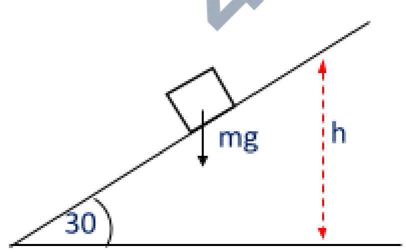
ENGAA S2 2019 - Question 9 - Worked Solution



$h = 4m\,.\ \sin sin\, 30°$

$\frac{1}{2}mu^2 + mgh = \frac{1}{v}mv^2 + mgh' + F\,.\,s$

$Initial\ E\ =\ Final\ E\ +\ Work\ done\ by\ friction$

$\frac{1}{2}(2)8^{2}\ +\ 2\times10\times4\ \sin sin\ 30\ \ =\frac{1}{2}(2)0^{7}\ +\ 2\times10\times0\ +\ F\ .\ 4$

$F\ =\frac{104}{4}=\ 26$

Answer is G

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ENGAA S2 2019 - Question 10

10 A non-uniform beam PQ of length 5.0 m and weight X rests on a pivot placed 3.0 m from end P. It is kept in equilibrium in a horizontal position by an upward force of magnitude $0.60X$ acting at end P.

The normal contact force at the pivot is 800 N.

What is the weight of the beam and how far is the centre of gravity of the beam from the pivot?

	weight of beam / N	*distance from pivot* / m
A	500	0.50
B	500	1.8
C	500	3.0
D	2000	0.50
E	2000	1.8
F	2000	3.0

ENGAA S2 2019 - Question 7 - Worked Solution

Let d be the distance to the Center of Mass:

Swimming torques about pivot.

$$d \,.\, X = 3 \,.\, (0.6\, X)$$

$$d = 1.8m\; from\; pivot$$

$$0.6\, X + 800 = X$$

$$X = 2000N$$

Answer is E

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ENGAA S2 2019 - Question 11

11 A car is travelling along a straight road with constant acceleration. It passes a road sign.

It travels 12.2 m in the 3rd second and 14.4 m in the 4th second after passing the road sign.

What was the speed of the car as it passed the road sign?

A $2.20\,\text{ms}^{-1}$

B $4.50\,\text{ms}^{-1}$

C $6.70\,\text{ms}^{-1}$

D $7.80\,\text{ms}^{-1}$

E $13.3\,\text{ms}^{-1}$

F $37.2\,\text{ms}^{-1}$

ENGAA S2 2019 - Question 11 - Worked Solution

$$S = u + \frac{1}{2}at^2$$

$$12.2m = V_2.(1) + \frac{1}{2}a(1)^2$$

$$12.2 + 14.4 = V_2(2) + \frac{1}{2}a(a)^2$$

$$24.4 = 2V_2 + a$$

$$26.6 = 2V_2 + 2a$$

$$a = 2.2ms^{-2}$$

$$V_2 = 11.1ms^{-1}$$

$$V_0 = V_2 - at$$

$$= 11.1 - 2.2 \times 2$$

$$V_0 = 6.7ms^{-1}$$

Answer is C

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ENGAA S2 2019 - Question 12

12 A light spring has unstretched length 0.40 m and spring constant 50 N m^{-1}.

The spring is stretched by a varying tension force that starts at a value of zero and increases at a constant rate of 0.20 N s^{-1} up to a maximum value.

When the force reaches its maximum value, the strain energy of the spring is 0.25 J.

What is the average power used to stretch the spring?

(Assume that the spring obeys Hooke's law.)

A 0.010 W

B 0.020 W

C 0.040 W

D 0.080 W

E 1.0 W

F 2.0 W

G 4.0 W

H 8.0 W

ENGAA S2 2019 - Question 7 - Worked Solution

$$\frac{1}{2}Fx = 0.25$$

$$\frac{1}{2}kx^2 = 0.25 \rightarrow PE$$

$$\frac{1}{2}kx^2 = 25x^2$$

$$x = 10m$$

$$\frac{1}{2}F.\ 10 = 0.25$$

$$\therefore F = 0.05N$$

$$Rate\ of\ increasing\ force: 0.2Ns^{-1}$$

$$\frac{0.05N}{0.2Ns^{-1}} = 25s$$

$$P = \frac{E}{t} = \frac{0.25J}{25s} = 0.01W$$

Answer is A

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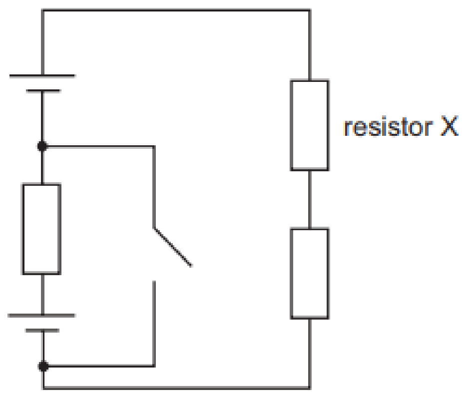
ENGAA S2 2019 - Question 13

13 The circuit below contains three identical resistors, and two identical cells. When the switch is open, the power dissipated by resistor X is P.



What is the power dissipated by resistor X after the switch is closed?

A $\frac{P}{4}$

B $\frac{9P}{16}$

C $\frac{3P}{4}$

D P

E $\frac{16P}{9}$

F $\frac{9P}{4}$

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ENGAA S2 2019 - Question 13 - Worked Solution

Switch	$\sum v$	$\sum R$	I	P
Open	2V	3R	$\frac{2}{3}\,V/R$	$\frac{4}{9}\,V^2/R$
Closed	V	2R	$\frac{1}{2}\,V/R$	$\frac{1}{4}\,V^2/R$

$$P^{'} = \frac{9}{16}P$$

Answer is B

ENGAA S2 2019 - Question 14

14 A car of mass m is pulling a caravan of mass M.

The caravan is connected to the car by a metal bar of length l and cross-sectional area A.

The Young modulus of the metal from which the bar is made is E.

The car and caravan have a constant forward acceleration a and there are total resistive forces D_1 acting on the car and D_2 acting on the caravan.

What is the extension of the bar?

(Assume that the bar obeys Hooke's law and that the cross-sectional area of the bar remains unchanged.)

A $\dfrac{Mal}{EA}$

B $\dfrac{Ma}{EA}$

C $\dfrac{(Ma + D_2)l}{EA}$

D $\dfrac{Ma + D_2}{EA}$

E $\dfrac{(Ma + ma + D_1 + D_2)l}{EA}$

F $\dfrac{Ma + ma + D_1 + D_2}{EA}$

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ENGAA S2 2019 – Question 14 - Worked Solution

By Newton's 2nd law on Caravan

$$T - D_2 = Ma$$

By definition of Young's Modulus

$$E = \frac{T \times l}{A \times x} \rightarrow \frac{EAx}{l} - D_2 = Ma$$

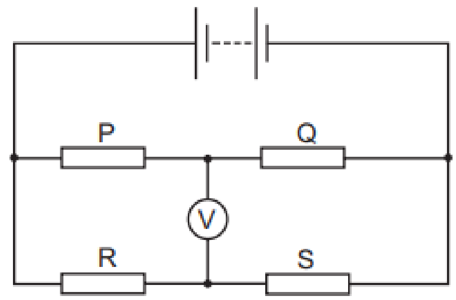
$$x = \frac{(Ma + D_2)l}{EA}$$

Answer is C

ENGAA S2 2019 - Question 15

15 Four resistors, P, Q, R and S, are connected to a battery with negligible internal resistance, as shown in the diagram.

P and S each have resistance x. Q and R each have resistance $2x$.

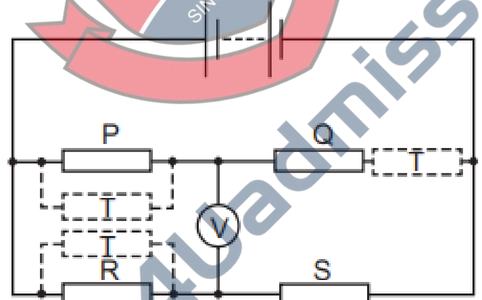


A fifth resistor, T, which has resistance x, is to be added to the circuit in one of the following listed positions, as shown in the diagram:

1 in parallel with P

2 in series with Q

3 in parallel with R



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Which of the positions for resistor T causes an increase in the magnitude of the voltmeter reading?

A none of them

B 1 only

C 2 only

D 3 only

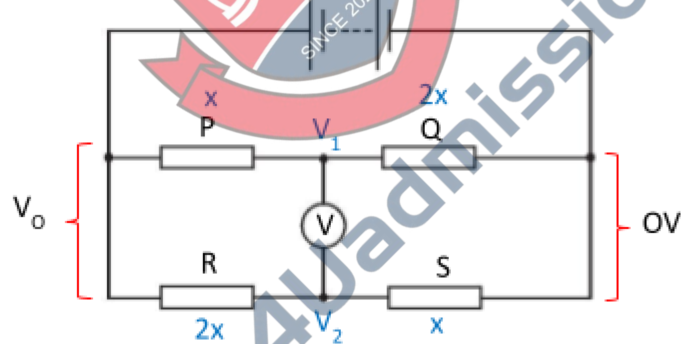
E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

ENGAA S2 2019 - Question 15 - Worked Solution



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To maximize Voltmeter reading, increase difference between $V_1 \& V_2$

1 in parallel with P $\rightarrow$ lowers R_p, lowers V_1

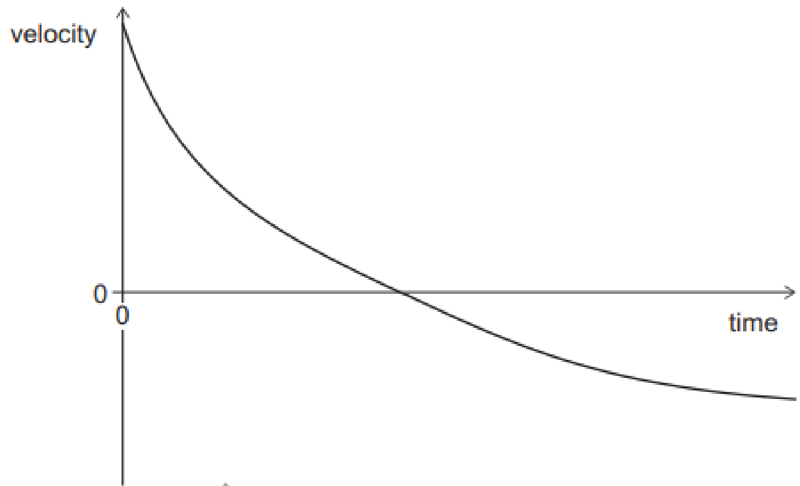
2 in series with Q $\rightarrow$ increases R_q, lower V_1

3 in parallel with R $\rightarrow$ makes V_2 closer to V_1

Answer is E

ENGAA S2 2019 - Question 16

16 A ball is thrown vertically upwards in air. The ball travels upwards to reach its highest point and then falls back down to its initial starting position. The velocity–time graph for the ball is shown.



Which of the following statements is/are correct?

1 The magnitude of the acceleration of the ball is only equal to the magnitude of the acceleration of free fall when it is at its highest point.

2 The time taken for the upward journey of the ball is equal to the time taken for the journey back down to its starting position.

3 The maximum increase in the gravitational potential energy of the ball is less than its initial kinetic energy and greater than its kinetic energy when it returns to its starting position.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

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ENGAA S2 2019 - Question 16 - Worked Solution

2 & 3 are based on reasoning of air resistance messing with the system's conservation.
Answer is F

ENGAA S2 2019 - Question 17

17 A stone is projected from level ground at an angle of 30° to the horizontal.

After 1.0 s the stone lands on a ledge at height h above the level ground.

During this journey the vertical component of velocity of the stone is upwards for the first 0.60 s and downwards for the remaining 0.40 s.

What is the value of h?

(gravitational field strength = 10 N kg^{-1}; assume that air resistance is negligible)

A 1.0 m

B 1.6 m

C 2.0 m

D 3.0 m

E 3.2 m

F 6.0 m

G 7.0 m

H 11 m

ENGAA S2 2019 - Question 17 - Worked Solution

$$At\ top\ ,\ v_y = 0$$

$$v_y = u_y - gt$$

$$v_y = v_0 \sin sin\, 30\ - 10\times 0.6s$$

$$\therefore v_0 = 12ms$$

$$S = ut + \frac{1}{2}at^2$$

$$h = 12 \sin sin\, 30\,.\,(1.0s) - \frac{1}{2}(10)(1.0)^2$$

$$h = 1m$$

Answer is A

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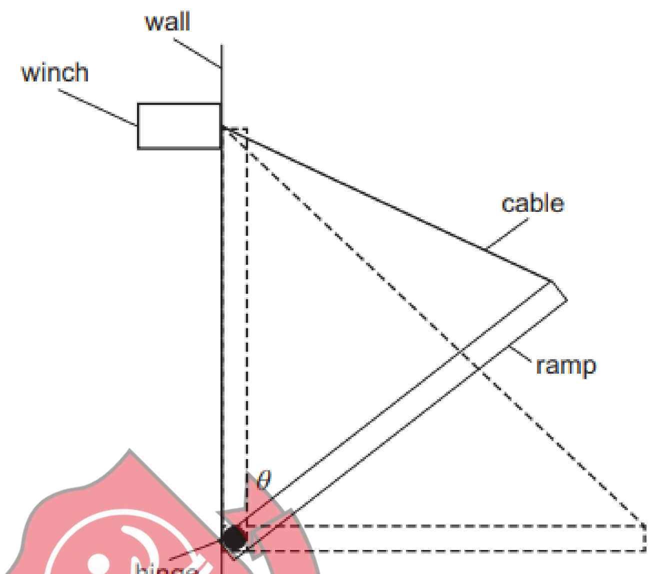
ENGAA S2 2019 - Question 18

18 A drawbridge system consists of a uniform ramp, of weight W, that is smoothly hinged at its lower end. The upper end is connected by a light, inextensible cable to a winch that is fixed to the wall in the position shown in the diagram.



The ramp is lowered slowly, at constant speed, from its closed (vertical) position ($\theta = 0°$) to its open (horizontal) position ($\theta = 90°$).

What is the maximum tension in the cable during this process?

(double-angle identities: $\sin 2\theta = 2\sin\theta\cos\theta$; $\cos 2\theta = \cos^2\theta - \sin^2\theta$)

A $\dfrac{W}{2}$

B $\dfrac{W}{\sqrt{2}}$

C $\dfrac{\sqrt{3}W}{2}$

D W

E $\dfrac{2W}{\sqrt{3}}$

F $\sqrt{2}W$

G $2W$

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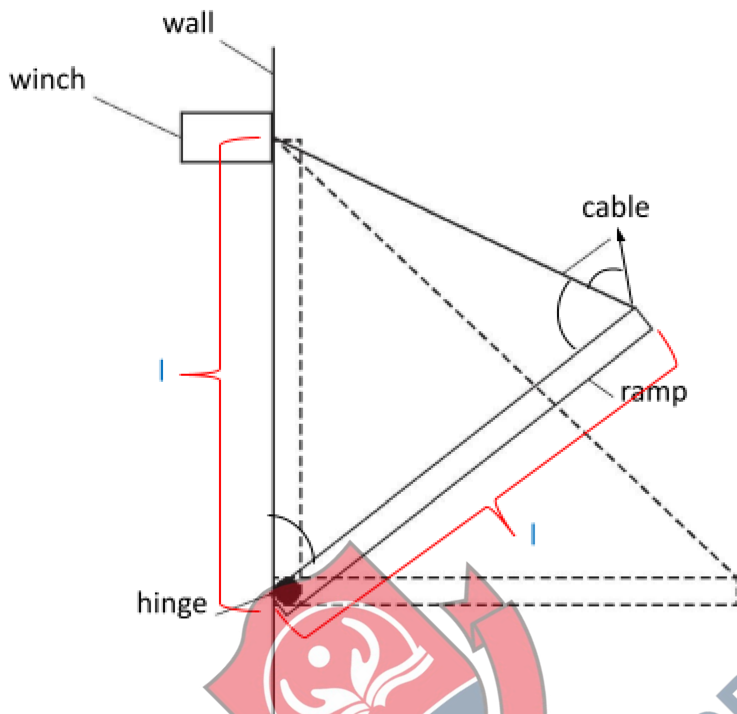
ENGAA S2 2019 - Question 18 - Worked Solution



Equating torques on bridge:

$$w \times l \sin sin\, \theta = T \cos cos\, \frac{\theta}{2} \times l$$

$$T = w \sin sin\, \frac{\theta}{2}$$

$$Max\ value\ of\ T\ is\ at\ \theta = 90°$$

$$\therefore T = \frac{w}{\sqrt{2}}$$

$$under\ limits:\ \theta \epsilon [0\ ,\ 90]$$

Answer is B

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ENGAA S2 2019 - Question 19

19 A particle of mass m has kinetic energy E when it collides with a stationary particle of mass M. The two particles coalesce.

Which of the following expressions gives the total kinetic energy transferred to other forms of energy in the collision?

A 0

B $\dfrac{ME}{(M+m)}$

C $\dfrac{mE}{(M+m)}$

D $\dfrac{(M+m)E}{m}$

E $\dfrac{(M+m)E}{M}$

F $\dfrac{mME}{(M+m)^2}$

G E

ENGAA S2 2019 - Question 19 - Worked Solution

KE of small particle:

$$E = \frac{1}{2}mv^2$$

$$u = \sqrt{\frac{2E}{m}}$$

Conservation of momentum

$$mu = (m + M)v$$

$$v = \frac{m}{m+M}u$$

$$Initial\ KE - Final\ KE$$

$$E_{lost} = \frac{1}{2}mv^2 - \frac{1}{2}(m + M)\left(\frac{m}{m+M}\right)^2$$

$$= E_0 - \frac{1}{2}\frac{m^2u^2}{m+M}$$

$$= E_0\left(1 - \frac{m}{m+M}\right)$$

$$= E_0\frac{M}{m+M}$$

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Answer is B

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ENGAA S2 2019 - Question 20

20 The critical angle for light incident on a boundary from medium X to air is 45°.

The critical angle for light of the same frequency incident on a boundary from medium Y to air is 60°.

There is a boundary between medium X and medium Y. Light of the same frequency travelling in one of these mediums is incident on this boundary.

In which direction of incidence is there a critical angle at this boundary, and within what range is this critical angle?

	direction of incidence	*critical angle*
A	X to Y	between 0° and 30°
B	X to Y	between 30° and 45°
C	X to Y	between 45° and 60°
D	X to Y	between 60° and 90°
E	Y to X	between 0° and 30°
F	Y to X	between 30° and 45°
G	Y to X	between 45° and 60°
H	Y to X	between 60° and 90°

ENGAA S2 2019 - Question 20 - Worked Solution

$$n_x = \frac{1}{\sin sin\, 45°}$$

$$n_y = \frac{1}{\sin sin\, 60°}$$

$$n_y < n_x$$

$$critical\ angel\ is\ from\ slower\ optical\ medium\ to\ higher\ so,$$

$$x \to y$$

$$n_x \sin sin\, \theta_c = n_y \sin sin\, 90\,°$$

$$\sin sin\, \theta_c = \frac{n_y}{n_x} = \frac{\sin sin\, 45°}{\sin sin\, 60°} = \frac{\sqrt{2}/2}{\sqrt{3}/2} = \frac{\sqrt{2}}{\sqrt{3}} \cong 0.8$$

$$\sin sin\, 45 = \frac{\sqrt{2}}{2} \cong 0.7$$

$$\sin sin\, 60 \;\; = \frac{\sqrt{3}}{2} \cong 0.87$$

$$\theta_c \;\; in\ between\ 45° \ \&\ 60°$$

Answer is C

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