



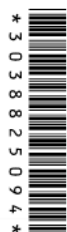
**ENGINEERING  
ADMISSIONS ASSESSMENT**

**D564/11**

**Wednesday 31 October 2018**

**80 minutes**

**SECTION 1**



**INSTRUCTIONS TO CANDIDATES**

**Please read these instructions carefully, but do not open this question paper until you are told that you may do so.** This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **two** parts, **A** and **B**, and you should attempt **both** parts.

**Part A** Mathematics and Physics (28 questions)

**Part B** Advanced Mathematics and Advanced Physics (26 questions)

This paper contains 54 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 54 questions. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators may NOT be used.

**Please wait to be told you may begin before turning this page.**

This question paper consists of 42 printed pages and 2 blank pages.

PV2

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## **PART A Mathematics and Physics**

- 1 A group of drivers, consisting of 200 women and 300 men, was asked if they passed their driving test at the first attempt.

Altogether 167 of the group said they passed at the first attempt.

Of the women, 143 said they did not pass at the first attempt.

How many of the men said they passed at the first attempt?

- A 10  
B 24  
C 33  
D 57  
☒ E 110  
F 133  
G 157

	P1	P1'	T
M	110		300
W	57	143	200
T	167		500

- 2 An unstable nucleus X becomes a stable nucleus Y after a succession of decays, during which a total of 5 alpha particles and 2 beta ( $\beta^-$ ) particles are emitted.

How many fewer protons does nucleus Y contain than nucleus X?

- A 6  
☒ B 8  
C 10  
D 12  
E 14  
F 16  
G 18  
H 20

$$5 \times \alpha = 10 \text{ fewer}$$

$$2 \times \beta^- = +2$$

$$-10 + 2 = -8$$

- 3 A cuboid has sides of length  $x$ ,  $\sqrt{2}x$  and  $2x$ , measured in cm.

The volume, in  $\text{cm}^3$ , of the cuboid is numerically equal to twice the total surface area, in  $\text{cm}^2$ , of the cuboid.

What is the value of  $x$ ?

A 10

☒ B  $6 + 2\sqrt{2}$

C 5

D  $3 + \sqrt{2}$

E  $\frac{5}{2}$

F  $\frac{3}{2} + \frac{1}{2}\sqrt{2}$

$$\text{Volume} = 2\sqrt{2}x^3$$

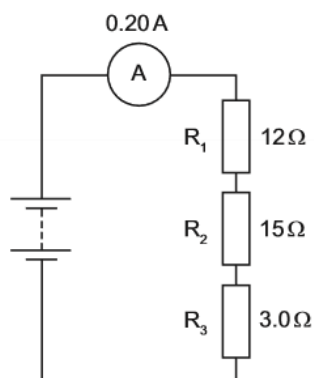
$$\text{SA} = 4x^2 + 4\sqrt{2}x^2 + 2\sqrt{2}x^2$$

$$2\sqrt{2}x^3 = 2(4x^2 + 4\sqrt{2}x^2 + 2\sqrt{2}x^2)$$

$$\sqrt{2}x = 4 + 6\sqrt{2}$$

$$x = 2\sqrt{2} + 6$$

- 4 The diagram shows three resistors  $R_1$ ,  $R_2$  and  $R_3$  connected in series with a battery of constant voltage. The resistance of each resistor and the corresponding current are also shown.



Resistor  $R_3$  is now removed and the circuit is reconnected.

What is the new current in the circuit?

A 0.20 A

**B** 0.22 A

C 0.33 A

D 0.40 A

E 0.50 A

F 2.0 A

G 6.0 A

$$V = (12 + 15 + 3) 0.2$$
$$= 6V$$
$$I = \frac{6}{27} = \frac{2}{9}$$

- 5 The line joining the points with coordinates  $(p, p - 1)$  and  $(1 - p, 2p)$  is parallel to the line with equation  $2x + 3y + 1 = 0$

What is the value of  $p$ ?

A  $-1$

B  $-\frac{1}{7}$

C  $\frac{1}{9}$

D  $\frac{1}{8}$

E  $1$

F  $\frac{5}{4}$

G  $2$

☒ H  $5$

$$2x + 3y + 1 = 0$$

$$y = -\frac{2}{3}x - \frac{1}{3}$$

$$\therefore \frac{2p - (p - 1)}{1 - p - p} = -\frac{2}{3}$$

$$\frac{p + 1}{1 - 2p} = -\frac{2}{3}$$

$$3p + 3 = -2 + 4p$$

$$\therefore p = 5$$

- 6 When travelling in a vacuum, visible light has a wavelength between 400 nm and 700 nm.

The speed of light in a vacuum is  $3.0 \times 10^8 \text{ ms}^{-1}$ .

What can be concluded about **ultraviolet** radiation from this information?

A It has a **maximum** frequency of  $2.7 \times 10^{14} \text{ Hz}$

B It has a **maximum** frequency of  $4.3 \times 10^{14} \text{ Hz}$

C It has a **maximum** frequency of  $7.5 \times 10^{14} \text{ Hz}$

D It has a **maximum** frequency of  $1.0 \times 10^{15} \text{ Hz}$

E It has a **minimum** frequency of  $2.7 \times 10^{14} \text{ Hz}$

F It has a **minimum** frequency of  $4.3 \times 10^{14} \text{ Hz}$

☒ G It has a **minimum** frequency of  $7.5 \times 10^{14} \text{ Hz}$

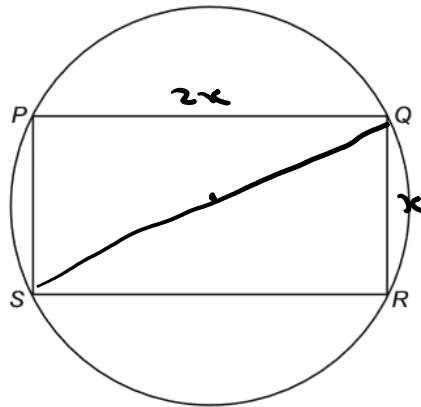
H It has a **minimum** frequency of  $1.0 \times 10^{15} \text{ Hz}$

$$f_{\min} = \frac{3 \times 10^8}{400 \times 10^{-9}}$$

$$= \frac{3 \times 10^8}{4 \times 10^{-7}}$$

$$= 7.5 \times 10^{14}$$

- 7 A rectangle  $PQRS$  is drawn inside a circle, with its vertices on the circumference of the circle.



[diagram not to scale]

The ratio of the length of  $PQ$  to the length of  $QR$  is  $2:1$

The area of the rectangle  $PQRS$  is  $96 \text{ cm}^2$ .

What is the radius, in cm, of the circle?

- A  $\sqrt{6}$
- B 3
- C  $3\sqrt{2}$
- ☒ D  $2\sqrt{15}$
- E  $4\sqrt{6}$
- F 12
- G  $12\sqrt{2}$
- H  $8\sqrt{15}$

$$2x^2 = 96$$

$$x^2 = 48$$

$$\therefore x = 4\sqrt{3}$$

$$d^2 = x^2 + (2x)^2 = 5x^2 = 240$$

$$d = \sqrt{240} = 4\sqrt{15}$$

$$\therefore r = \underline{\underline{2\sqrt{15}}}$$



- 8 A filament lamp working at its operating voltage converts electrical energy at a rate of 100 W.

The lamp has an efficiency of 5.0%.

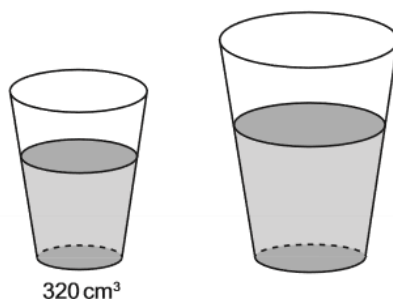
How much energy is wasted by the lamp in 10 minutes?

- A 50 J  
B 950 J  
C 1000 J  
D 3000 J  
☒ E 57 000 J  
F 60 000 J

$$0.95 \times 100 = 95 \text{ W wasted}$$

$$95 \times 10 \times 60$$

$$= 57000 \text{ J}$$



[diagram not to scale]

At a cinema, drinks are sold in regular and large sizes.

The cups for these are mathematically similar.

The ratio of the heights of the cups and the ratio of the depths of the drinks are both 4 : 5

The volume of drink in a regular size cup is  $320 \text{ cm}^3$ .

What is the volume, in  $\text{cm}^3$ , of drink in a large size cup?

A 384

B 400

C 500

D 576

☒ E 625

F 640

$$\begin{aligned} \text{Ratio of volumes} &= 4^3 : 5^3 \\ &= 64 : 125 \\ \frac{320}{64} \times 125 &= \underline{\underline{625 \text{ cm}^3}} \end{aligned}$$

- 10 The potential difference across the motor in an electric car is 400 V and the current in the motor is 1250 A.

The car accelerates along a horizontal road from rest for 4.0 s.

The efficiency of the overall system is 45%.

What is the kinetic energy of the car at the end of the 4.0 s?

(Ignore energy losses due to air resistance and due to friction between the tyres and the road.)

- A 225 000 J  
B 500 000 J  
**C 900 000 J**  
D 1 250 000 J  
E 2 000 000 J

$$P = VI = 400 \times 1250 = 500000 \text{ W}$$

$$\text{Useful Power} = 500000 \times 0.45 = 225000$$

$$Wd = 225000 \times 4 = 900000 = KE$$

- 11 The straight lines

$$5x + 2y = 20 \quad y = 10 - 2.5x$$

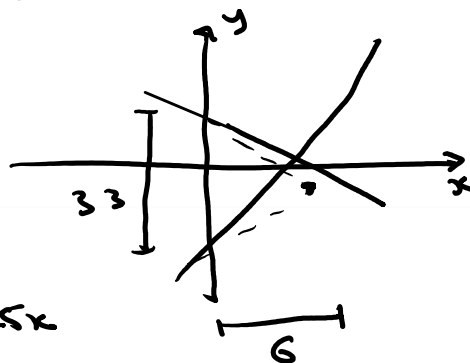
$$y = 3x - 23$$

$$x = 0$$

enclose a region with area  $K$  square units.

What is the value of  $K$ ?

- A 39  
B 78  
**C 99**  
D 129  
E 198  
F 258



$$3x - 23 = 10 - 2.5x$$

$$5.5x = 33 \therefore x = 6$$

$$y = -5$$

$$\text{Area} = \frac{1}{2} (10 - (-23)) (6) = 99$$

- 12 The momentum of a small object moving in a straight line is  $24 \text{ kg m s}^{-1}$  and its kinetic energy is  $96 \text{ J}$ .

What is the mass of the object?

- ☒ A  $3.0 \text{ kg}$   
☐ B  $4.0 \text{ kg}$   
☐ C  $6.0 \text{ kg}$   
☐ D  $8.0 \text{ kg}$   
☐ E  $12 \text{ kg}$

$$\begin{aligned} mv &= 24 \\ mv^2 &= 192 \\ \therefore v &= 8 \\ m &= 3 \end{aligned}$$

- 13 A scale model of a cylindrical pillar is to be made.

The full-sized pillar has a volume of  $12\pi \text{ m}^3$ .

The model will use a length scale of 1:40

The model is to be a solid cylinder made of a plastic which has a density of  $\frac{4}{3} \text{ g cm}^{-3}$ .

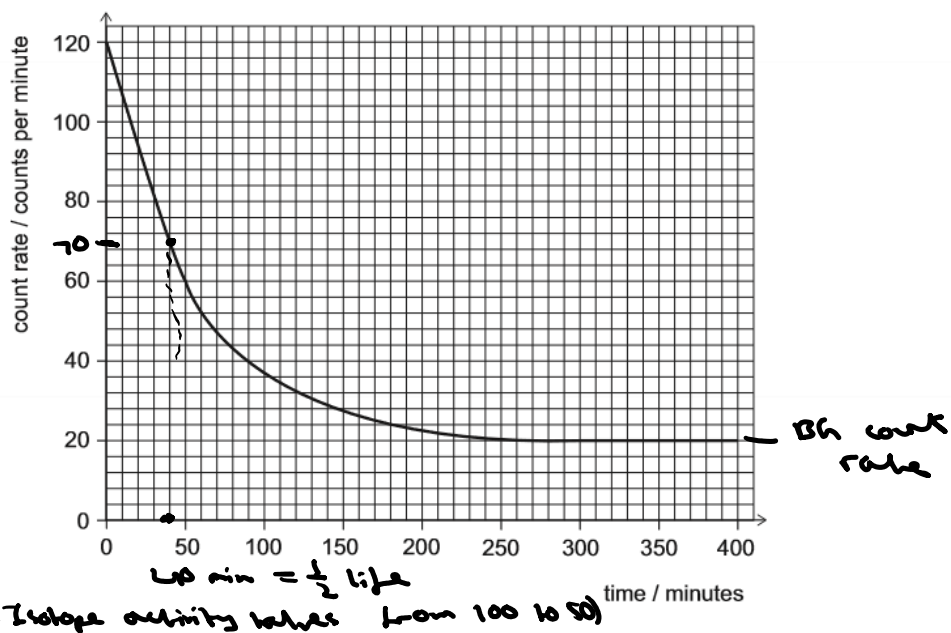
What is the mass of the model in grams?

- A  $\frac{9}{640}\pi$   
☐ B  $\frac{1}{40}\pi$   
☐ C  $40\pi$   
☐ D  $\frac{1125}{8}\pi$   
☒ E  $250\pi$   
☐ F  $10000\pi$   
☐ G  $225000\pi$   
☐ H  $400000\pi$

$$\begin{aligned} V_{\text{scale}} &= 1:64000 \\ \therefore V_{\text{model}} &= \frac{12\pi}{64000} \text{ m}^3 \\ &= \frac{12\pi \times 10^6}{64000} \text{ cm}^3 \\ &= \frac{12000\pi}{64} \text{ cm}^3 \\ &= \frac{4000\pi}{16} \end{aligned}$$

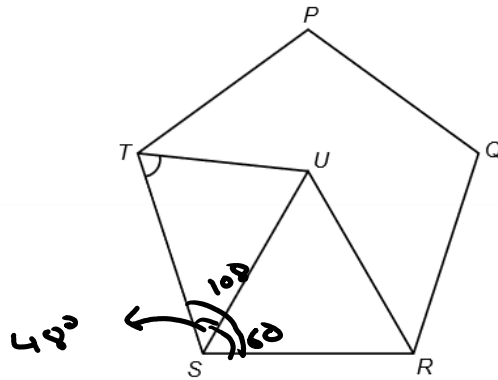
- 14 A radioactive isotope decays in a single step to a stable isotope.

A radiation detector is placed very near to a sample of the radioactive isotope in a laboratory. The count rate on the detector changes as time elapses. The graph shows how the measured count rate changes with time.



What is the background count rate and what is the half-life of the isotope?

	background count rate / counts per minute	half-life of isotope / minutes
<b>A</b>	20	40
B	20	50
C	20	60
D	20	65
E	120	40
F	120	50
G	120	60
H	120	65



[diagram not to scale]

$PQRST$  is a regular pentagon.

$RSU$  is an equilateral triangle.

What is the size of angle  $STU$ ?

- A  $48^\circ$
- B  $54^\circ$
- C  $60^\circ$
- ☒ D  $66^\circ$
- E  $84^\circ$

$$\angle STU = \frac{180 - 48}{2} = 66^\circ$$

- 16 A rock falling vertically experiences an air resistance force of 12 N at an instant when its acceleration is  $2.0 \text{ m s}^{-2}$  downwards.

What is the mass of the rock?

(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

$$mg - 12 = 2m$$

$$8m = 12$$

$$m = \underline{\underline{1.5}}$$

- A 1.0 kg  
B 1.2 kg  
☒ C 1.5 kg  
D 6.0 kg  
E 10 kg  
F 12 kg  
G 15 kg  
H 60 kg

- 17 The original price of an item is  $p$

The price is **increased by** 125%

$$= \frac{5p}{4}$$

The increased price is then **decreased by** 40% to  $q$

$$= \frac{3}{5} \times \frac{5p}{4} = \frac{3p}{4}$$

The relationship between  $p$  and  $q$  can be expressed as  $mp = q$

What is the value of  $m$ ?

- A  $\frac{7}{20}$   
B  $\frac{17}{20}$   
☒ C  $\frac{27}{20}$   
D  $\frac{33}{20}$   
E  $\frac{37}{20}$

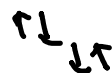
- 18 A transverse wave with an amplitude of 4.0 cm and a frequency of 10 Hz travels along a rope at a speed of  $2.4 \text{ m s}^{-1}$ .

What is the total distance travelled by a particle in the rope in a time of 20 s?

- A 2.4 m  
B 4.8 m  
C 8.0 m  
D 16 m  
**E 32 m**  
F 48 m

$$T = \frac{1}{10} = 0.1 \text{ s}$$

In 0.1s, particle travels 16 cm



$\therefore 1.6 \text{ m in } 1 \text{ s}$

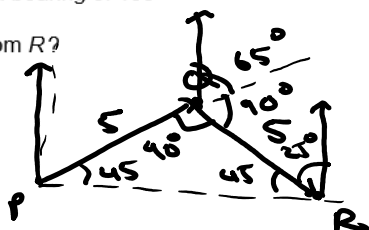
$\therefore \underline{32 \text{ m in } 20 \text{ s}}$

- 19 Q is 5 km away from P on a bearing of  $065^\circ$

R is 5 km away from Q on a bearing of  $155^\circ$

What is the bearing of P from R?

- A  $070^\circ$   
B  $110^\circ$   
C  $225^\circ$   
D  $270^\circ$   
**E  $290^\circ$**   
F  $315^\circ$   
G  $335^\circ$



Q from R  $\approx 335^\circ$

$\therefore \text{P from R} \approx 335 - 45$   
 $= \underline{290^\circ}$



- 20 A student places a measuring cylinder on a balance. She pours a volume  $V$  of water into the measuring cylinder, and finds that the mass of the measuring cylinder and water together is 290 g.

She then empties the measuring cylinder and dries it before putting it back on the balance.

She now pours the same volume  $V$  of olive oil into the measuring cylinder, and finds that the mass of the measuring cylinder and olive oil together is 270 g.

What is the mass of the measuring cylinder?

(densities: olive oil =  $0.90 \text{ g cm}^{-3}$ ; water =  $1.0 \text{ g cm}^{-3}$ )

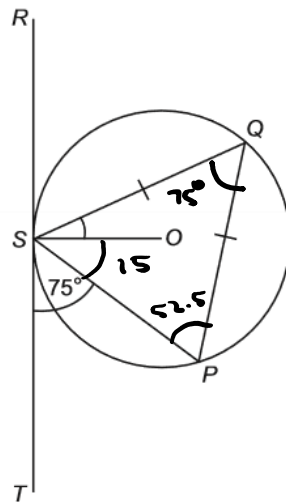
- A 18 g  
B 20 g  
☒ C 90 g  
D 180 g  
E 200 g

$$290 = M_{\text{cy}} + V$$

$$270 = M_{\text{cy}} + 0.9V$$

$$\therefore 0.1V = 20, V = 200$$

$$\therefore M_{\text{cy}} = \underline{\underline{90 \text{ g}}}$$



$$\frac{180 - 75}{2} = 52.5^\circ$$

$$52.5 - 15 = 37.5^\circ$$

[diagram not to scale]

The line segment  $RT$  is a tangent at the point  $S$  to a circle with centre  $O$

$Q$  and  $P$  are points on the circumference of the circle such that  $QS = QP$

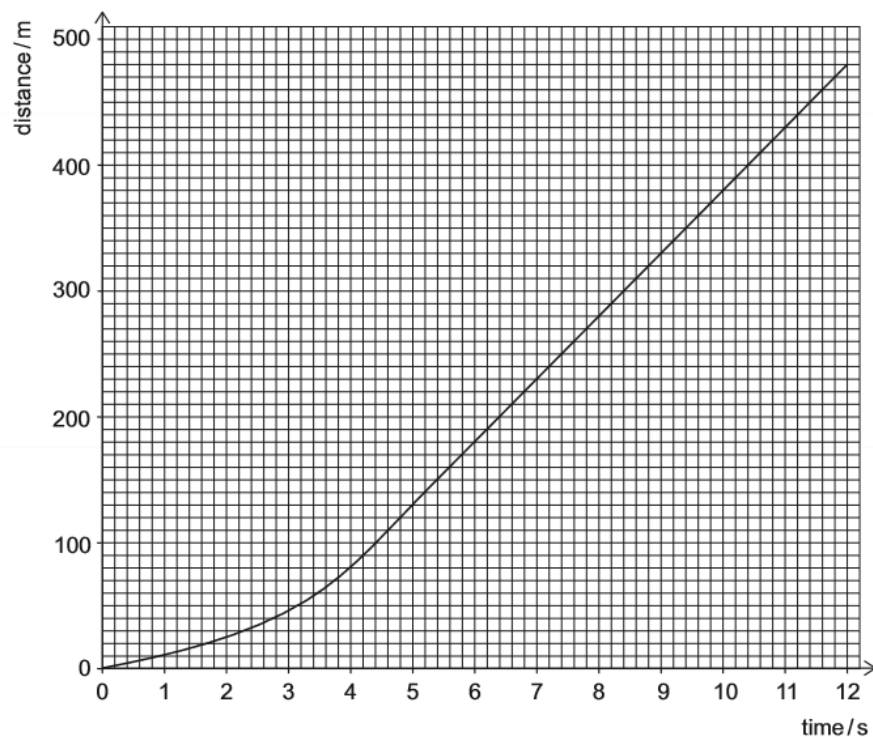
Angle  $PST = 75^\circ$

What is the size of angle  $QSO$ ?

- A  $15^\circ$
- B  $30^\circ$
- ☒ C  $37.5^\circ$
- D  $45^\circ$
- E  $52.5^\circ$
- F  $60^\circ$
- G  $67.5^\circ$
- H  $75^\circ$

- 22 A skydiver of weight 1000 N falls vertically.

The distance–time graph for the skydiver is shown below.



The air resistance  $F$  (in N) acting on the skydiver travelling at velocity  $v$  (in  $\text{m s}^{-1}$ ) is given by the equation

$$F = kv^2$$

where  $k$  (in  $\text{N m}^{-2} \text{s}^2$ ) is a constant.

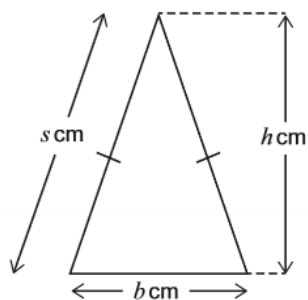
What is the numerical value of  $k$  for the skydiver?

- A 0.050
- B 0.40**
- C 0.63
- D 2.5
- E 20

constant  $v \rightarrow F = 1000 \text{ N}$

$$v = \frac{480 - 80}{12 - 4} = 50 \text{ m/s}$$

$$k = \frac{1000}{2500} = 0.4$$



[diagram not to scale]

The vertical height  $h$  cm of an isosceles triangle is 3 cm longer than the base length of  $b$  cm.

The sloping side is of length  $s$  cm.

The area of the triangle is  $14 \text{ cm}^2$ .

There is one value of  $s$  which satisfies these conditions.

Within which range does this value of  $s$  lie?

- A  $5 < s < 6$
- B  $6 < s < 7$
- C**  $7 < s < 8$
- D  $8 < s < 9$
- E  $9 < s < 10$
- F  $10 < s < 11$

$$\frac{1}{2}b(b+3) = 14$$

$$b^2 + 3b - 28 = 0$$

$$(b+7)(b-4) = 0$$

$$\therefore b = 4 \text{ cm}$$

$$h = 7 \text{ cm}$$

$$s = \sqrt{2^2 + 7^2} = \sqrt{53}$$

- 24 A neutron is absorbed by a uranium-235 ( $^{235}_{92}\text{U}$ ) nuclide.

The resulting nuclide undergoes fission to produce a bromine-88 ( $^{88}_{35}\text{Br}$ ) nuclide, a lanthanum-145 nuclide and some neutrons.

The lanthanum-145 nuclide is radioactive and emits a beta ( $\beta^-$ ) particle.

How many neutrons are emitted in the fission reaction and how many protons are there in the nuclide formed by the decay of lanthanum-145?

	neutrons	protons
A	2	55
B	2	56
C	2	57
D	2	58
E	3	55
F	3	56
G	3	57
H	3	58

Neutrons

$$= 1 + 235 - 88 - 145$$

absorbed

$$= 3$$

Protons

$$= 92 - 35 + 1 = \beta^-$$

$$= 58$$

- 25 The first five terms of a sequence in order are:

2    17    42    77    122

The  $n^{\text{th}}$  term of this sequence is  $pn^2 + q$  where  $p$  and  $q$  are integers.

What is the value of  $\frac{p-q}{p+q}$ ?

A  $\frac{1}{4}$

B  $\frac{1}{2}$

C 1

D  $\frac{23}{17}$

E  $\frac{13}{7}$

F 2

☒ G 4

H 14

$$2 = p + q$$

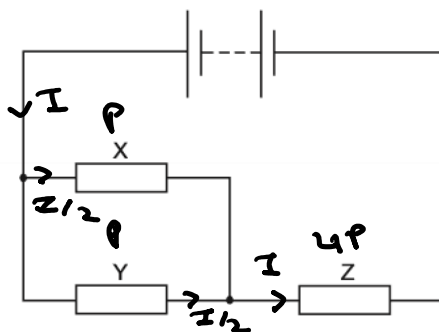
$$17 = 4p + q$$

$$3p = 15 \therefore p = 5$$

$$q = -3$$

$$\frac{5 - (-3)}{5 + (-3)} = 4$$

- 26 The diagram shows a circuit containing a battery and three identical resistors X, Y and Z.



The total power supplied by the battery is 18 W.

What is the power dissipated as heat in resistor X?

- A 1.5 W
- B 2.0 W
- C 3.0 W**
- D 4.5 W
- E 6.0 W
- F 8.0 W
- G 12 W

$$6P = 18 \therefore P = \underline{\underline{3W}}$$

$$P = I^2 R$$

$$\therefore P_X = \frac{1}{4} P_Z = P_Y$$

- 27 A bag contains 6 red and 6 green sweets. The sweets are identical apart from their colour.

A child takes a sweet at random from the bag.

If the sweet is red, the child stops taking sweets.

If the sweet is green, it is not replaced and the child takes another sweet.

This continues until a red sweet is taken at which point the child stops taking sweets.

What is the probability that the child takes more green sweets than red sweets?

A  $\frac{3}{22}$

☒ B  $\frac{5}{22}$

C  $\frac{3}{11}$

D  $\frac{1}{2}$

E  $\frac{8}{11}$

F  $\frac{17}{22}$

$$= 1 - [P(R) + P(G, R)]$$
$$= \frac{1}{2} = \frac{1}{2} \times \frac{6}{11} = \frac{6}{22}$$

$$\frac{1}{2} + \frac{6}{22} = \frac{17}{22}$$

$$1 - \frac{17}{22} = \frac{5}{22} //$$






- 28 Three detectors X, Y and Z are separated by large distances.

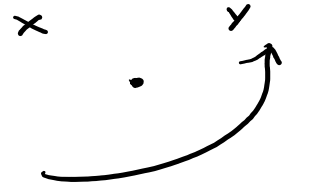
Each of the detectors records a seismic wave from the same earthquake whose epicentre (source) is very close to the surface of the Earth.

The wave travels out from the epicentre at  $4.0 \text{ km s}^{-1}$ .

Detectors X and Y start to detect the wave at the same time, but detector Z starts to detect it one minute later.

Which of the following statements **must** be correct?

- 1 The epicentre is at the midpoint of the line XY. 
- 2 Z is equidistant from X and Y. 
- 3 Z is no more than 240 km away from X and from Y. 



☒ 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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## **PART B Advanced Mathematics and Advanced Physics**

**NOTE:** questions in this part that are not covered by the ESAT content specification are indicated by a cross through the question number.

29 Curve C has equation  $y = 9 - x^2$

Line L has equation  $y = 5$

What is the area enclosed between C and L?

☒ A  $\frac{32}{3}$

B  $\frac{62}{3}$

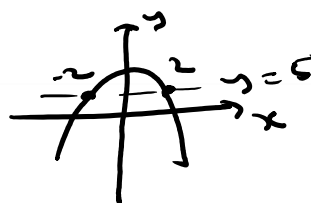
C  $\frac{92}{3}$

D  $\frac{122}{3}$

E  $\frac{152}{3}$

$$9 - x^2 = 5$$

$$x = \pm 2$$



$$= 36 - \frac{16}{3} - 20$$

$$= \frac{32}{3}$$

$$\text{Area} = \int_{-2}^2 (9 - x^2) dx - 5(4)$$

$$= \left[ 9x - \frac{x^3}{3} \right]_{-2}^2 - 20$$

$$= 18 - \frac{8}{3} - \left( -18 + \frac{8}{3} \right) - 20$$

☒ An aircraft moves from rest with uniform acceleration along a horizontal runway. After travelling 1600 m it reaches a speed of  $80 \text{ ms}^{-1}$ .

What is the acceleration of the aircraft?

A  $0.025 \text{ ms}^{-2}$

B  $0.050 \text{ ms}^{-2}$

C  $0.10 \text{ ms}^{-2}$

D  $0.50 \text{ ms}^{-2}$

☒ E  $2.0 \text{ ms}^{-2}$

F  $4.0 \text{ ms}^{-2}$

G  $10 \text{ ms}^{-2}$

H  $20 \text{ ms}^{-2}$

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

$$6400 = 0 + 2a(1600)$$

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

31 How many solutions of the equation  $2\sin^3\theta = \sin\theta$  lie in the interval  $-\frac{\pi}{2} \leq \theta \leq \pi$ ?

- A 2
- B 3
- C 4
- ☒ D 5
- E 6
- F 7

$$\begin{aligned} \sin\theta (2\sin^2\theta - 1) &= 0 \\ \sin\theta &= 0 \rightarrow 2 \text{ sols } (0, \pi) \\ \sin^2\theta &= \pm \frac{1}{2} \rightarrow 3 \text{ sols} \\ &\quad \left(-\frac{\pi}{4}, \frac{\pi}{4}, \frac{3\pi}{4}\right) \end{aligned}$$

☒ The diagram represents a mass that is moving in a straight line at constant speed up a slope of constant gradient.



Which statement about the forces acting on the mass **must** be correct?

- A All the forces acting on the mass are equal in magnitude. ~~x~~  $W \neq \text{Driving force}$
- B Only three forces act on the mass. ~~x~~  $\text{Driving, } W$
- C The force of friction on the mass is equal to the driving force. ~~x~~
- D The weight of the mass acts in the opposite direction to the contact force. ~~x~~  $\text{act } \perp \text{ to each other}$
- E There is no air resistance acting on the mass. ~~x~~
- ☒ F There is no resultant force acting on the mass.  $\equiv$

- 33 The line  $y = x + k$ , where  $k$  is a constant, is a tangent to the curve  $y = 3x^2 - 2x + 1$

What is the value of  $k$ ?

A -2

B -1

☒ C  $\frac{1}{4}$

D  $\frac{1}{3}$

E  $\frac{1}{2}$

F  $\frac{3}{4}$

G 1

H 2

$$y' = 6x - 2 = 1$$

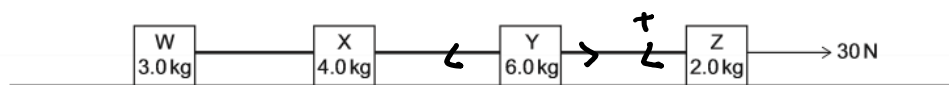
$$x = \frac{1}{2}$$

$$y = 3\left(\frac{1}{2}\right)^2 - 1 + 1 = \frac{3}{4}$$

$$\frac{3}{4} = \frac{1}{2} + k$$

- ☒ The diagram shows four objects W, X, Y and Z, of masses 3.0 kg, 4.0 kg, 6.0 kg and 2.0 kg respectively, connected by light, inextensible rods.

The objects are pulled along a smooth, horizontal surface by a constant force of 30 N in the direction indicated.



What is the tension in the rod connecting X and Y?

A 8.0 N

B 10 N

C 12 N

☒ D 14 N

E 16 N

$$30 - T_{YZ} = 2a$$

$$T_{YZ} - T_{XY} = 6a$$

$$\therefore 30 - T_{XY} = 8a$$

$$T_{XY} - T_{WX} = 4a$$

$$T_{WX} = 3a$$

$$\therefore T_{XY} = 7a$$

$$a = 2$$

$$T_{XY} = 30 - 16 = 14$$

- 35 A sector  $S$  of a circle has area  $10\pi \text{ cm}^2$ .

The angle of sector  $S$  is increased by  $\frac{\pi}{20}$  radians to form sector  $T$ .

The total area of sector  $T$  is  $\frac{25}{2}\pi \text{ cm}^2$ .

What is the total arc length, in cm, of sector  $T$ ?

A  $\frac{9\sqrt{5}}{10}\pi$

B  $\frac{5\sqrt{2}}{4}\pi$

C  $2\pi$

D  $\frac{5}{2}\pi$

$$\frac{1}{2}r^2\theta = 10\pi$$

$$\frac{1}{2}r^2\left(\theta + \frac{\pi}{20}\right) = \frac{25\pi}{2}$$

$$\frac{\theta + \frac{\pi}{20}}{\theta} = \frac{25}{10} = 1.25$$

$$\frac{\pi}{20\theta} = 0.25$$

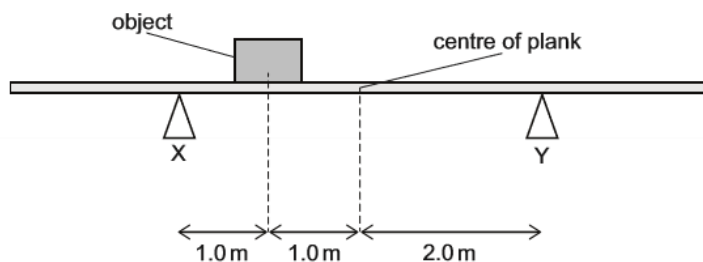
$$30 = \pi = \theta = \frac{\pi}{5}$$

$$\frac{\pi}{5} + \frac{\pi}{20} = \frac{\pi}{4}$$

$$\frac{1}{2}r^2\left(\frac{\pi}{5}\right) = 10\pi \therefore r = 10\text{ cm}$$

$$\text{Arc} = r\theta = 10 \times \frac{\pi}{4}$$

- ✗ An object of mass 40 kg is placed on a uniform, horizontal plank of mass 10 kg between two supports X and Y as shown in the diagram.



What is the contact force at X?

(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

- A 15 N  
B 35 N  
C 150 N  
D 250 N  
E 300 N  
**F 350 N**  
G 375 N

$$R_x + R_y = 500$$

$$\uparrow: 100(2) + 400(3) = R_x(4)$$

$$R_x(4) = 1400$$

$$R_x = 350$$

- 37 In a particular arithmetic progression:

- the 13<sup>th</sup> term is six times the 1<sup>st</sup> term
- the 11<sup>th</sup> term is 1 less than twice the 5<sup>th</sup> term

What is the 3<sup>rd</sup> term of the progression?

- A -14.5  
B -11  
C  $\frac{29}{19}$   
D 3.5  
**E 11**  
F 14.5

$$a + 12d = 6a \quad \therefore 5a = 12d \rightarrow a = \frac{12d}{5}$$

$$2(a + 4d) - 1 = a + 10d$$

$$\therefore 2a + 8d - 1 = a + 10d$$

$$a - 2d = 1$$

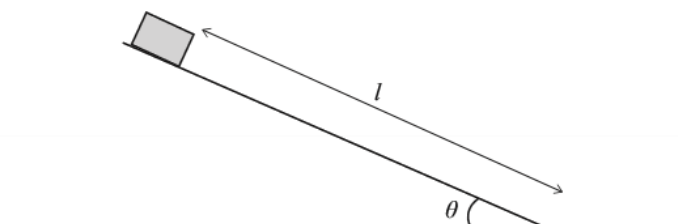
$$\frac{12d}{5} - 2d = 1 \quad \therefore \frac{2d}{5} = 1, \quad d = 2.5$$

$$a = 6$$

$$3^{\text{rd}} \text{ term} = 11$$



- ✗ A block of mass  $m$  slides a distance  $l$  down a slope that is inclined at angle  $\theta$  to the horizontal, as shown:



The block experiences a friction force of  $kW\sin\theta$ , where  $W$  is the weight of the block and  $k$  is a constant.

The block starts from rest at the top of the slope and slides down a distance  $l$  to the bottom, where its potential energy is zero.

What fraction of the initial potential energy at the top has become kinetic energy as the block reaches the bottom?

- A  $k$   
 (B)  $-k$   
 C  $k\sin\theta$   
 D  $1 - k\sin\theta$   
 E  $k\tan\theta$   
 F  $1 - k\tan\theta$

$$\Delta GPE = mgl\sin\theta$$

$$KE = mgl\sin\theta - kWl\sin\theta$$

$$\text{Fraction} = \frac{KE}{mgl\sin\theta} = 1 - \frac{kW}{mg} = 1 - k$$

- 39 The first three terms of a geometric progression, whose terms are all greater than zero, are  $(p-2)$ ,  $(2p+2)$  and  $(5p+14)$

What is the fifth term of the progression?

- A 324  
 (B) 486  
 C 1250  
 D 1458  
 E 3888

$$\frac{2p+2}{p-2} = \frac{5p+14}{2p+2}$$

$$4p^2 + 8p + 4 = 5p^2 + 4p - 28$$

$$p^2 - 4p - 32 = 0$$

$$(p-8)(p+4) = 0$$

$$6, 18, 54, 162, 486$$

- ~~30~~ An object X of mass 2.0 kg is initially moving at a speed of  $4.5 \text{ m s}^{-1}$  on a smooth, horizontal surface.

A 5.0 N force is applied to X in the direction of its motion for 3.0 seconds.

A short time later it collides head on with, and sticks to, a stationary object Y of mass 3.0 kg.

What is the speed of X and Y as they move off together after the collision?

A  $1.8 \text{ m s}^{-1}$

B  $3.0 \text{ m s}^{-1}$

C  $3.6 \text{ m s}^{-1}$

☒ D  $4.8 \text{ m s}^{-1}$

E  $5.4 \text{ m s}^{-1}$

$$m(v-u) = F(t) = 15$$

$$2(v - 4.5) = 15$$

$$v = \underline{\underline{12 \text{ m/s}}}$$

$$2(12) + 3(0) = 5v$$

$$v = 4.8$$

41 Evaluate

$$\log_2\left(\frac{5}{4}\right) + \log_2\left(\frac{6}{5}\right) + \log_2\left(\frac{7}{6}\right) + \dots + \log_2\left(\frac{64}{63}\right)$$

A -2

B 3

☒ C 4

D 6

E  $\log_2(3!)$

F  $\log_2 60$

$$= \log_2\left(\frac{5}{4} \times \frac{6}{5} \times \frac{7}{6} \times \dots \times \frac{64}{63}\right)$$

$$= \log_2 16 = 4$$

- ✗ A ball of mass  $0.20\text{ kg}$  is thrown vertically downwards at an initial speed of  $4.0\text{ ms}^{-1}$  and travels a distance of  $0.45\text{ m}$  to the ground.

The ball hits the ground, and rebounds with an initial speed of  $2.0\text{ ms}^{-1}$ .

How much energy does the ball lose in the bounce?

(gravitational field strength =  $10\text{ N kg}^{-1}$ ; air resistance can be ignored)

A  $0.10\text{ J}$

B  $0.40\text{ J}$

C  $0.50\text{ J}$

D  $0.90\text{ J}$

E  $1.2\text{ J}$

F  $1.6\text{ J}$

☒ G  $2.1\text{ J}$

$$E_{\text{initial}} = \frac{1}{2}(0.2)(4)^2 + 0.2(10)(0.45)$$

$$= 1.6 + 0.9 = 2.5$$

$$E_{\text{final}} = \frac{1}{2}(0.2)(2)^2 = \underline{\underline{0.4}}$$

- 43 Circle C has equation  $(x + 3)^2 + (y - 2)^2 = 5$

The length of the tangent from the circle C to the point P is  $5\sqrt{3}$

What is the shortest distance from P to C?

A  $5\sqrt{3}$

B  $5\sqrt{3} + \sqrt{5}$

☒ C  $3\sqrt{5}$

D  $5$

E  $10$



$$\text{Radius} = \sqrt{5}$$

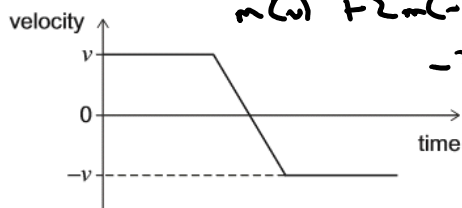
$$a^2 = (5\sqrt{3})^2 + (\sqrt{5})^2$$

$$= 75 + 5 = 80 \Rightarrow a = 4\sqrt{5}$$

$$\text{Distance} = a - \sqrt{5} = \underline{\underline{3\sqrt{5}}}$$

- ✗ Two solid spheres X and Y have masses  $m$  and  $2m$  respectively. They travel in opposite directions towards each other along the same line with speeds  $v$  and  $2v$  respectively and collide head on.

The graph shows the variation of velocity with time for sphere X before, during, and after the collision.



$$m(v) + 2m(-2v) = m(-v) + 2mv$$

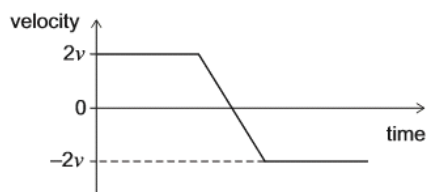
$$-3mv = -mv + 2mv$$

$$-2mv = 2mv$$

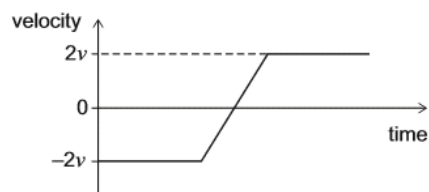
$$v = -v$$

Which sketch shows the variation of velocity with time for sphere Y?

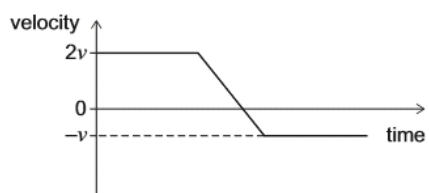
A



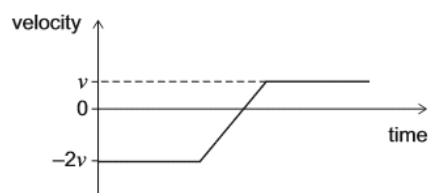
B



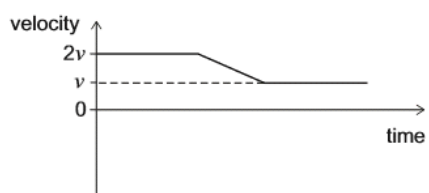
C



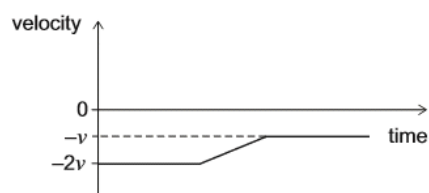
D



E



F



- 45 The points  $A(-3, 2)$ ,  $B(1, 3)$  and  $C(-1, u)$  are such that the distances  $AC$  and  $AB$  are related by:

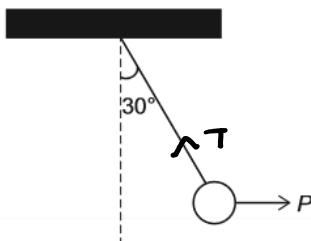
$$AC = 2AB$$

What are the possible values of  $u$ ?

- A 2 and -6  
B -2 and 6  
C 6 and -10  
D -6 and 10  
E  $2+2\sqrt{13}$  and  $2-2\sqrt{13}$   
F  $-3+2\sqrt{13}$  and  $-3-2\sqrt{13}$

$$\begin{aligned} AB &= \sqrt{4^2 + 1^2} = \sqrt{17} \\ AC &= \sqrt{2^2 + (2-u)^2} \\ \sqrt{2^2 + (2-u)^2} &= 2\sqrt{17} \\ 4 + (2-u)^2 &= 68 \\ (2-u)^2 &= 64 \\ -u &= 6 \text{ or } -10 \\ u &= -6 \text{ or } 10 \end{aligned}$$

- \* A metal ball suspended from a steel cable is held at rest by a horizontal force  $P$ . The cable makes an angle of  $30^\circ$  to the vertical as shown in the diagram. The cable exerts a force  $T$  on the ball.



What is the magnitude of  $P$ ?

- A  $\frac{T}{2}$   
B  $T$   
C  $2T$   
D  $\frac{T}{\sqrt{2}}$   
E  $\frac{T}{\sqrt{3}}$   
F  $\frac{2T}{\sqrt{3}}$   
G  $\frac{\sqrt{3}T}{2}$

$$P = T \sin 30$$

47 What is the coefficient of  $x^3$  in the expansion of  $(1 - 2x)^5(1 + 2x)^5$ ?

A -6400

B -640

C -80

☒ D 0

E 80

F 800

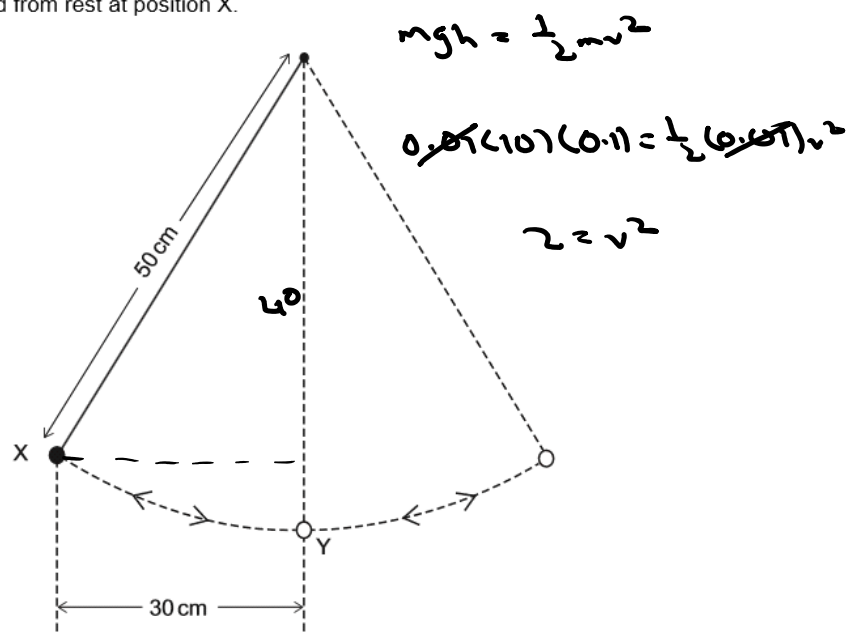
G 960

$$= (1 - 10x + 40x^2 - 120x^3 + \dots) \\ (1 + 10x + 40x^2 + 120x^3 + \dots)$$

$$\text{Coefficient} = 120 - 120 - 400 + 400 \\ = 0$$

- ✗ A pendulum bob of mass 10 g is suspended by a light, inextensible string of length 50 cm.

The bob is released from rest at position X.



What is the speed of the bob as it passes through position Y?

(gravitational field strength  $g = 10 \text{ N kg}^{-1}$ ; assume that resistive forces are negligible)

- ☒ A  $\sqrt{2} \text{ m s}^{-1}$
- ☐ B  $\sqrt{4} \text{ m s}^{-1}$
- ☐ C  $\sqrt{6} \text{ m s}^{-1}$
- ☐ D  $\sqrt{8} \text{ m s}^{-1}$
- ☐ E  $\sqrt{10} \text{ m s}^{-1}$

49 Given that

$$\int_0^2 x^m dx = \frac{16\sqrt{2}}{7}$$

and

$$\int_0^2 x^{m+1} dx = \frac{32\sqrt{2}}{9}$$

what is the value of  $m$ ?

A  $-\frac{11}{2}$

B  $-\frac{9}{2}$

C  $-\frac{22}{29}$

D  $\frac{7}{22}$

☒ E  $\frac{5}{2}$

F  $\frac{7}{2}$

$$\frac{2^{m+1}}{m+1} = \frac{16\sqrt{2}}{7} \quad (1)$$

$$\frac{2^{m+2}}{m+2} = \frac{32\sqrt{2}}{9} \quad (2)$$

$$\therefore (2) \div (1) : \frac{2(m+1)}{m+2} = \frac{14}{9}$$

$$18m + 18 = 14m + 28$$

$$4m = 10$$

$$m = \underline{\underline{2.5}}$$

☒ An object of mass  $m$  is initially moving at constant speed  $u$  to the right. It collides with a stationary object of greater mass  $M$  and bounces back in the opposite direction at speed  $v$ .

What is the speed of the greater mass immediately after the collision?

A  $\frac{mu}{M}$

B  $\frac{Mu}{m}$

C  $\frac{m(v-u)}{M}$

D  $\frac{M(v-u)}{m}$

☒ E  $\frac{m(v+u)}{M}$

F  $\frac{M(v+u)}{m}$

$$mu + M(0) = m(-v) + Mx$$

$$x = \frac{m(v+u)}{M}$$



- 51 The two functions  $f$  and  $g$  satisfy

$$f'(x) = ax + g(x)$$

where  $a$  is a constant.

$$f(x) = \frac{ax^2}{2} + \int g(x) dx$$

Given that

$$\int_2^4 g(x) dx = 12$$

and

$$f(4) = 18 + f(2)$$

$$f(4) - f(2) = \frac{a(4^2)}{2} - \frac{a(2^2)}{2} + \int_2^4 g(x) dx$$

what is the value of  $a$ ?

$$6a + 12 = 18$$

$$6a = 6 \therefore \underline{\underline{a = 1}}$$

☒ A 1

B 3

C 5

D 6

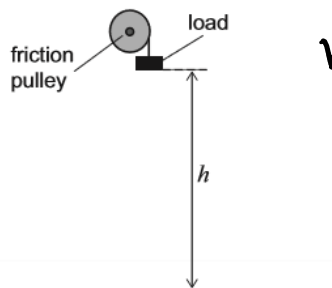
E 15

~~X~~ A load drops from rest through a vertical height  $h$  to the ground.

A light cable attached to the load passes over a friction pulley that provides a braking force during the fall.

As the load falls through height  $h$ , 50% of the gravitational potential energy lost is transferred into thermal energy.

The load reaches a final speed of  $10 \text{ m s}^{-1}$ .



$$\text{GPE} = mgh$$

$$\text{KE}_{\text{final}} = \frac{1}{2} m (10^2)$$

$$= 50m$$

$$= \frac{\text{GPE}}{2}$$

$$50m = \frac{mgh}{2}$$

What is the vertical height  $h$ ?

(gravitational field strength  $g = 10 \text{ N kg}^{-1}$ ; air resistance can be ignored)

- A 0.50 m
- B 1.0 m
- C 2.0 m
- D 2.5 m
- E 5.0 m
- ☒ F 10 m
- G 20 m

$$100m = 10gh$$

$$\therefore h = \underline{\underline{10}}$$

- 53 The dimensions of a solid cuboid, in cm, are  $x$ ,  $2x$  and  $y$

The volume of the cuboid is  $576 \text{ cm}^3$ .

At this volume, the surface area of the cuboid has its maximum value.

What is the area, in  $\text{cm}^2$ , of the face that has the largest area?

A  $2(288)^{\frac{2}{3}}$

B 72

☒ C 96

D 432

E  $4(144)^{\frac{2}{3}}$

$$\begin{aligned}
 y &= \frac{576}{72} = 8 \\
 \text{largest SA} &= 12(8) = 96 \\
 2x^2y &= 576 \therefore y = \frac{576}{2x^2} \\
 SA &= 2x^2 + 6xy \\
 &= 2x^2 + 6x \left( \frac{576}{2x^2} \right) \\
 &= 2x^2 + \frac{1728}{x} \\
 \frac{dSA}{dx} &= 4x - \frac{1728}{x^2} = 0 \therefore x^3 = \frac{1728}{4} \\
 x &= \sqrt[3]{432} = 6
 \end{aligned}$$

- ~~54~~ An object is thrown vertically upwards from ground level with an initial velocity of  $40 \text{ m s}^{-1}$ .

2.0 seconds later another object is released from a height above the ground and falls vertically from rest.

Both of the objects hit the ground at the same time.

From what height above the ground was the second object released?

(gravitational field strength  $g = 10 \text{ N kg}^{-1}$ ; air resistance can be ignored)

A 80 m

☒ B 180 m

C 320 m

D 500 m

E 900 m

$$\begin{aligned}
 \textcircled{1} \quad s &= 40t - 5t^2 \\
 \textcircled{2} \quad s &= -5(t-2)^2 + h \\
 s &= 0 \therefore t = 0 \text{ or } t = 8 \\
 -5(6^2) + h &= 0 \therefore h = 5(36) = 180 \text{ m}
 \end{aligned}$$

END OF TEST

- 1 A man is cycling along a straight horizontal road at a constant speed of  $9.00 \text{ m s}^{-1}$ .

He passes a boy who is cycling at  $5.00 \text{ m s}^{-1}$  in the same direction.

When the man is level with the boy, the boy begins to accelerate at a constant rate of  $0.800 \text{ m s}^{-2}$ .

The boy maintains this constant acceleration and the man continues at constant speed until the boy passes the man.

What is the time interval between the two instances when the man and the boy are level?

- A 5.00 s  
**B 10.0 s**  
C 22.5 s  
D 35.0 s  
E 90.0 s

$$\text{Man} \rightarrow s = 9t$$

$$\text{Boy} \rightarrow s = 5t + 0.4t^2$$

$$9t = 5t + 0.4t^2$$

$$4t - 0.4t^2 = 0$$

$$0.4t(10 - t) = 0$$

$$t = 0 \text{ or } \underline{t = 10}$$

- 2 Two liquids P and Q can be mixed together in any proportion.

The density of liquid P is  $\rho_P$  and the density of liquid Q is  $\rho_Q$ .

A volume  $V_P$  of liquid P and a volume  $V_Q$  of liquid Q are mixed together to produce a volume that is equal to  $V_P + V_Q$ .

What is the density of the mixture?

A  $\frac{\rho_P + \rho_Q}{2}$

$$\text{Mass}_{\text{mix}} = \rho_P V_P + \rho_Q V_Q$$

☒ B  $\frac{\rho_P V_P + \rho_Q V_Q}{V_P + V_Q}$

$$\rho = \frac{\rho_P V_P + \rho_Q V_Q}{V_P + V_Q}$$

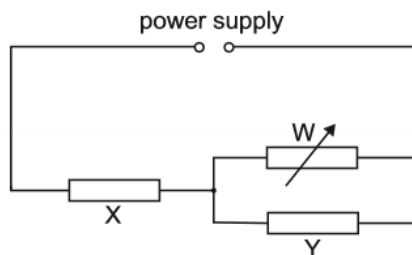
C  $\left(\frac{\rho_P}{V_P} + \frac{\rho_Q}{V_Q}\right)(V_P + V_Q)$

D  $\frac{\rho_P V_Q + \rho_Q V_P}{V_P + V_Q}$

E  $\frac{\left(\frac{\rho_P}{V_P} + \frac{\rho_Q}{V_Q}\right)}{V_P + V_Q}$

F  $\left(\frac{\rho_P}{V_Q} + \frac{\rho_Q}{V_P}\right)(V_P + V_Q)$

- 3 A circuit contains two fixed resistors, X and Y, and a variable resistor W. The power supply has no internal resistance.



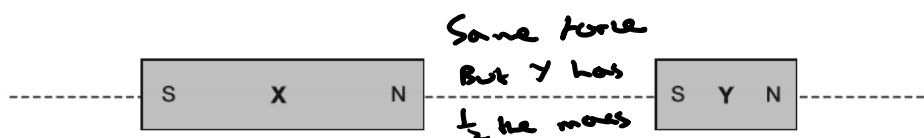
The resistance of W increases.

$V_X \downarrow$  and  $V_Y \uparrow$   
 $\therefore$  for same  $R_X, R_Y$ ,  $P_X \downarrow$  and  $P_Y \uparrow$   
 $P = \frac{V^2}{R}$

What happens to the power dissipated in X and in Y?

	power dissipated in X	power dissipated in Y
A	decreases	decreases
B	decreases	stays constant
<b>C</b>	decreases	increases
D	increases	decreases
E	increases	stays constant
F	increases	increases

- 4 The diagram shows two bar magnets, X and Y, held at rest a short distance apart from one another on a smooth horizontal surface. They are aligned as shown in the diagram and both are released at the same time. They move towards each other, collide and coalesce. Just before they collide X has a velocity  $v$  to the right.



$$a \propto \frac{F}{m} \therefore 2 \times a = 2 \times v$$

The mass of X is double the mass of Y.

Which row in the table gives the magnitude and direction of the velocity of the two magnets after the collision?

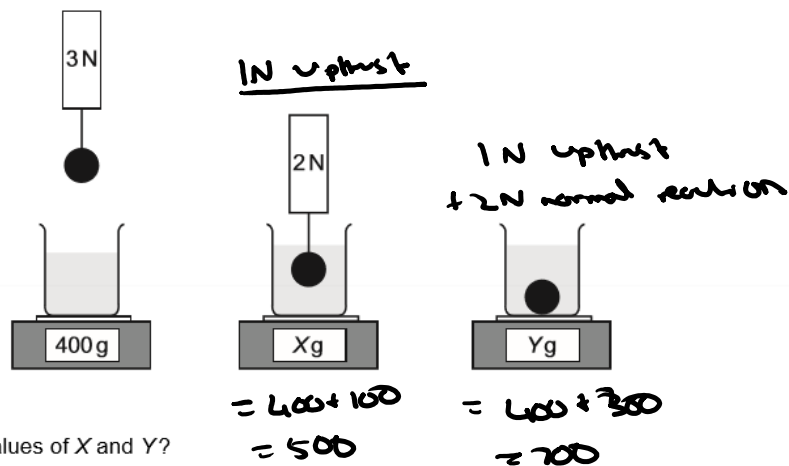
$$2m(v) + m(-2v) = 2mv + m(-2v) = 0$$

	magnitude of velocity	direction of velocity
<b>A</b>	0	not applicable
<b>B</b>	$\frac{1}{3}v$	to the left
<b>C</b>	$\frac{2}{3}v$	to the left
<b>D</b>	$\frac{4}{3}v$	to the left
<b>E</b>	$\frac{1}{3}v$	to the right
<b>F</b>	$\frac{2}{3}v$	to the right
<b>G</b>	$\frac{4}{3}v$	to the right

- 5 A stone is suspended from a newtonmeter and the meter reads 3 N. A beaker of water is placed on a top pan balance and the top pan balance reads 400 g.

The stone is lowered into the water so that it is at rest and fully submerged, but not touching the bottom of the beaker. The reading on the newtonmeter is now 2 N and the top pan balance reads X g.

The stone is detached from the newtonmeter and allowed to rest under water on the base of the beaker. The top pan balance now reads Y g.



What are the values of X and Y?

(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

	X	Y
A	400	500
B	400	600
C	400	700
D	500	500
E	500	600
<b>F</b>	500	700



- 6 Diagram 1 represents a stationary wave produced by sound in an open-ended tube of length 0.50 m containing a liquid. The speed of the wave in the liquid is  $1000 \text{ m s}^{-1}$ .

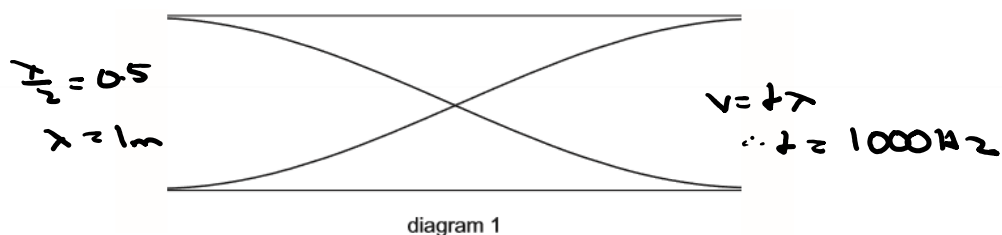
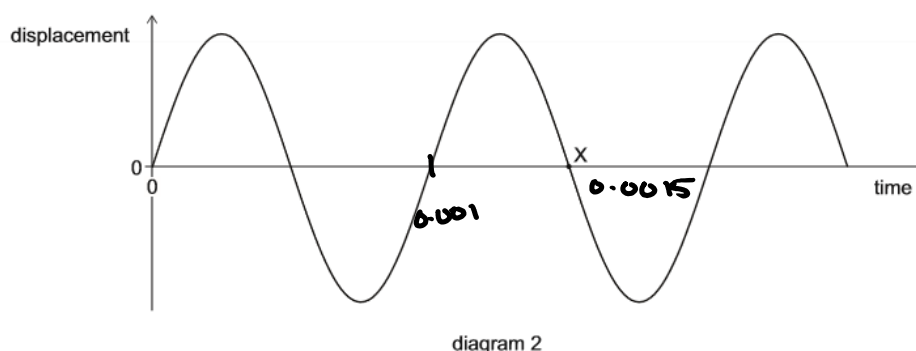


Diagram 2 is a displacement–time graph representing a progressive sound wave with the same frequency in the same liquid.



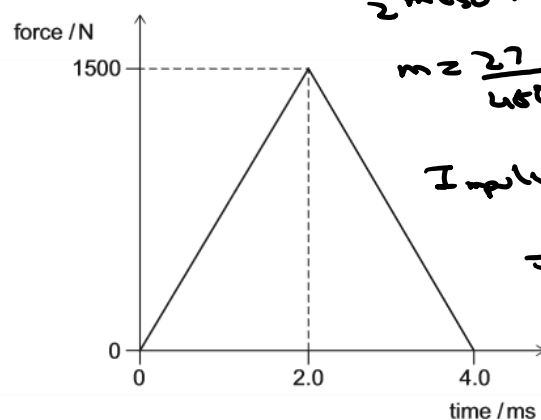
What is the value of the time at point X on the graph?  
(End effects of the stationary wave can be ignored.)

$$T = \frac{1}{f} = \underline{0.001 \text{ s}}$$

- A  $2.5 \times 10^{-4} \text{ s}$
- B  $3.75 \times 10^{-4} \text{ s}$
- C  $5.0 \times 10^{-4} \text{ s}$
- D  $7.5 \times 10^{-4} \text{ s}$
- E  $1.0 \times 10^{-3} \text{ s}$
- F**  $1.5 \times 10^{-3} \text{ s}$

- 7 A tennis ball travelling at a speed of  $30 \text{ m s}^{-1}$  hits a racket elastically with a kinetic energy of 27 J.

The racket applies a variable force to the tennis ball for a time of 4.0 ms as shown.



$$\frac{1}{2} m (30^2) = 27$$

$$m = \frac{27}{450} = \frac{3}{50} = 0.06 \text{ kg}$$

$$\text{Impulse} = \frac{1}{2} (0.004)(1500)$$

$$= 0.002(1500)$$

$$= \underline{\underline{3 \text{ N s}}}$$

The ball moves away in the opposite direction to its initial motion.

With what speed does the ball leave the racket?

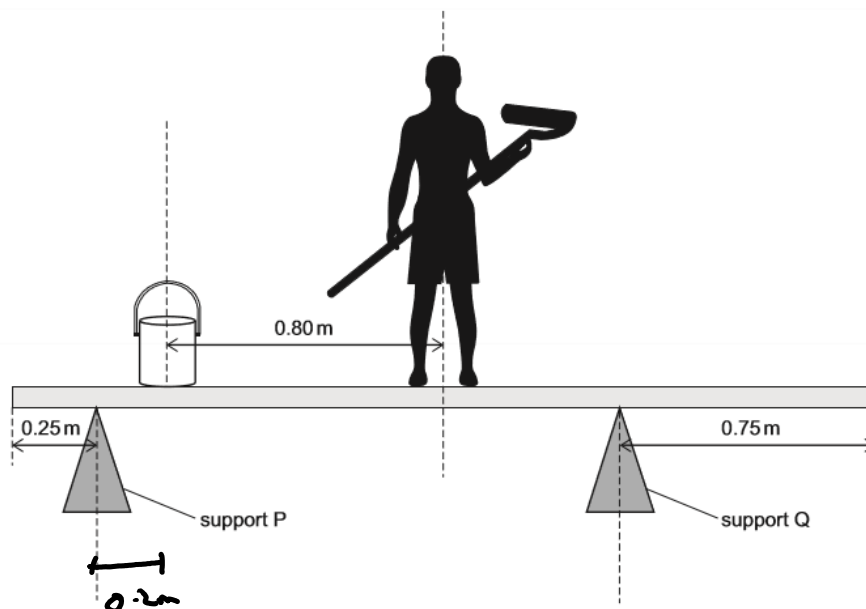
(Assume that resistive forces are negligible.)

$$3 = 0.06(v - -30)$$

$$50 - 30 = v = \underline{\underline{20}}$$

- ☒ A  $20 \text{ m s}^{-1}$
- ☐ B  $28 \text{ m s}^{-1}$
- ☐ C  $32 \text{ m s}^{-1}$
- ☐ D  $50 \text{ m s}^{-1}$
- ☐ E  $70 \text{ m s}^{-1}$
- ☐ F  $80 \text{ m s}^{-1}$
- ☐ G  $100 \text{ m s}^{-1}$
- ☐ H  $130 \text{ m s}^{-1}$

- 8 A painter of mass 74 kg stands on a uniform wooden plank of length 2.5 m and of mass 24 kg. The painter stands at the middle of the plank. The plank rests on two supports. Support P is 0.25 m from one end of the plank and support Q is 0.75 m from the other end. A pot of paint of mass 5.0 kg is 0.80 m from the centre of mass of the painter.



What is the force exerted by support Q on the plank?

(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

- A 50 N
- B 51.5 N
- C 66 N
- D 177 N
- E 500 N
- F 515 N
- ☒ G 660 N
- H 1770 N

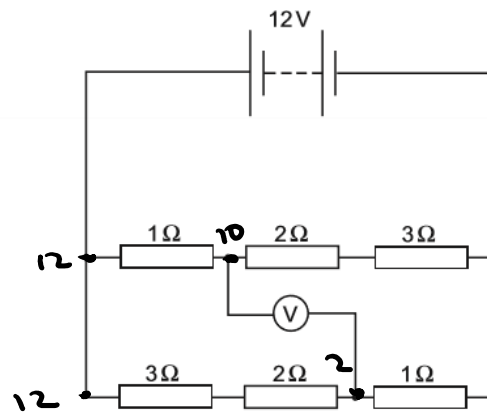
$\uparrow P:$

$$50(0.2) + 740(1) + 240(1) = R_Q(1.5)$$

$$990 = 1.5 R_Q$$

$$R_Q = \underline{\underline{660 \text{ N}}}$$

- 9 The circuit shown in the diagram contains six resistors and an ideal digital voltmeter.

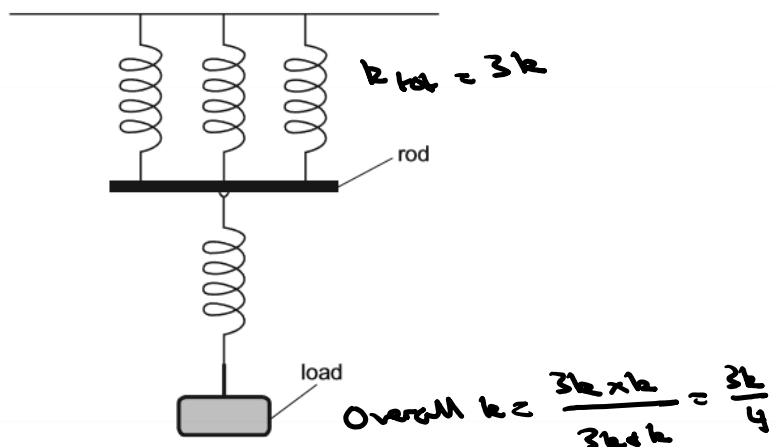


What is the reading on the voltmeter?

- A 0V
- B 2V
- C 4V
- D 6V
- ☒ E 8V
- F 10V
- G 12V

$$10 - 2 = 8V$$

- 10 Four identical light springs are connected together using a light rod. A load of mass  $m$  is suspended from the system so that the rod is horizontal, as shown in the diagram.



The spring constant of each spring is  $k$  and all four springs obey Hooke's law throughout.

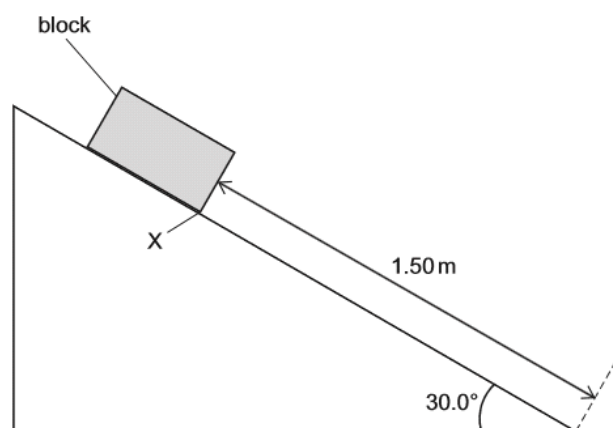
Which of the following expressions gives the elastic potential energy stored in the system?

(gravitational field strength =  $g$ )

$$EPE = \frac{F^2}{2k} = \frac{(mg)^2}{2k/2} = \frac{2(mg)^2}{3k}$$

- A  $\frac{(mg)^2}{6k}$   
 B  $\frac{(mg)^2}{2k}$   
 C  $\frac{5(mg)^2}{9k}$   
 D  $\frac{2(mg)^2}{3k}$   
 E  $\frac{(mg)^2}{k}$   
 F  $\frac{2(mg)^2}{k}$

- 11 A block of mass 3.60 kg is held stationary on a rough slope inclined at  $30.0^\circ$  to the horizontal. The edge X of the block is 1.50 m from the bottom of the slope.



The block is released and it accelerates uniformly down the slope. When X reaches the bottom of the slope, the speed of the block is  $2.00 \text{ m s}^{-1}$ .

What is the average rate at which work is done against resistive forces?

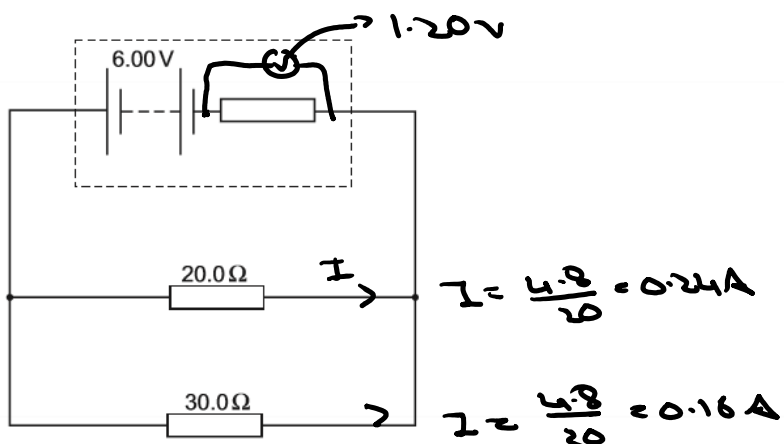
(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

- A 4.8 W
- B 13.2 W**
- C 15.6 W
- D 18.0 W
- E 26.4 W

$$\begin{aligned}
 \Delta GPE &= 3.6(10)(1.5 \sin 30) \\
 &= 36 \times 0.75 = 27 \text{ J} \\
 \Delta KE &= \frac{1}{2}(3.6)(4) = 7.2 \text{ J} \\
 27 - 7.2 &= 19.8 \\
 s &= \left(\frac{u+v}{2}\right)t \quad \therefore t = \frac{2(1.5)}{0+2} = 1.5 \\
 \frac{19.8}{1.5} &=
 \end{aligned}$$

- 12 A circuit contains a battery with internal resistance and two resistors, connected as shown in the diagram.

The emf of the battery is 6.00 V. The pd across the 20.0  $\Omega$  resistor is 4.80 V.



What is the internal resistance of the battery?

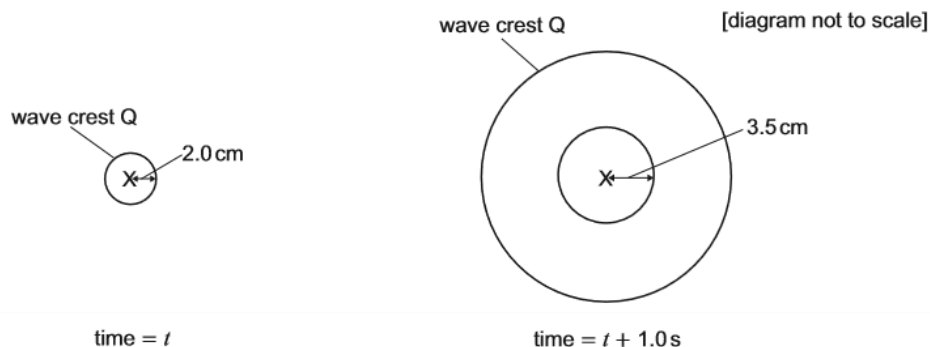
- A 0.0800  $\Omega$
- B 0.333  $\Omega$
- C 0.480  $\Omega$
- ☒ D 3.00  $\Omega$
- E 12.0  $\Omega$
- F 12.5  $\Omega$
- G 15.0  $\Omega$

$$r = \frac{1.2}{0.24 + 0.16} = 3 \Omega$$

- 13 A stick at position X dips into water every 0.80 s, creating a circular wave which travels at a constant speed.

The diagrams show the wave crests at a time  $t$  and 1.0 s later. One of the wave crests, labelled Q, appears in both diagrams.

In each diagram, the distance from X to a wave crest is labelled.



What is the wavelength of the wave?

- A 1.2 cm
- B 1.5 cm
- C 2.0 cm
- D 3.5 cm
- E 4.4 cm
- ☒ F 6.0 cm
- G 7.5 cm
- H 14 cm

$$\text{Speed} = v$$

$$vt = 2, \text{ where } t = \text{time since Q was created}$$

$$\text{2nd wave created at } t = 0.8 \text{ s}$$

$$v(t + 1 - 0.8) = 3.5$$

$$vt + 0.2v = 3.5$$

$$0.2v = 1.5 \therefore v = 7.5$$

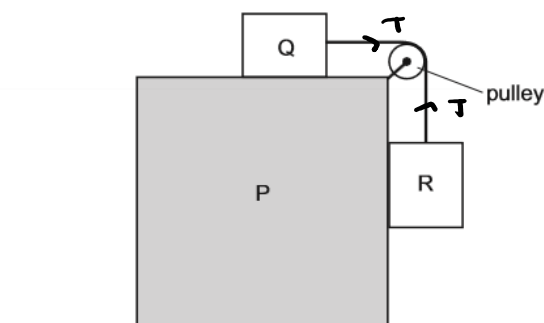
$$7.5 = \frac{\lambda}{T} = \frac{\lambda}{0.8}$$

$$\lambda = 7.5 \times \frac{4}{5} = \underline{\underline{6 \text{ cm}}}$$



- 14 A block P has a smaller block Q resting on its top surface.

Q is connected to a hanging block, R, by a light, inextensible string. The string passes over a smooth pulley which is connected to block P, as shown in the diagram.



The masses of blocks P, Q and R are  $m_P$ ,  $m_Q$  and  $m_R$  respectively.

The surfaces of the three blocks are smooth.

P is accelerated horizontally to the right by an external force. While this is happening, Q and R do not move relative to P.

What is the acceleration of P?

(gravitational field strength =  $g$ )

$$R: T = m_R g$$

$$Q: T = m_Q a$$

$$a = a_P \text{ (0 rel. movement)}$$

$$\therefore m_R g = m_Q a_P$$

$$a_P = \frac{m_R g}{m_Q}$$

A  $\frac{m_Q g}{m_R}$

**B**  $\frac{m_R g}{m_Q}$

C  $\frac{m_R g}{m_R + m_Q}$

D  $\frac{m_Q g}{(m_P + m_Q + m_R)}$

E  $\frac{m_R g}{(m_P + m_Q + m_R)}$

F  $\frac{(m_Q + m_R) g}{(m_P + m_Q + m_R)}$

- 15 A solid cube with a total surface area of  $96 \text{ cm}^2$  is suspended from a spring of spring constant  $2.0 \times 10^4 \text{ Nm}^{-1}$  and causes the spring to extend by  $1.6 \times 10^{-4} \text{ m}$ .

The cube is removed from the spring and placed on a horizontal surface where it rests with one face on the surface.

What is the pressure exerted by the cube on the surface and what is the density of the material from which the cube is made?

(gravitational field strength =  $10 \text{ N kg}^{-1}$ )

$$F = 2 \times 10^4 \times 1.6 \times 10^{-4} = 3.2 \text{ N}$$

	pressure / $\text{Nm}^{-2}$	density / $\text{kg m}^{-3}$
A	$2.0 \times 10^1$	$5.0 \times 10^{-2}$
B	$2.0 \times 10^1$	$5.0 \times 10^4$
C	$3.3 \times 10^2$	$5.0 \times 10^{-2}$
D	$3.3 \times 10^2$	$5.0 \times 10^3$
E	$3.3 \times 10^2$	$5.0 \times 10^4$
F	$2.0 \times 10^3$	$5.0 \times 10^{-2}$
G	$2.0 \times 10^3$	$5.0 \times 10^3$
H	$2.0 \times 10^3$	$5.0 \times 10^4$

Pressure

$$= \frac{3.2 \text{ N}}{16 \text{ cm}^2}$$

1 face area

$$= \frac{3.2}{16 \times 10^{-4}}$$

$$= \frac{3200}{1.6}$$

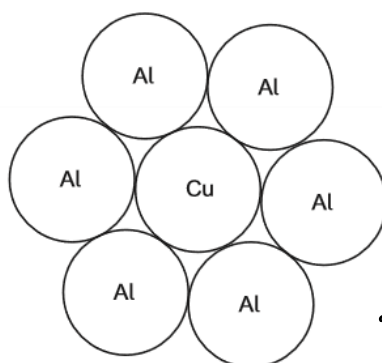
$$= 2 \times 10^3$$

$$6x^2 = 96 \therefore x = \text{side length} = 4 \text{ cm}$$

$$\text{Volume} = 64 \text{ cm}^3 //$$

$$\rho = \frac{0.32 \text{ kg}}{64 \times 10^{-6} \text{ m}^3} = 5000 \text{ kg/m}^3$$

- 16 A power cable consists of a cylindrical copper (Cu) wire surrounded by six cylindrical aluminium (Al) wires. All the wires are of the same cross-sectional area as shown:



$$\begin{aligned}
 M &= AL(3d) \\
 &+ AL(d)(6) \\
 &= 9ALd \\
 \therefore A &= \frac{M}{9Ld}
 \end{aligned}$$

The table gives the densities and resistivities of aluminium and copper.

material	density	resistivity
aluminium	$d$	$3\rho$
copper	$3d$	$2\rho$

The cable has mass  $M$  and length  $L$ .

Which expression gives the resistance between the two ends of the cable?

A  $\frac{18\rho dL^2}{5M}$

B  $\frac{21\rho dL^2}{M}$

C  $\frac{81\rho dL^2}{5M}$

D  $\frac{180\rho dL^2}{M}$

E  $\frac{12\rho dL^2}{5M}$

F  $\frac{28\rho dL^2}{3M}$

G  $\frac{36\rho dL^2}{5M}$

H  $\frac{80\rho dL^2}{M}$

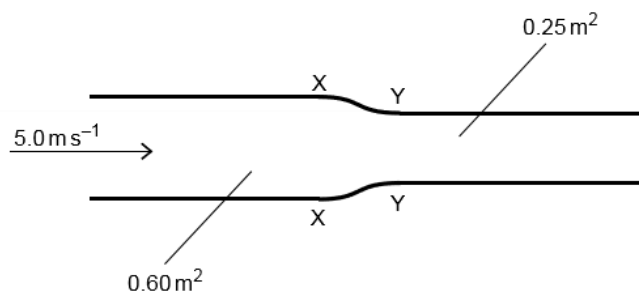
$$R_{Cu} = \frac{2\rho L}{\frac{M}{9Ld}} = \frac{18\rho L^2 d}{M}$$

$$R_{Al} = \frac{3\rho L}{\frac{M}{9Ld}} = \frac{27\rho L^2 d}{M}$$

$$R_{Al \text{ parallel}} = \frac{27\rho L^2 d}{6M} = \frac{9\rho L^2 d}{2M}$$

$$R_{tot} = \frac{18 \times \frac{9}{2}}{18 + \frac{9}{2}} = \frac{81}{45/2} = \frac{162}{45} = \frac{18}{5}$$

- 17 Oil of density  $800 \text{ kg m}^{-3}$  is pumped through a pipe of circular cross-sectional area  $0.60 \text{ m}^2$  at a speed of  $5.0 \text{ m s}^{-1}$ . Between X and Y, the cross-sectional area of the pipe decreases to  $0.25 \text{ m}^2$ .



What is the resultant force exerted on the oil as it passes from X to Y?

- A 0 N
- B 7000 N
- C 12000 N
- D 16800 N**
- E 19000 N
- F 24000 N
- G 40800 N
- H 143000 N

$$\text{Continuity} \rightarrow 5(0.6) = v_y(0.25)$$

$$v_y = \frac{5}{0.25} \times 0.6 = 12 \text{ ms}^{-1}$$

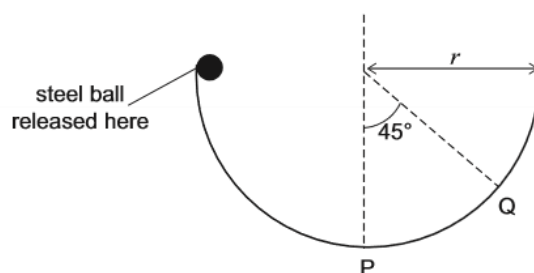
$$F_{\text{res}} = \frac{d(mv)}{dt} = m v - m v$$

$$\dot{m} = \rho A v = 800 \times 0.6 \times 5 = 2400$$

$$F_{\text{res}} = 2400(12 - 5)$$

$$= \underline{\underline{16800 \text{ N}}}$$

- 18 A small steel ball of mass  $m$  is released from the top of a semi-circular ramp of radius  $r$  as shown in the diagram:



[diagram not to scale]

After being released, the ball moves around the semi-circle to the lowest point at position P and then rises to a maximum height on the other side at position Q before falling down again.

Assume that the friction force acting on the ball has a constant magnitude whilst the ball is moving.

What is the kinetic energy of the ball as it first passes position P?

(gravitational field strength =  $g$ )

- A  $mgr(\sqrt{2} - 1)$
- B  $mgr\left(1 - \frac{\sqrt{2}}{3}\right)$**
- C  $mgr\left(1 - \frac{\sqrt{2}}{4}\right)$
- D  $\frac{2mgr}{3}$
- E  $\frac{3mgr}{4}$
- F  $mgr\left(\frac{1+\sqrt{2}}{3}\right)$
- G  $mgr$
- H  $mgr\left(2 - \frac{\sqrt{2}}{2}\right)$

$$mgr = W_{\text{fric}} + mg\left(r - \frac{r\sqrt{2}}{2}\right)$$

$$W_{\text{fric}} = mgr - mgr + \frac{mgr\sqrt{2}}{2}$$

$$\therefore \text{At P, } W_{\text{fric}} = \frac{2}{3} \times W_{\text{fricQ}} = \frac{mgr\sqrt{2}}{3}$$

$$mgr = \frac{mgr\sqrt{2}}{3} + \frac{1}{2}mv^2$$

$$\therefore \frac{1}{2}mv^2 = mgr\left(1 - \frac{\sqrt{2}}{3}\right) //$$

END OF TEST