A LEVEL PHYSICS

WORKED SOLUTIONS

4.1. Force, Energy and Momentum MCQ

1. An electron has speed v. The electron's kinetic energy is doubled.

What is the new speed of the electron?

A $\dfrac{v}{\sqrt{2}}$ ○

B $\sqrt{2}v$ ●

C $2v$ ○

D $4v$ ○

$E_k = \frac{1}{2}mv^2 \qquad v = \sqrt{\dfrac{2E_k}{m}} \qquad v \propto \sqrt{E_k}$

$V_2 = V\sqrt{\dfrac{2E}{E}} = \sqrt{2}V$

(Total 1 mark)

2. An object of mass m is accelerated from rest to a velocity v by a constant resultant force F.

What is the work done on the object during this acceleration?

A $\dfrac{Fv}{2}$ ○

B Fv ○

C mv^2 ○

D $\dfrac{mv^2}{2}$ ●

Work done = energy transferred

$= E_K$

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

(Total 1 mark)

3. What is true for an inelastic collision between two isolated objects?

A Both total momentum and total kinetic energy are conserved. ○

B Neither total momentum nor total kinetic energy is conserved. ○

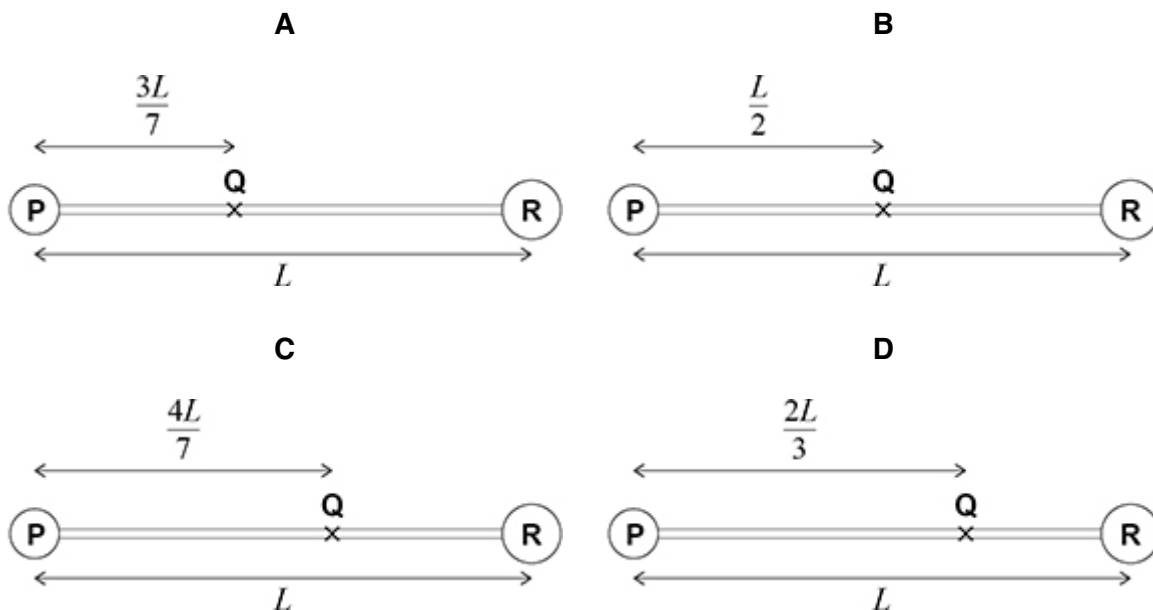C Only total kinetic energy is conserved. ○

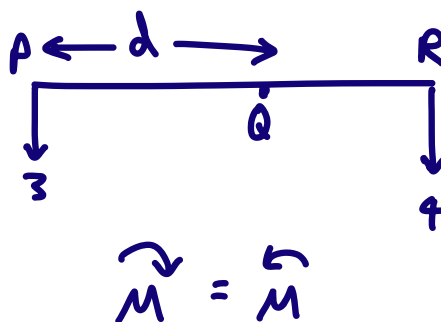D Only total momentum is conserved. ●

(Total 1 mark)

p conserved, E_K not conserved in an inelastic collision

4. P and R are uniform spheres of mass 3 kg and 4 kg respectively.
P and R are joined by a rod of negligible mass.
The distance between their centres is L.
The centre of mass of this system is at **Q**.

Which diagram shows the position of the centre of mass?

A

$$\frac{3L}{7}$$

P ═══ Q ═══ R

L

B

$$\frac{L}{2}$$

P ═══ Q ═══ R

L

C

$$\frac{4L}{7}$$

P ═══ Q ═══ R

L

D

$$\frac{2L}{3}$$

P ═══ Q ═══ R

L

A   ⬭

B   ⬭

<u>C</u>   ⬤

D   ⬭

(Total 1 mark)

P ←— d —→ R

Q

3   4

$$\widetilde{M} = \overline{M}$$

M about Q $3 \times d = 4 \times (L - d)$
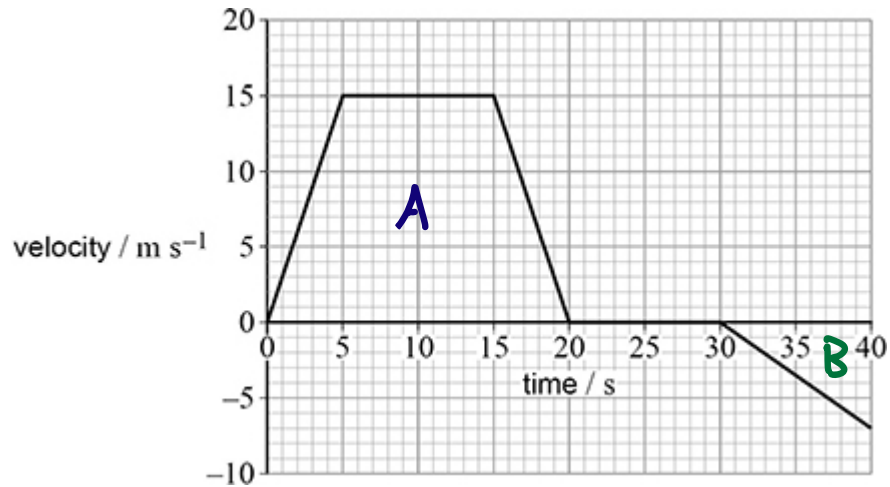
$3d = 4L - 4d$

$7d = 4L$

$$d = \frac{4L}{7}$$

5. A vehicle travels on a straight road, starting at time $t = 0$
The graph shows how its velocity varies with time.

What is the distance of the vehicle from its start position when $t = 40$ s?

Distance = A − B

$$= \left(\frac{10+20}{2}\right) \times 15 - \frac{1}{2} \times 10 \times 7$$

$$= 225 - 35 = 190m$$

A   115 m   ○

B   190 m   ●

C   260 m   ○
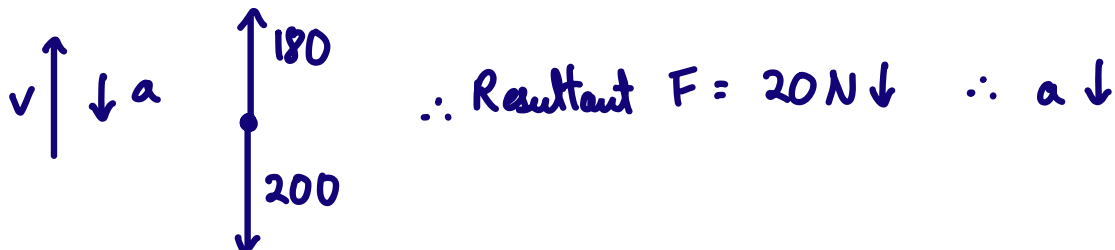
D   370 m   ○

(Total 1 mark)

6. A suitcase weighing 200 N is placed on a weighing scale in a lift.
The scale reads 180 N when the lift is moving.

The lift is

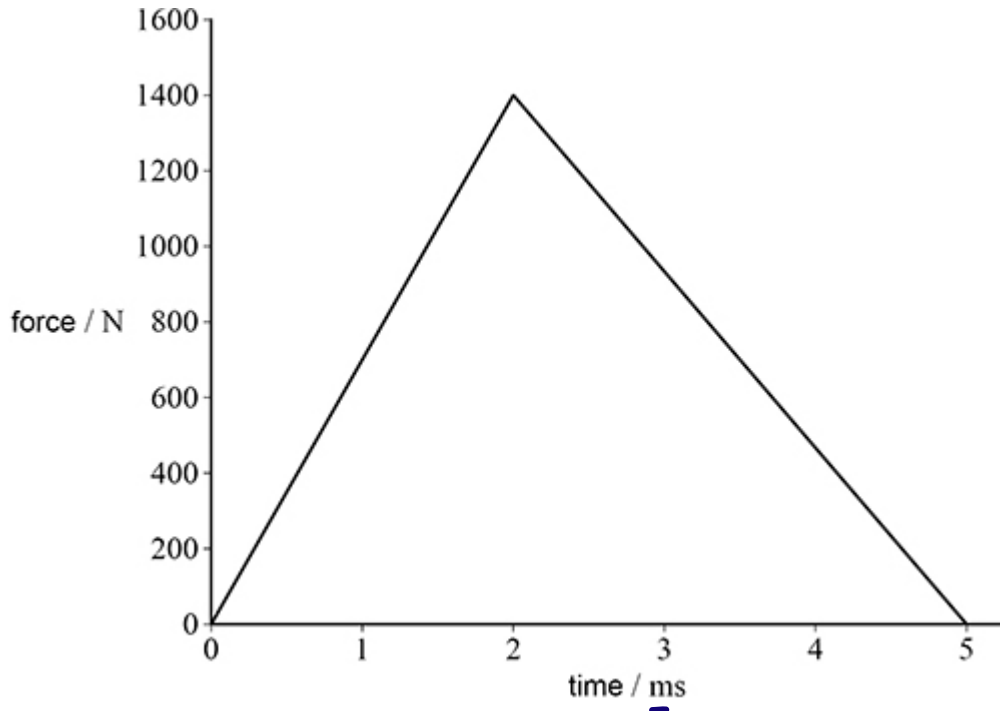A   moving down at a constant velocity.   200 N   ○

B   moving down with a decreasing velocity.   >200 N   ○

C   moving up at a constant velocity.   200 N   ○

D   moving up with a decreasing velocity.   ●

(Total 1 mark)

$v \uparrow \quad \downarrow a$ $\uparrow 180$ ∴ Resultant F = 20N↓   ∴ a↓

$\downarrow 200$

7. A stationary ball is free to move. The ball is hit with a bat.

The graph shows how the force of the bat on the ball changes with time.

The ball has a mass of 0.044 kg.

What is the speed of the ball immediately after being hit?

A   13 m s⁻¹   ⬭

B   60 m s⁻¹   ⬭

C   80 m s⁻¹   ⬤

D   160 m s⁻¹   ⬭

$F\Delta t = m\Delta v$

$\Delta v = \dfrac{F\Delta t}{m} = \dfrac{area}{m}$

$\Delta v = \dfrac{\frac{1}{2} \times 5.0 \times 10^{-3} \times 1400}{0.044}$

$= 79.5$

(Total 1 mark)

8. The question below is about three spheres **X**, **Y** and **Z**.

The relative mass and relative diameter of each sphere are given in the table.

	X	Y	Z
relative mass	1	5	1
relative diameter	1	1	5

Initial acceleration independent of mass

Each sphere is dropped from rest and accelerates to its terminal speed.

What is true about the accelerations of the spheres at the instant they are released?

A   The acceleration of **X** is less than that of **Y**.   ○

B   The acceleration of **X** is greater than that of **Z**.   ○

C   The acceleration of **X** is the same as that of **Y**.   ●

D   The acceleration of **Y** is less than that of **Z**.   ○

(Total 1 mark)

9. The question below is about three spheres **X**, **Y** and **Z**.

The relative mass and relative diameter of each sphere are given in the table.

	X	Y	Z
relative mass	1	5	1
relative diameter	1	1	5

*Terminal speed is inversely proportional to surface area ∴ diameter*

Each sphere is dropped from rest and accelerates to its terminal speed.

What is true about the terminal speeds?

A   The terminal speed of **X** is greater than that of **Y**.   ○

B   The terminal speed of **X** is the same as that of **Y**.   ○

C   The terminal speed of **Y** is greater than that of **Z**.   ●

D   The terminal speed of **X** is less than that of **Z**.   ○

(Total 1 mark)

10. The diagram shows a vector diagram of two forces acting on an object.
The diagram is drawn to scale.
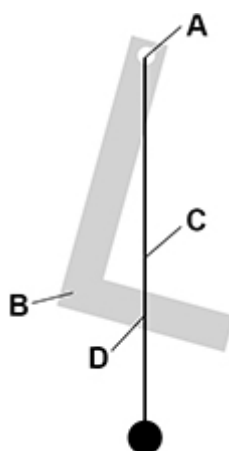The magnitude of the smaller force is 5.0 N.

Measure this to work out your own scale
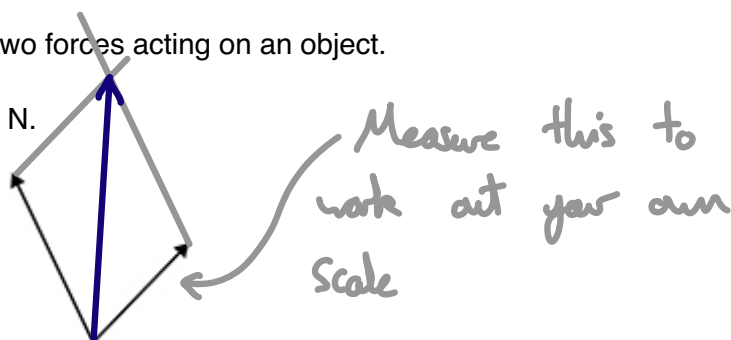
What is the magnitude of the resultant force on the object?

A   3.2 N

B   7.5 N

C   8.6 N

D   9.6 N

(Total 1 mark)

11. A uniform piece of card in the shape of the letter L is suspended freely from a horizontal pin.
A plumb line is also suspended from the pin.
The diagram shows the card in its equilibrium position.

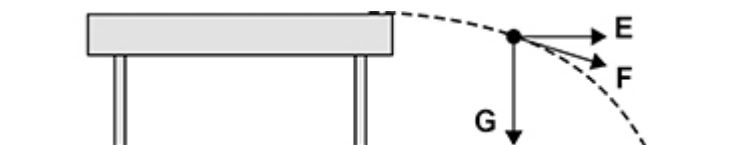What is the position of the centre of mass of the piece of card?

A

B

C

D

It must lie somewhere on the line, but position D is too low

(Total 1 mark)

12. A coin is projected horizontally from the top of a desk.

The diagram shows the coin at one point in its path. The air resistance is negligible.

The arrows **E**, **F** and **G** represent different directions.

Which row gives the direction of the acceleration and the direction of the momentum of the coin at this point?
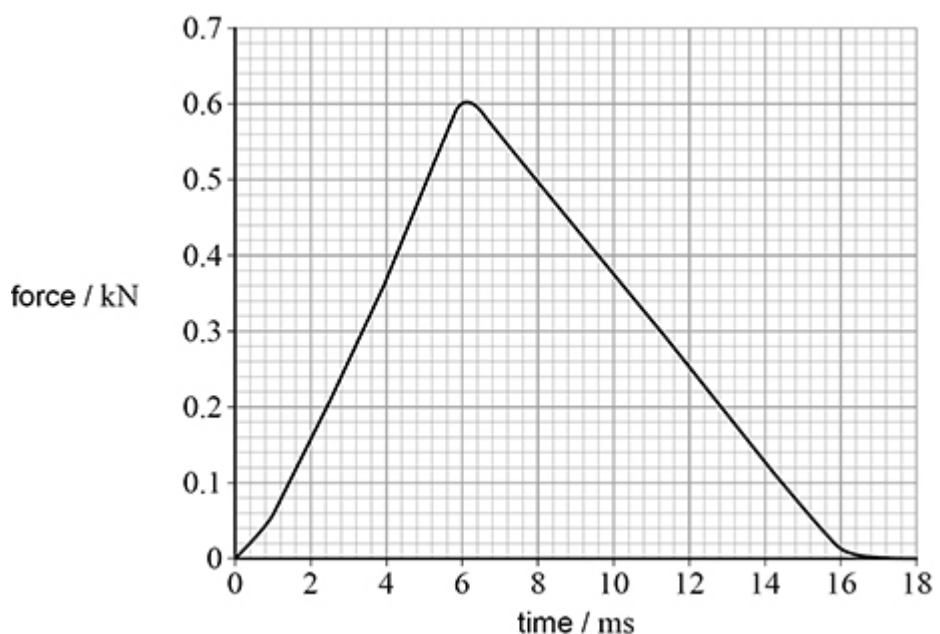
	Acceleration	Momentum	
A	F	F	○
B	F	E	○
C	G	F	●
D	G	E	○

Acceleration due to gravity is straight down ∴ G

Momentum in direction of motion ∴ F

(Total 1 mark)

13. A golf ball has a mass of 46 g and is initially stationary.
The diagram shows the variation with time of the force acting on the golf ball as it is hit with a golf club.

What is an estimate of the kinetic energy of the golf ball immediately after it is hit?

A 5 J ○

B 50 J ○

C 250 J ●

D 500 J ○

$$E_K = \frac{p^2}{2m} = \frac{(F\Delta t)^2}{2m} = \frac{area^2}{2m}$$

$$E_K = \frac{(½ \times 16 \times 10^{-3} \times 0.6 \times 10^3)^2}{2 \times 0.046}$$

$$E_K = 250\,J$$

(Total 1 mark)

14. A Formula 1 racing car uses up its fuel during the race, causing its lap times to decrease.

The lap times decrease because

A   the acceleration of the car increases. ●

B   the drag forces on the car decrease. ○

C   the maximum speed of the car increases. ○

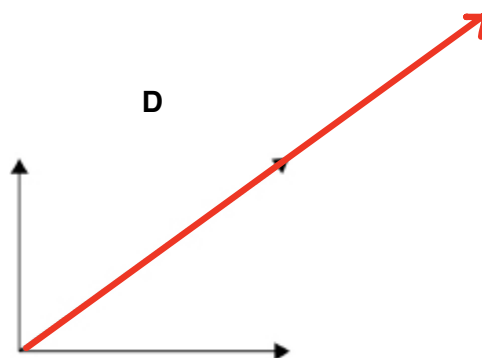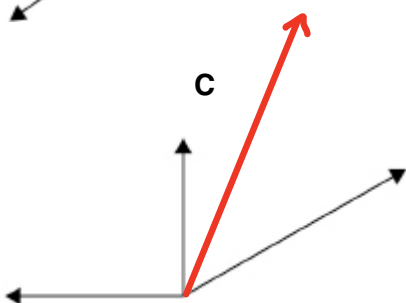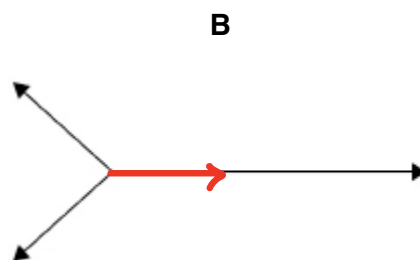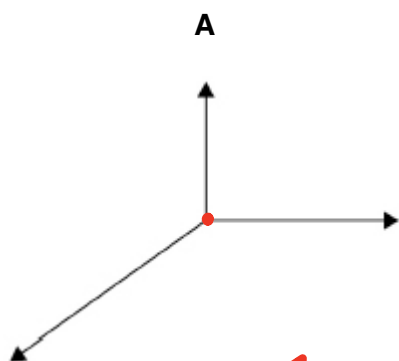**D**   the tyres become worn, reducing the friction with the road. ○

(Total 1 mark)

$$a = \frac{F}{m} \qquad m\downarrow \therefore a\uparrow$$

15. An object is in equilibrium when acted on by three coplanar forces.

Which free-body diagram is correct?

Each diagram is drawn to scale.

A

B

C

D

A ⎯

B

C

D

(Total 1 mark)

16. Which quantity is represented by the area under a force–time graph?

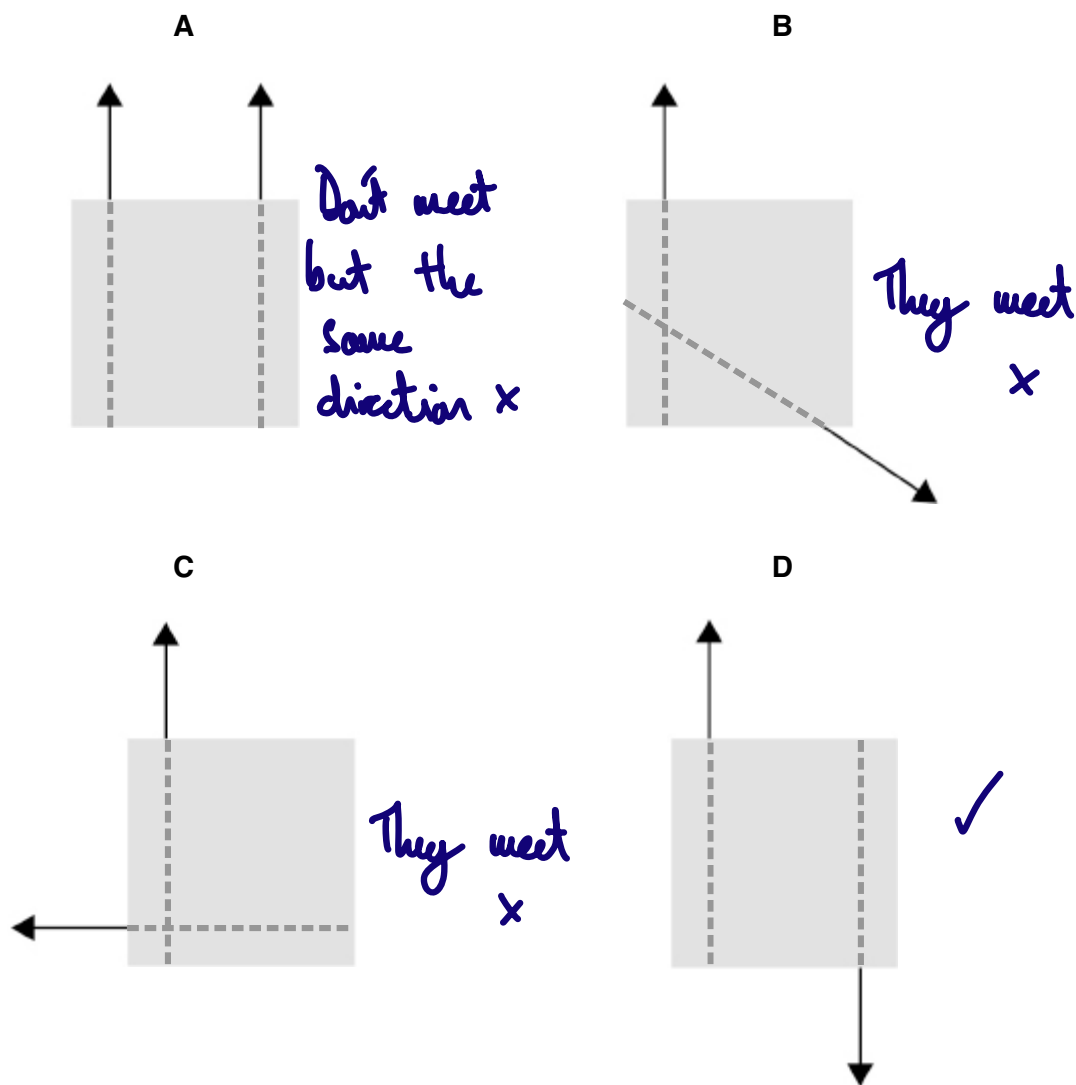A average power

B elastic strain energy stored

C momentum change

D work done

(Total 1 mark)

17. Each diagram shows two horizontal forces acting on a solid square object seen from above.

All the forces have the same magnitude.

A

B

Don't meet but the same direction ✗

They meet ✗

C

D

They meet ✗

✓

Which system produces a couple about any point inside the object?
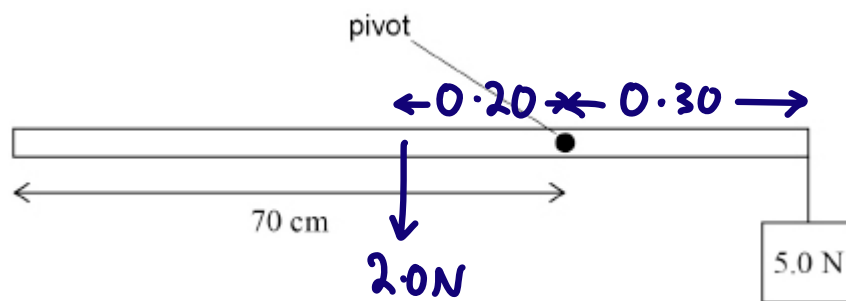
A ⬭

B ⬭

C ⬭

D ⬬

The line of action of the forces don't meet and are in opposite directions

(Total 1 mark)

18. A uniform metre ruler of weight 2.0 N is freely pivoted at the 70 cm mark.

A student holds the ruler in a horizontal position and suspends a 5.0 N weight from the 100 cm end.

What is the magnitude of the resultant moment when the student releases the ruler?

A   0.15 N m   ○

B   0.19 N m   ○

C   1.1 N m   ●

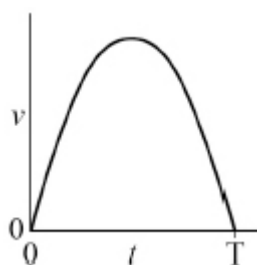D   1.9 N m   ○

$$M = \overset{\frown}{M} - \overset{\frown}{M}$$

$$= (2.0 \times 0.20) - (5.0 \times 0.30)$$
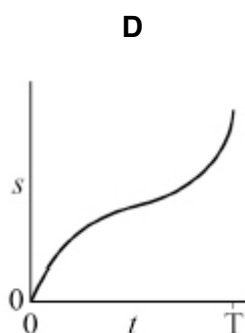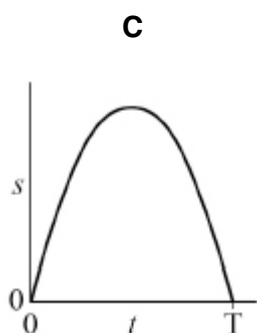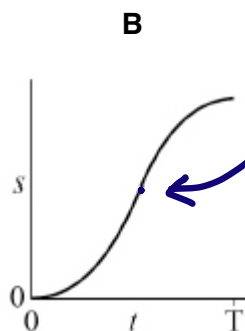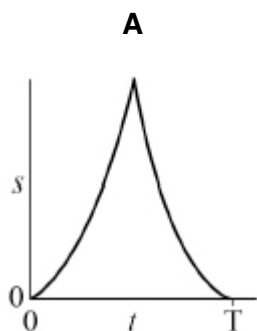
$$= 0.4 - 1.5 = -1.1 \ Nm$$

(Total 1 mark)

19.   The diagram shows how the speed v of an object varies with time t.

Which graph shows the variation of distance s with t for the object?

A

B

steep gradient
∴ V_{max}

C

D

A   ○

B   ●
—

C   ○

D   ○

s always increases

object accelerates then decelerates

(Total 1 mark)

20. Two ball bearings **X** and **Y** are projected from horizontal ground at the same time.

X has mass $2m$ and is projected vertically upwards with speed u.

Y has mass m and is projected at 30° to the horizontal with speed $2u$.

Air resistance is negligible. $\sin 30° = \frac{1}{2}$ $\therefore$ vertically $2u \sin 30 = u$

Which statement is correct? $\therefore$ both balls
                                                                 have the same
A   **X** and **Y** have the same initial momentum.   ○   vertical component
                                                                      of velocity
B   **X** and **Y** reach their maximum heights at different times.   ○   throughout

C   The maximum height reached by **Y** is half that reached by **X**.   ○

D   **X** and **Y** reach the ground at the same time.   ●

(Total 1 mark)

21. Which row is true for an elastic collision between two objects in an isolated system?

	Kinetic energy	Momentum
A	conserved	conserved
B	not conserved	conserved
C	conserved	not conserved
D	not conserved	not conserved

A ● $p + E_k$ conserved

B ○

C ○

D ○

(Total 1 mark)

22. The drag force on a boat is kv^2, where v is the speed and $k = 64$ kg m⁻¹.

The boat's engine has a useful power output of 8000 W.

What is the maximum speed of the boat? $P = Fv$

A   0.2 m s⁻¹   ○

B   5 m s⁻¹   ● $v = \dfrac{P}{F} = \dfrac{8000}{64 \times v^2}$

C   11 m s⁻¹   ○

D   125 m s⁻¹   ○ $v^3 = \dfrac{8000}{64} = 125$

                              $v = 5$ **(Total 1 mark)**

23. A railway truck of mass 2000 kg travelling horizontally at 1.5 m s⁻¹ collides with a stationary truck of mass 3000 kg.

After the collision they move together. → *Inelastic collision* ∴ E_k *not conserved*

Which row is correct? $P_{before} = P_{after}$ $2000 \times 1.5 = 5000 \times v$

$$v = 0.60 \text{ m s}^{-1}$$

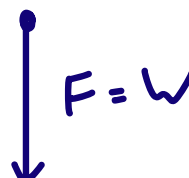|	Speed of the trucks immediately after collision / m s⁻¹	Effect of collision on total kinetic energy	
A	0.6	~~no change~~	○
B	0.6	decrease	●
C	~~1.0~~	~~no change~~	○
D	~~1.0~~	decrease	○

(Total 1 mark)

24. A body of constant mass falls freely due to gravity.

The rate of change of momentum of the body is equal to its

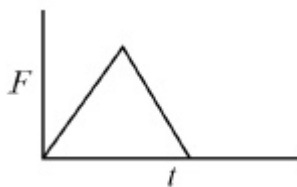A   kinetic energy.   ○

B   mass.   ○

C   gravitational potential energy.   ○

D   weight.   ●

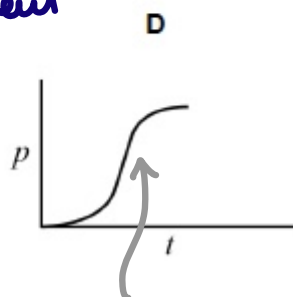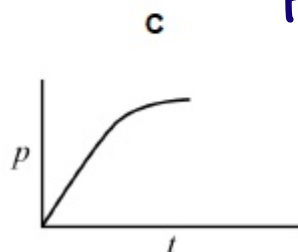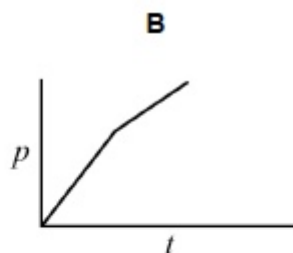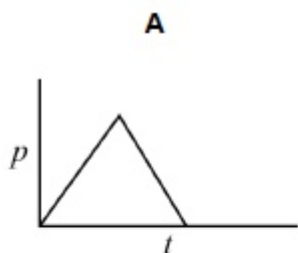$$F = \frac{m \Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$$

$F = W$

(Total 1 mark)

25. The graph shows how the resultant force F on a football, which is initially at rest, varies with time t.

F always positive
F increases to a maximum
then decreases

Which graph shows how the momentum p of the football varies with time t?

A

B

$F = \dfrac{\Delta p}{\Delta t} =$ gradient

C

D

gradient always positive
+
gradient increases to a
maximum then decreases

A ⭘

B ⭘

C ⭘

D ⬤

(Total 1 mark)

26. Objects **P** and **Q** are initially at rest at time $t = 0$

The same resultant force F is applied to **P** and **Q** for time T.

The mass of **P** is 10 times greater than the mass of **Q**.

What is the ratio $\dfrac{\text{kinetic energy of } \textbf{P}}{\text{kinetic energy of } \textbf{Q}}$?
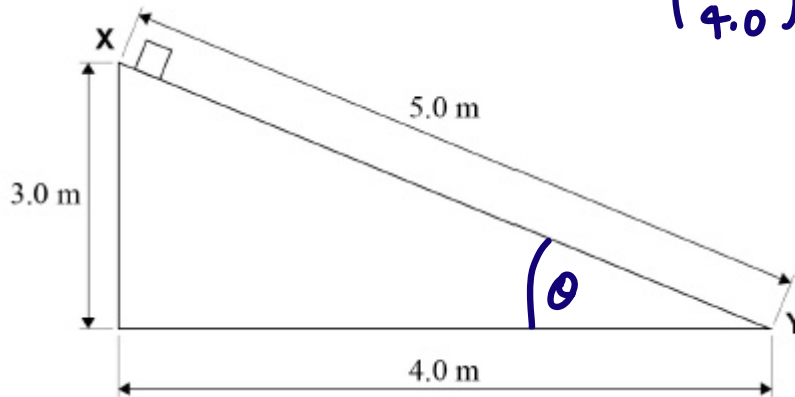
$F\Delta t = m\Delta v$

$\dfrac{m_Q}{m_P} = \dfrac{\Delta v_P}{\Delta v_Q} = \dfrac{1}{10}$

A   0.1   ●

$\dfrac{E_{kP}}{E_{kQ}} = \dfrac{m_P}{m_Q} \cdot \left(\dfrac{v_P}{v_Q}\right)^2 = \dfrac{10}{1} \times \left(\dfrac{1}{10}\right)^2$

B   1   ○

C   10   ○

D   100   ○

$= \dfrac{1}{10} = 0.1$

(Total 1 mark)

27. A mass of 2.5 kg is released from rest at **X** and slides down a ramp, of height 3.0 m, to point **Y** as shown.

$\theta = \tan^{-1}\left(\dfrac{3.0}{4.0}\right) = 36.9°$

X

5.0 m

3.0 m

θ

Y

4.0 m

When the mass reaches **Y** at the bottom of the ramp it has a velocity of 5.0 m s⁻¹.

What is the average frictional force between the mass and the ramp?

$F_{Resultant} = ma$

A   8.5 N   ●

B   10.6 N   ○

$2.5 \times 9.81 \times \sin 36.9° - F_F = 2.5 \times 2.5$

C   14.7 N   ○

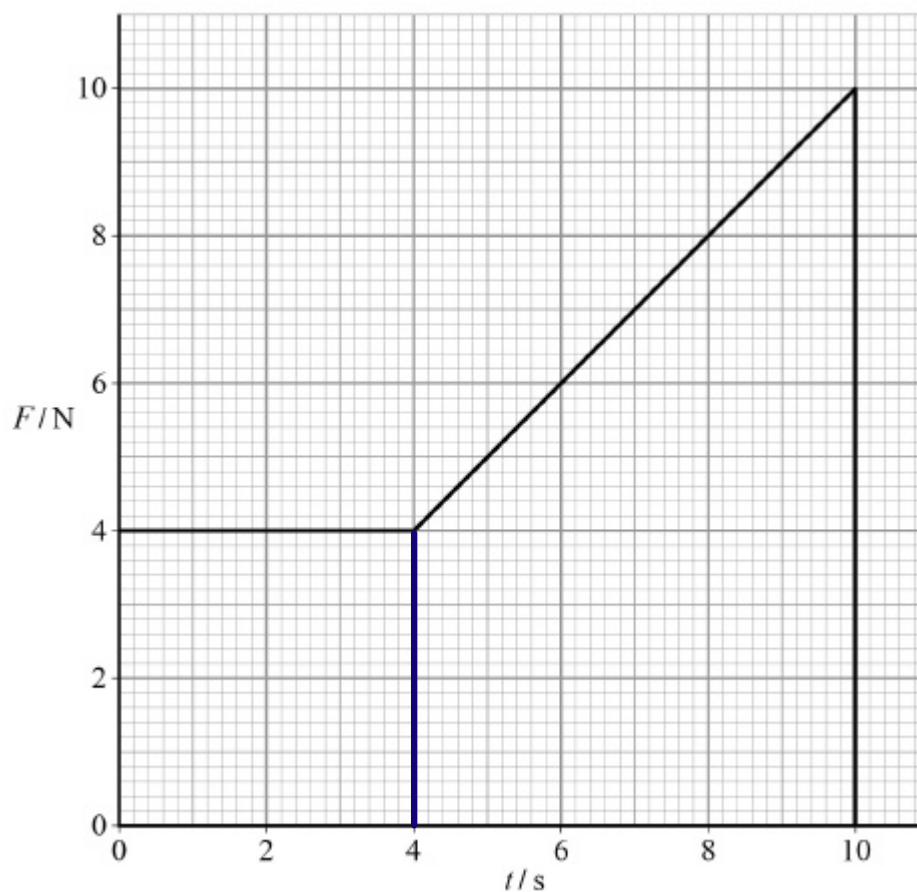$F_F = 14.7 - 6.25 = 8.48 N$

D   24.5 N   ○

$s = 5.0 \quad u = 0 \quad v = 5.0 \quad a = ? \quad t$

(Total 1 mark)

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

$a = \dfrac{v^2 - u^2}{2s} = \dfrac{5.0^2}{2 \times 5.0} = 2.5 \, m s^{-2}$

28. The graph shows how the force F applied to an object varies with time t.

What is the momentum gained by the object from $t = 0$ to $t = 10$ s?

A   18 kg m s^{-1} ☐

B   32 kg m s^{-1} ☐

C   40 kg m s^{-1} ☐

D   58 kg m s^{-1} ⬤

$\Delta p = F\Delta t = $ area

$\Delta p = (4 \times 4) + \left(\left(\dfrac{4 + 10}{2}\right) \times 6\right)$

$\Delta p = 16 + 42 = 58$

(Total 1 mark)

29. Two identical balls, **X** and **Y**, are at the same height and a horizontal distance of 25 cm apart.

X is projected horizontally with a velocity of 0.10 m s⁻¹ towards **Y** at the same time that **Y** is released from rest. Both **X** and **Y** move freely in the absence of air resistance.

What is the distance between the balls 1.0 s later?

A 0.15 m

B 0.25 m

C 2.4 m

D 4.9 m

Horizontally $s = vt = 0.10 \times 1.0 = 0.10m$

$0.25 - 0.10 = 0.15m$

Vertically Both fall at the same rate

(Total 1 mark)

30. Two bodies of different masses undergo an elastic collision in the absence of any external force.

Which row gives the effect on the total kinetic energy of the masses and the magnitudes of the forces exerted on the masses during the collision?

	Total kinetic energy	Magnitudes of forces	
A	remains unchanged	same on both masses	
B	remains unchanged	greater on the smaller mass	
C	decreases	same on both masses	
D	decreases	greater on the smaller mass	

(Total 1 mark)

Elastic ∴ E_K conserved

Newton's 3rd Law, F equal is size, opposite in direction

31. The diagram shows a uniform metre ruler of weight 1.5 N pivoted 15 cm from one end for use as a simple balance.

object of unknown weight   2.5 N weight

←35cm→

↓1.5

pan

ruler

15 cm   60 cm
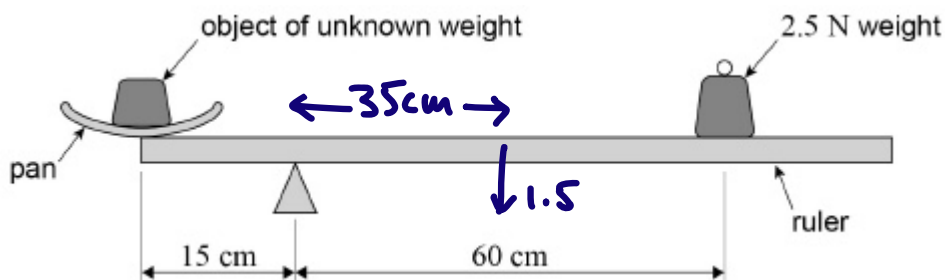
A scale pan of weight 0.5 N is placed at the end of the ruler and an object of unknown weight is placed in the pan. The ruler moves to a steady horizontal position when a weight of 2.5 N is added at a distance of 60 cm from the pivot as shown.

What is the weight of the object?

$$\stackrel{\curvearrowleft}{M} = \stackrel{\curvearrowright}{M}$$

$$(0.5 + w) \times 0.15 = (1.5 \times 0.35)$$
$$+ (2.5 \times 0.60)$$

A 9.5 N

B 10.0 N

C 13.0 N

$$w = \frac{2.025 - 0.075}{0.15}$$

D 13.5 N

$$w = 13.0 \text{ N}$$

(Total 1 mark)

32. A non-uniform sign is 0.80 m long and has a weight of 18 N
It is suspended from two vertical springs **P** and **Q**. The springs obey Hooke's law and the spring constant of each spring is 240 N m^{-1}

P   Q

centre
of mass

0.65 m   0.15 m

18 N
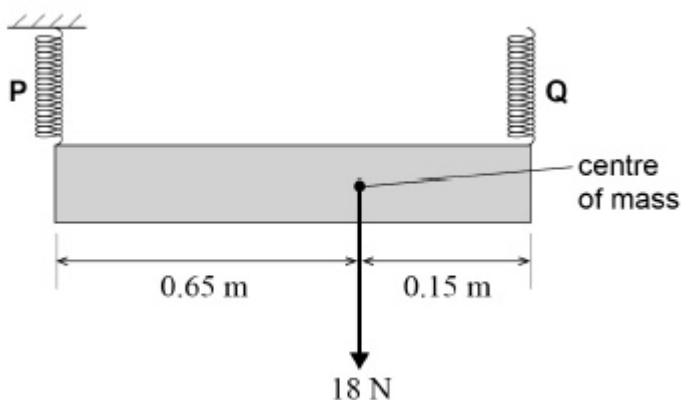
The top end of spring **P** is fixed and the top end of spring **Q** is adjusted until the sign is horizontal and in equilibrium.

About P $\stackrel{\curvearrowright}{M} = \stackrel{\curvearrowleft}{M}$

$$18 \times 0.65 = F \times 0.80 \qquad F = 14.625 \text{ N}$$

What is the extension of spring **Q**?

A 0.014 m ○

B 0.038 m ○

C 0.049 m ○

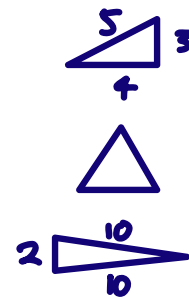**D** 0.061 m ●

$F = ke$

$e = \dfrac{F}{k} = \dfrac{14.625}{240} = 0.0609 \text{ m}$

(Total 1 mark)

33. Three coplanar forces F_1, F_2 and F_3 act on a point object.

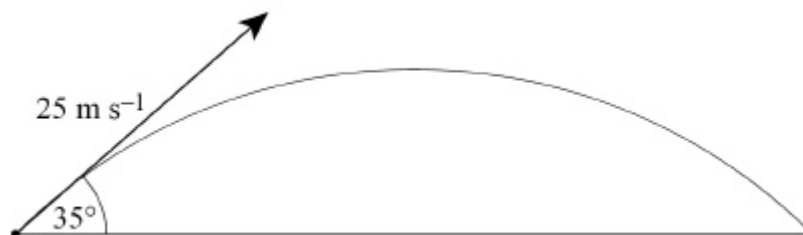Which combination of forces can never produce a resultant force of zero?

	F_1 / N	F_2 / N	F_3 / N	
A	3	4	5	○
B	8	8	8	○
C	2	10	10	○
D	3	6	10	●

$3 + 6 = 9$ $9 < 10$ So can never balance the 10N force

(Total 1 mark)

34. A projectile is launched with a speed of 25 m s⁻¹ at an angle of 35° to the horizontal, as shown in the diagram.

25 m s⁻¹

35°

Air resistance is negligible.

↑ s

$u = 25 \sin 35 = 14.3$

$v = 0$

$a = -9.81$

$t = ?$ (to max height)

$t = \dfrac{v-u}{a} = \dfrac{0 - 14.3}{-9.81} = 1.46\,s$

What is the time taken for the projectile to return to the ground?
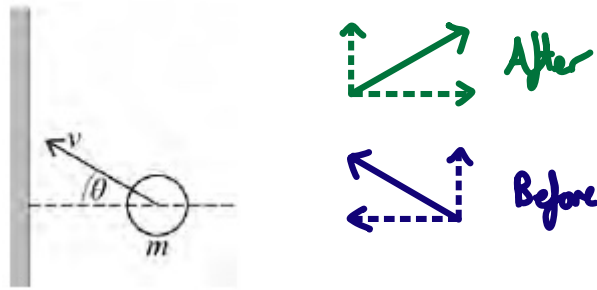
A   1.5 s   ⬭

B   2.1 s   ⬭

C   2.9 s   ⬤

D   4.2 s   ⬭
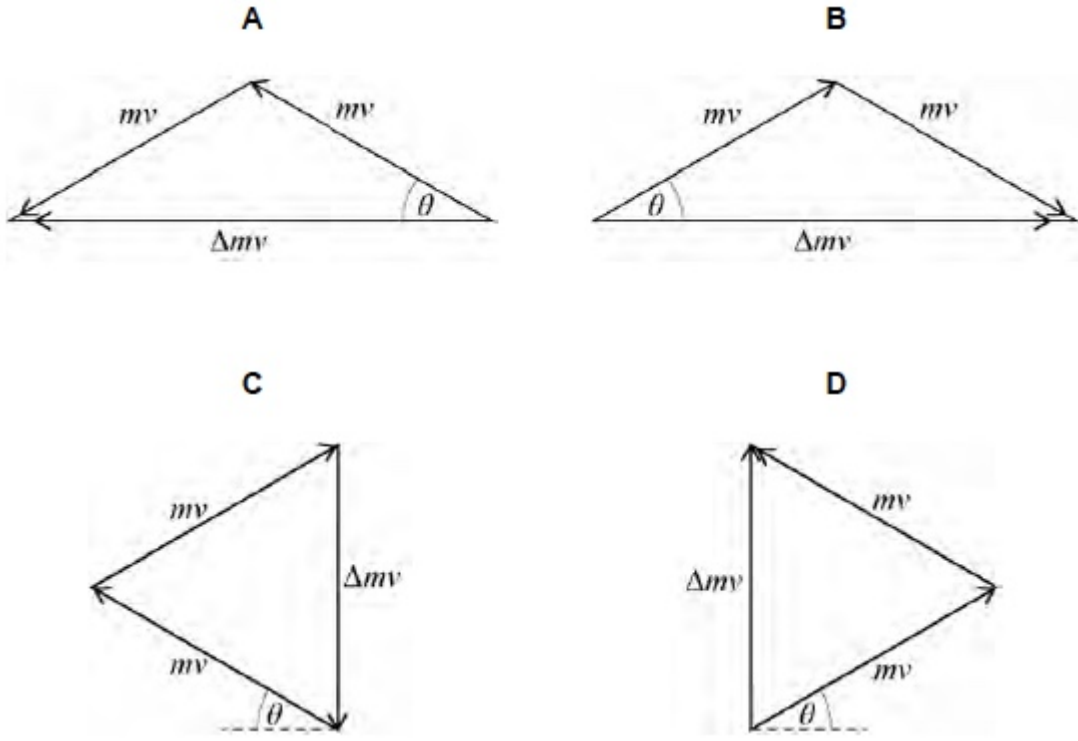
Total $t = 2 \times 1.46 = 2.92$ s

(Total 1 mark)

35. The diagram shows a gas particle about to collide elastically with a wall.

Which diagram shows the correct change in momentum Δ*mv* that occurs during the collision?

A

B

C

D

A ○

B ●

C ○

D ○

Vertically no change in momentum

Δmv horizontally to the right

(Total 1 mark)