Projectile *[86 marks]*

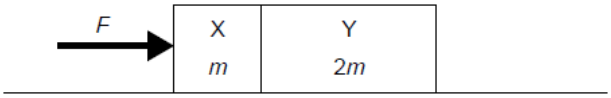
1. An object is released from rest in the gravitational field of the Earth. Air resistance is negligible. How far does the object move during the fourth second of its motion? *[1 mark]*

A. 15 m
B. 25 m
C. 35 m
D. 45 m

Markscheme

C

2. Two boxes in contact are pushed along a floor with a force *F*. The boxes move at a constant speed. Box X has a mass *m* and box Y has a mass 2*m*. *[1 mark]*



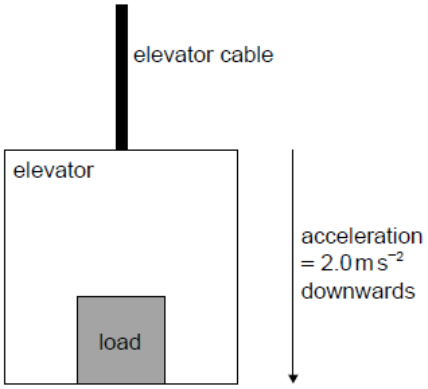
What is the resultant force acting on Y?

A. 0
B. $\frac{F}{2}$
C. *F*
D. 2*F*

Markscheme

A

3. An elevator (lift) and its load have a total mass of 750 kg and accelerate vertically downwards at 2.0 m s^{-2}. *[1 mark]*



What is the tension in the elevator cable?

A. 1.5 kN
B. 6.0 kN
C. 7.5 kN
D. 9.0 kN

Markscheme

B

4. A ball is tossed vertically upwards with a speed of 5.0 m s^{-1}. After how many seconds will the ball return to its initial position? *[1 mark]*

A. 0.50 s

B. 1.0 s

C. 1.5 s

D. 2.0 s

Markscheme

B

5. A net force acts on a body. Which characteristic of the body will definitely change? *[1 mark]*

A. Speed

B. Momentum

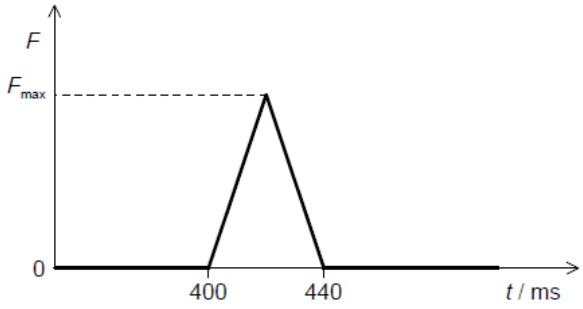
C. Kinetic energy

D. Direction of motion

Markscheme

B

6. A ball of mass 0.2 kg strikes a force sensor and sticks to it. Just before impact the ball is travelling horizontally at a speed of 4.0 m s^{-1}. The graph shows the variation with time t of the force F recorded by the sensor. *[1 mark]*



What is F_{max}?

A. 2 N

B. 4 N

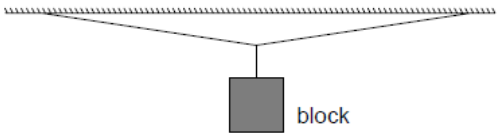
C. 20 N

D. 40 N

Markscheme

D

7. A block of weight *W* is suspended by two strings of equal length. The strings are almost horizontal. *[1 mark]*



What is correct about the tension *T* in one string?

A. $T < \frac{W}{2}$

B. $T = \frac{W}{2}$

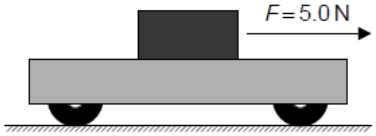
C. $\frac{W}{2} < T \leqslant W$

D. $T > W$

Markscheme

D

8. A block of mass 1.0 kg rests on a trolley of mass 4.0 kg. The coefficient of dynamic friction between the block and the trolley is 0.30. *[1 mark]*



A horizontal force *F* = 5.0 N acts on the block. The block slides over the trolley. What is the acceleration of the trolley?

A. 5.0 m s^{-2}

B. 1.0 m s^{-2}

C. 0.75 m s^{-2}

D. 0.60 m s^{-2}

Markscheme

C

9a. The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

Markscheme

correct use of kinematic equation/equations

148.5 ***or*** 149 ***or*** 150 «m»

Substitution(s) must be correct.

9b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. *[3 marks]* Determine the average tension in the cable as the glider accelerates.

Markscheme

$a = \frac{27}{11}$ ***or*** 2.45 «m s^{-2}»

$F - 160 = 492 \times 2.45$

1370 «N»

Could be seen in part (a).
*Award **[0]** for solution that uses $a = 9.81$ m s^{-2}*

9c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

Markscheme

ALTERNATIVE 1

«work done to launch glider» = 1370 x 149 «= 204 kJ»

«work done by motor» $= \frac{204 \times 100}{23}$

«power input to motor» $= \frac{204 \times 100}{23} \times \frac{1}{11} = 80$ ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 2

use of average speed 13.5 m s^{-1}

«useful power output» = force x average speed «= 1370 x 13.5»

power input = «$1370 \times 13.5 \times \frac{100}{23}$ =» 80 ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 3

work required from motor = KE + work done against friction «$= 0.5 \times 492 \times 27^2 + (160 \times 148.5)$» = 204 «kJ»

«energy input» $= \frac{\text{work required from motor} \times 100}{23}$

power input $= \frac{883000}{11} = 80.3$ k«W»

*Award **[2 max]** for an answer of 160 k«W».*

9d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. *[2 marks]*

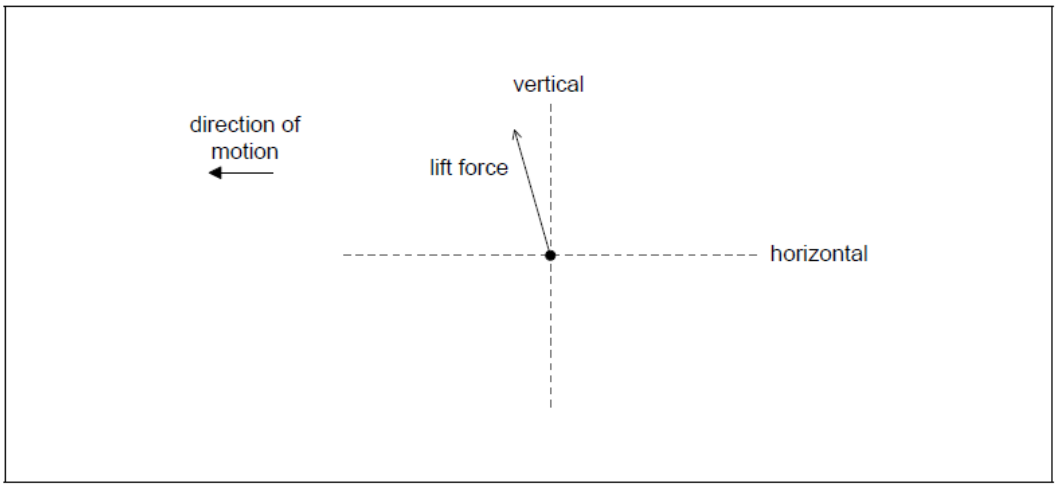
Markscheme

$\omega = \text{«}\frac{v}{r}\text{=»} \frac{27}{0.6} = 45$

rad s^{-1}

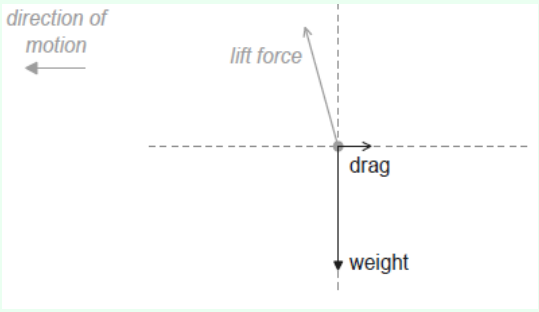
Do not accept Hz.
*Award **[1 max]** if unit is missing.*

9e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

Markscheme



drag correctly labelled and in correct direction

weight correctly labelled and in correct direction ***AND*** no other incorrect force shown

*Award **[1 max]** if forces do not touch the dot, but are otherwise OK.*

9f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

Markscheme

name Newton's first law

vertical/all forces are in equilibrium/balanced/add to zero
OR
vertical component of lift mentioned

as equal to weight

9g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

Markscheme

any speed and any direction quoted together as the answer

quotes their answer(s) to 3 significant figures

speed = 12.7 m s^{-1} ***or*** direction = 9.46° ***or*** 0.165 rad «below the horizontal» ***or*** gradient of $-\frac{1}{6}$

10. Two objects m_1 and m_2 approach each other along a straight line with speeds v_1 and v_2 as shown. The objects collide and stick together. *[1 mark]*

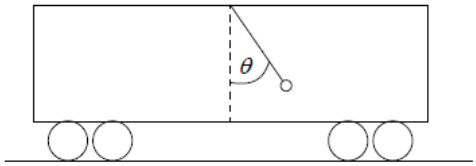
What is the total change of linear momentum of the objects as a result of the collision?

A. $m_1v_1 + m_2v_2$
B. $m_1v_1 - m_2v_2$
C. $m_2v_2 - m_1v_1$
D. zero

Markscheme

D

11. A mass is suspended from the ceiling of a train carriage by a string. The string makes an angle θ with the vertical when the train is accelerating along a straight horizontal track. *[4 marks]*



What is the acceleration of the train?

A. $g \sin \theta$

B. $g \cos \theta$

C. $g \tan \theta$

D. $\frac{g}{\tan\theta}$

Markscheme

C

12a. Determine the coefficient of dynamic friction between the stone and the ice during the last 14.0 s of the stone's motion. *[3 marks]*

Markscheme

ALTERNATIVE 1

«deceleration» $= \frac{3.41}{14.0}$ «$= 0.243\,\mathrm{m\,s^{-2}}$»

F = 0.243 × *m*

$\mu = \frac{0.243 \times m}{m \times 9.81} = 0.025$

ALTERNATIVE 2

distance travelled after release = 23.85 «m»
KE lost = 5.81*m* «J»

$\mu_{\mathrm{d}} = \frac{\text{KE lost}}{mg \times \text{distance}} = \frac{5.81m}{23.85mg} = 0.025$

*Award **[3]** for a bald correct answer.*

Ignore sign in acceleration.

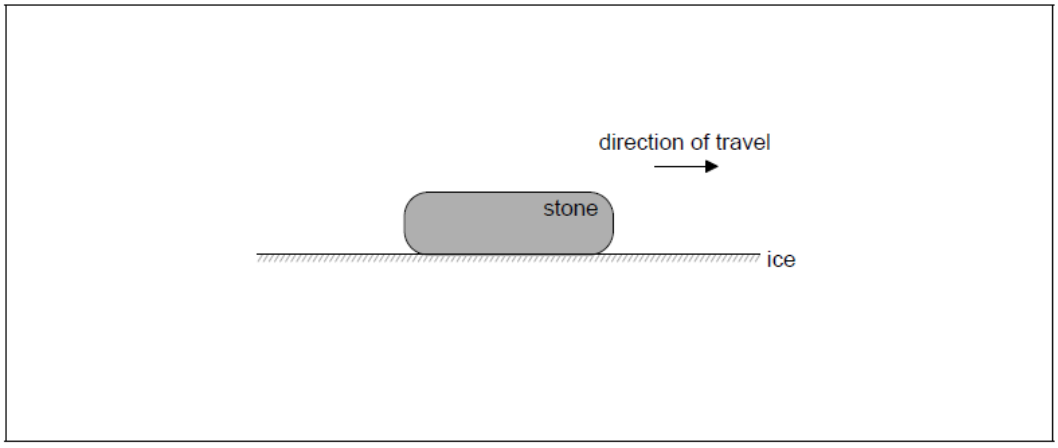
Allow ECF from (a) (note that
$\mu = 0.0073$ *x candidate answer to (a)).*

Ignore any units in answer.

Condone omission of m in solution.

Allow g = 10 N kg^{-1} (gives 0.024).

12b. The diagram shows the stone during its motion **after** release. *[3 marks]*



Label the diagram to show the forces acting on the stone. Your answer should include the name, the direction **and** point of application of each force.

Markscheme

normal force, upwards, ignore point of application

Force must be labeled for its mark to be awarded. Blob at poa not required.
Allow OWTTE for normal force. Allow N, R, reaction.
The vertical forces must lie within the middle third of the stone

weight/weight force/force of gravity, downwards, ignore point of application

Allow mg, W but not "gravity".

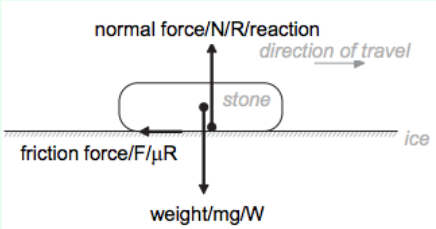
Penalise gross deviations from vertical/horizontal once only

friction/resistive force, to left, at bottom of stone, point of application must be **on** the interface between ice and stone

Allow F, μR. Only allow arrows/lines that lie on the interface. Take the tail of the arrow as the definitive point of application and expect line to be drawn horizontal.

*Award **[2 max]** if any force arrow does not touch the stone*

Do not award MP3 if a "driving force" is shown acting to the right. This need not be labelled to disqualify the mark. Treat arrows labelled "air resistance" as neutral.



***N.B:** Diagram in MS is drawn with the vertical forces not direction of travel collinear for clarity*

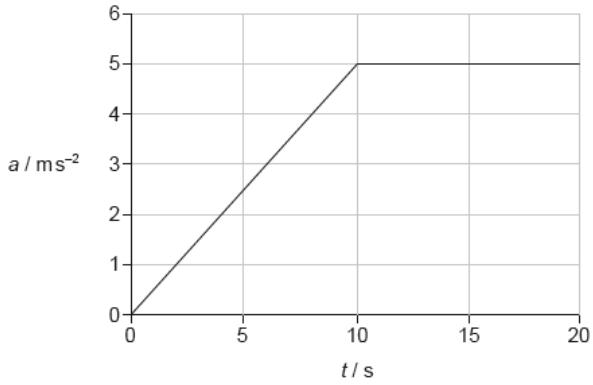
13. An object of mass m rests on a horizontal plane. The angle θ that the plane makes with the horizontal is slowly increased from zero. *[1 mark]*
When $\theta=\theta_0$, the object begins to slide. What are the coefficient of static friction μ_s and the normal reaction force N of the plane at $\theta=\theta_0$?

	μ_s	N
A.	$\sin\theta_0$	$mg\cos\theta_0$
B.	$\tan\theta_0$	$mg\sin\theta_0$
C.	$\sin\theta_0$	$mg\sin\theta_0$
D.	$\tan\theta_0$	$mg\cos\theta_0$

Markscheme

D

14. An object is at rest at time $t = 0$. The variation with t of the acceleration a of the object is shown from $t = 0$ to $t = 20$ s. *[1 mark]*



What is the speed of the object when $t = 15$ s?

A. $25\ \text{m s}^{-1}$

B. $50\ \text{m s}^{-1}$

C. $75\ \text{m s}^{-1}$

D. $100\ \text{m s}^{-1}$

Markscheme

B

15. Which of the following is proportional to the net external force acting on a body? *[1 mark]*

A. Speed

B. Velocity

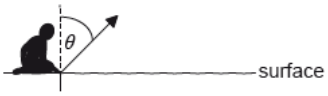
C. Rate of change of speed

D. Rate of change of velocity

Markscheme

D

16. A student throws a stone with velocity v at an angle θ to the vertical from the surface of a lake. Air resistance can be ignored. The acceleration due to gravity is g. *[1 mark]*



What is the time taken for the stone to hit the surface of the lake?

A. $\frac{v\sin\theta}{g}$

B. $\frac{v\cos\theta}{g}$

C. $\frac{2v\sin\theta}{g}$

D. $\frac{2v\cos\theta}{g}$

Markscheme

D

17a. Show that the time taken for B to pass I is approximately 28 s. *[4 marks]*

Markscheme

distances itemized; *(it must be clear through use of s_I or distance I etc)*

distances equated;

$t = \frac{2v}{a}$ / cancel and re-arrange;

substitution $\left(\frac{2\times 45}{3.2}\right)$ shown / 28.1(s) seen;

or

clear written statement that the average speed of B must be the same as constant speed of I;

as B starts from rest the final speed must be 2×45;

so $t = \frac{\Delta v}{a} = \frac{90}{3.2}$;

28.1 (s) seen; *(for this alternative the method must be clearly described)*

or

attempts to compare distance travelled by I and B for 28 s;

I distance $= (45 \times 28 =)\ 1260\ (\text{m})$;

B distance $= (\frac{1}{2} \times 3.2 \times 28^2 =)\ 1255\ (\text{m})$;

deduces that overtake must occur about $\left(\frac{5}{45} =\right)\ 0.1\ \text{s}$ later;

17b. Calculate the distance travelled by B in this time. *[2 marks]*

Markscheme

use of appropriate equation of motion;

$(1.26 \approx)$ 1.3 (km);

*Award **[2]** for a bald correct answer.*

17c. B slows down while I remains at a constant speed. The driver in each car wears a seat belt. Using Newton's laws of motion, explain the difference in the tension in the seat belts of the two cars. *[3 marks]*

Markscheme

driver I moves at constant speed so no net (extra) force according to Newton 1;

driver B decelerating so (extra) force (to rear of car) (according to Newton 1) / momentum/inertia change so (extra) force must be present;

(hence) greater tension in belt B than belt I;

*Award **[0]** for stating that tension is less in the decelerating car (B).*

17d. Calculate the speed of O immediately before the collision. *[2 marks]*

Markscheme

$930 \times v + 850 \times 45 = 1780 \times 52$ ***or*** statement that momentum is conserved;

$v = 58\ (\text{m}\,\text{s}^{-1})$;

*Allow **[2]** for a bald correct answer.*

17e. The duration of the collision is 0.45 s. Determine the average force acting on O. *[2 marks]*

Markscheme

use of force $\frac{\text{change of momentum}}{\text{time}}$ (or any variant, *eg*: $\frac{930 \times 6.4}{0.45}$);

$13.2 \times 10^3\ (\text{N});\}$ *(must see matched units and value ie: 13 200 without unit gains MP2, 13.2 does not)*

*Award **[2]** for a bald correct answer.*

Allow use of 58 m s^{-1} from (c)(i) to give 12 400 (N).

17f. An ammeter and a voltmeter are used to investigate the characteristics of a variable resistor of resistance R. State how the resistance of the ammeter and of the voltmeter compare to R so that the readings of the instruments are reliable. *[2 marks]*

Markscheme

ammeter must have very low resistance/much smaller than R;

voltmeter must have very large resistance/much larger than R;

*Allow **[1 max]** for zero and infinite resistance for ammeter and voltmeter respectively.*

*Allow **[1 max]** if superlative (eg: very/much/OWTTE) is missing.*

17g. Show that the current in the circuit is approximately 0.70 A when $R = 0.80\ \Omega$. *[3 marks]*

Markscheme

power (loss in resistor)
$= 0.36\ (\text{W});\}$ *(accept answers in the range of 0.35 to 0.37 (W) – treat value outside this range as ECF (could still lead to 0.7))*

$I^2 \times 0.80 = 0.36;$

$I = 0.67\ (\text{A})$ ***or*** $\sqrt{\left(\frac{0.36}{0.8}\right)};$ *(allow answers in the range of 0.66 to 0.68 (A).*

17h. Outline what is meant by the internal resistance of a cell. *[2 marks]*

Markscheme

resistance of the components/chemicals/materials within the cell itself;} *(not "resistance of cell")*

leading to energy/power loss in the cell;

17i. Determine the internal resistance of the cell. *[3 marks]*

Markscheme

power (in cell with 0.7 A) $= 0.58\ \text{W};\}$ *(allow answers in the range of 0.57 W to 0.62 W)*

$0.7^2 \times r = 0.58;$

$r = 1.2\ (\Omega);$ *(allow answers in the range of 1.18 to 1.27 (Ω))*

or

when powers are equal;

$I^2R = I^2r;$

so $r = R$ which occurs at 1.2(5) (Ω);

*Award **[1 max]** for bald 1.2(5) (Ω).*

17j. Calculate the electromotive force (emf) of the cell. *[2 marks]*

Markscheme

$(E = I(R + r)) = 0.7(0.8 + 1.2);$

1.4 (V);

Allow ECF from (e) or (f)(ii).

or

when $R = 0$, power loss $= 1.55;$

$E = (\sqrt{1.55 \times 1.2} =)\ 1.4\ (\text{V});$

18. Which statement applies to an object in translational equilibrium? *[1 mark]*

A. The object must be stationary.

B. The object must be moving with constant acceleration.

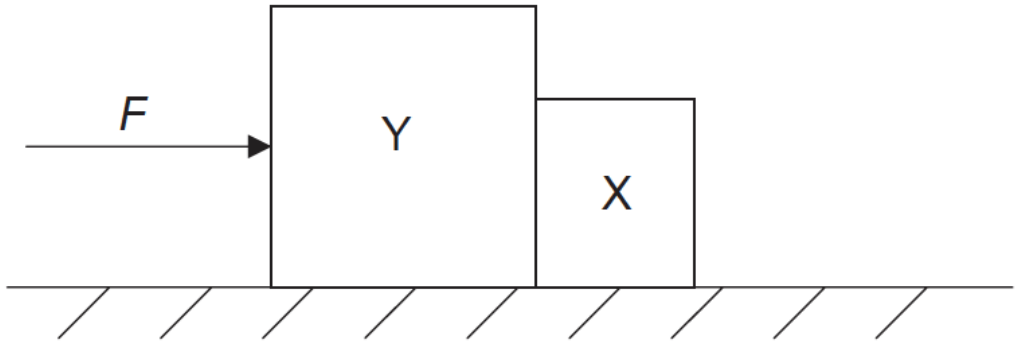
C. The resultant force acting on the object must be zero.

D. There must be no external forces acting on the object.

Markscheme

C

19. A constant horizontal force *F* is applied to a block Y. Block Y is in contact with a separate block X. *[1 mark]*



The blocks remain in contact as they accelerate along a horizontal frictionless surface. Y has a greater mass than X. Air resistance is negligible.

Which statement is correct?

A. The force *F* is equal to the product of the mass of Y and the acceleration of Y.

B. The force that Y exerts on X is less than *F*.

C. The force that Y exerts on X is less than the force that X exerts on Y.

D. The force that Y exerts on X is equal to *F*.

Markscheme

B

20. A body moves in a straight line. In order for the equations for uniformly accelerated motion to be applied, which condition **must** be true? *[1 mark]*

A. A constant net force acts on the body of fixed mass.

B. A constant net force acts on the body.

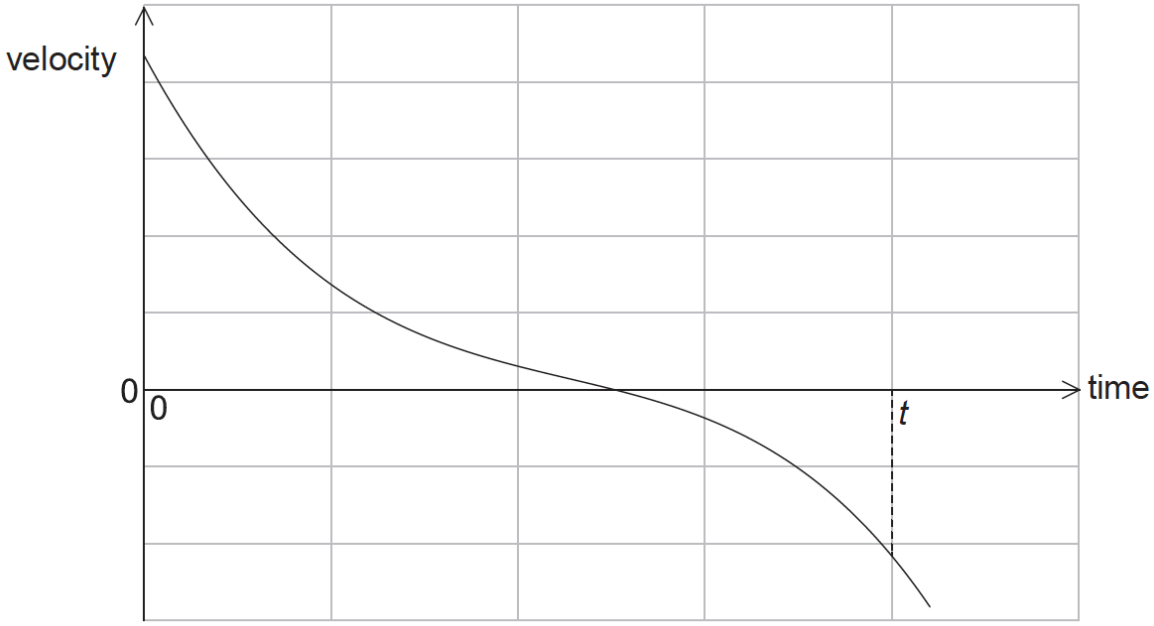
C. The body falls towards the surface of a planet.

D. The body has an initial velocity of zero.

Markscheme

A

21. The graph shows the variation with time of the velocity of a truck of fixed mass. *[1 mark]*



What can be deduced from the graph?

A. The truck is always accelerating.

B. The truck is always moving.

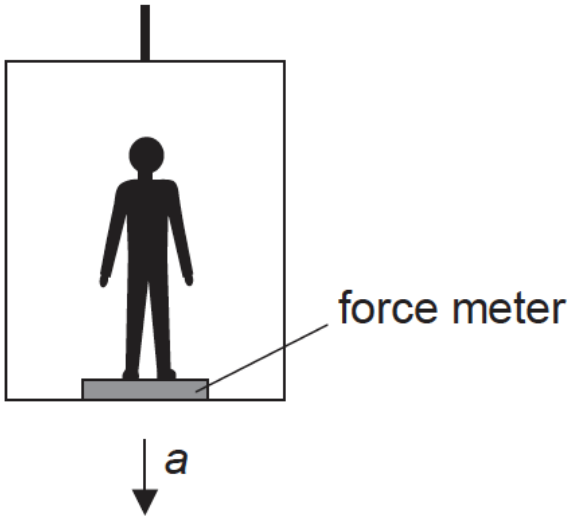
C. The truck is always moving in one direction.

D. The displacement of the truck after time *t* is zero.

Markscheme

A

22. A student of mass *m* is in an elevator which is accelerating downwards at an acceleration *a*. *[1 mark]*



What is the reading on the force meter?

A. *mg*

B. *mg* – *ma*

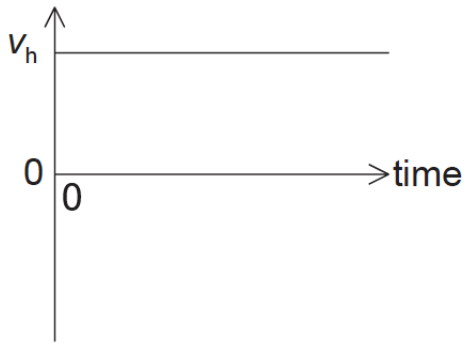
C. *mg* + *ma*

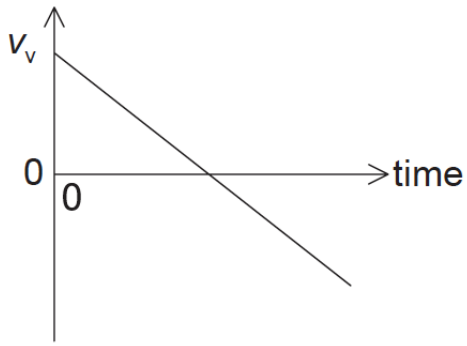
D. *ma* – *mg*

Markscheme

B

23. The horizontal component v_h and the vertical component v_v of velocity of an object are shown on the graphs. Air resistance is negligible. *[1 mark]*





These graphs could represent the motion of an object fired from a cliff

A. vertically upwards.

B. at an angle above the horizontal.

C. horizontally.

D. at an angle below the horizontal.

Markscheme

B

24a. Calculate the *[3 marks]*

(i) component of the weight of the cyclist and bicycle parallel to the slope.

(ii) normal reaction force on the bicycle from the slope.

Markscheme

(i) (weight) = 85 × 9.81(=834N); *(if 850 (N) seen, award this mark)*
component =(834×sin19=)271 (N);
Allow use of g=10ms^{-2}. Answer is 277 (N).

(ii) component=(834×cos19=) 788 (N);
Allow use of g=10ms $^{-2}$. Answer is 804 (N).
Allow a bald correct answer.
Do not award ECF if cos used in (a)(i) and sin used in (a)(ii).

24b. At the bottom of the slope the cyclist has a speed of 5.5ms^{-1}. The cyclist stops pedalling and applies the brakes which provide an additional decelerating force of 250 N. Determine the distance taken for the cyclist to stop. Assume air resistance is negligible and that there are no other frictional forces. *[4 marks]*

Markscheme

total decelerating force =271+250(=521N);
acceleration $= (-)\frac{521}{85}\left(= -6.13\text{ms}^{-2}\right)$;
$s = \frac{v^2-u^2}{2a}$;
2.47 (m);} *(signs must be consistent for this mark, ie: if acceleration assumed positive, look for negative distance)*
Allow use of g=10. Answers are 527 N, 6.2ms^{-2}, 2.44 m.

or

total decelerating force =271+250(=521N) ;
initial kinetic energy $= \frac{1}{2}mv^2 = 1290\text{J}$
$\text{distance} = \frac{\text{energylost}}{\text{force}} = \frac{1290}{521}$
2.47 (m);

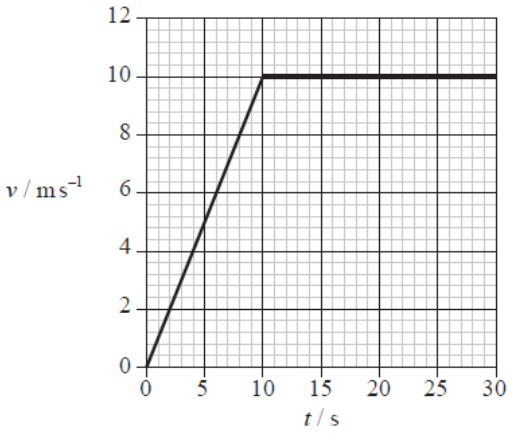
25. A skydiver of mass 80 kg falls vertically with a constant speed of 50 m s $^{-1}$. The upward force acting on the skydiver is approximately*[1 mark]*

A. 0 N.
B. 80 N.
C. 800 N.
D. 4000 N.

Markscheme

C

26. Joseph runs along a long straight track. The variation of his speed *v* with time *t* is shown below. *[1 mark]*



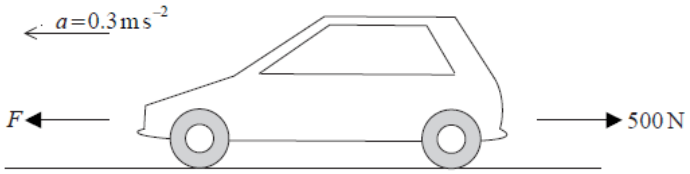
After 25 seconds Joseph has run 200 m. Which of the following is correct at 25 seconds?

	Instantaneous speed / m s^{-1}	Average speed / m s^{-1}
A.	8 m s^{-1}	8 m s^{-1}
B.	8 m s^{-1}	10 m s^{-1}
C.	10 m s^{-1}	8 m s^{-1}
D.	10 m s^{-1}	10 m s^{-1}

Markscheme

C

27. A car of mass 1000 kg accelerates on a straight, flat, horizontal road with an acceleration $a = 0.3\ \text{m s}^{-2}$. The driving force F on the car is opposed by a resistive force of 500 N. *[1 mark]*



The net (resultant) force on the car is

A. 200 N.
B. 300 N.
C. 500 N.
D. 800 N.

Markscheme

B

28a. Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2 marks]*

Markscheme

$h = \frac{v^2}{2g}$;
$= \left(\frac{225}{20} =\right) 11\text{m}$;
*Award **[1 max]** for 91m or 91.25m (candidate adds cliff height incorrectly).*

28b. Determine the time for the stone to reach the surface of the sea after leaving Lucy's hand. *[3 marks]*

Markscheme

time to reach maximum height=1.5s;
time to fall 91m=4.3s;
total time=5.8s;
Answer can be alternatively expressed as 3.0 (to return to hand) +2.8 (to fall 80m) .

or

use of $s=ut+\frac{1}{2}at^2$;
$80=-15t+5t^2$ or $-80=15t-5t^2$;
t=5.8s;