AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 5

SCORE	PERCENTAGE
/347	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

1. (a) (i) vertical speed = 22 sin 30 = 11 m s^{-1} **(1)**

C1

(ii) use of $v = u + at$ or substitution **(1)**

B1

or any correct alternative using equations of motion working leading to 1.12 s **(1)**

B1

working showing that it is doubled for up and down **(1)**

B1

(iii) 41.9 – 43m **(1)**

B1

5

(b) (i) **max 3 from**

tennis ball doesn't travel as far because:

tennis ball has lower KE when hit **(1)**

B1

tennis ball has a rougher surface so more friction/air resistance) **(1)**

B1

(although)rate of energy loss to air (initially) is the same **(1)**

B1

tennis ball loses KE quicker **(1)**

B1

STEMUP.CO.UK

(ii) sketch showing significantly lower height and range **(1)**

M1

acceptable flight path initially same (for short distance then always below cricket ball path° **(1)**

A1

5

[10]

2.

(a) force acting per unit mass **or** $g = F / m$ **or** $g = \frac{GM}{R^2}$ with terms defined

(1)

(b) (i) direction of F_E correct in each diagram

B1

direction of F_M correct in each diagram

B1

direction of F_S correct in each diagram

B1

F_S must be distinguished from F_M

penalty of 1 mark for any missing labelling

(3)

(ii) sun and moon pulling in same direction / resultant of F_M and F_S is greatest / clear response including summation of F_M and F_S

M1

configuration A

A1

(2)

(c) $F = GMm / R^2$

C1

correct substitution $\frac{6.7 \times 10^{-11} \times 2.0 \times 10^{30}}{(1.5 \times 10^{11})^2}$

C1

(5.95 **or** 5.96 **or** 5.9 **or** 6.0) × 10^{-3} N kg^{-1}

A1

(3)

[9]

3.

A

[1]

STEMUP.CO.UK

4. (a) (vector) sum of forces is zero / no resultant force / no net force

B1

sum of moments (about any point) zero / no resultant moment / no net moment

B1

(2)

(b) Clear attempt to resolve

C1

horizontal resolution: $F_R \cos\theta$ = 2800 cos 20° – 3200 cos 42°

C1

vertical resolution: $F_R \sin\theta$ = 3200 sin 42° – 2800 sin 20°

C1

horizontal (253N) or vertical (1180N) resolution correct

C1

correct method for resultant

C1

F_R = 1200 N (1210)

A1

or

scale drawing of correct approximate shape i.e. closed triangle

C1

correct triangle with either labels or arrows

C1

2800 and 3200 drawn to scale to nearest mm

C1

angles correct to nearest°

C1

F_R = 1190 N to 1230 N (sf penalty for more than 2 sf)

A1

acceptable scale quoted giving triangle of at least 6 cm

B1

STEMUP.CO.UK

or

a closed triangle sketch

C1

correct triangle with either labels or arrows

C1

correct angle shown (22°)

C1

cosine rule quoted correctly

C1

correct substitution $F_R^2 = 2800^2 + 3200^2 - 2(2800)(3200)\cos 22°$

C1

F_R = 1200 N (1210)

A1

(6)

[8]

5. (a) force × distance from the point

C1

force × perpendicular distance of the force from the point

A1

(2)

(b) (i) arrow drawn from mid-point of rod

M1

vertically down

A1

(2)

(ii) correct moments equation

C1

2.3 N

A1

(2)

(iii) 15.7 N (18 – (ii))

B1

(1)

[7]

6. (a) conservation of momentum equation or statement quoted or used even with incorrect data

C1

$1.4 \times 10^7 \times 1.7 \times 10^{-27} = 401.7 \times 10^{-27} \times v$

C1

$5.9(3) \times 10^4$ m s^{-1}

A1

(3)

STEMUP.CO.UK

(b) neutron will rebound / have velocity / momentum to the left

B1

momentum transferred to the uranium will be greater

B1

velocity of uranium will be greater

(no loss of kinetic energy argument gets the final mark only)

B1

(3)

(c) KE = $\frac{1}{2}mv^2$ seen or used

C1

$0.5 \times 1.7 \times 10^{-27} \times (1.4 \times 10^{7})^2$

C1

1.7×10^{-13} J ($1.67 - 10^{-13}$ J)

A1

(3)

[9]

7. (a) (i) 0.02 C of charge produce a p.d. of 1 V between the two terminals

or 0.02 C of charge per unit p.d.

B1

(2)

(ii) straight line through the origin

M1

correct gradient (possible check point 0.2 C at 10 V)

and graph line up to 20 V

A1

(2)

STEMUP.CO.UK

(iii) area between graph line and charge axis

(allow area under graph)

not area of the graph

not area under graph / 2

M1

from 0 to the required voltage or up to the required voltage

A1

or energy = ½QV or ½CV^2

M1

read corresponding Q from the graph

A1

(only allow second mark if graph is straight line through the origin)

or C determined from gradient of graph and V given

(2)

(iv) sketch showing two capacitors in parallel connected to a supply

B1

(1)

(b) (i) energy stored = 0.5 CV^2

C1

4.0 J (condone 1 sf answer)

A1

(2)

(ii) (useful) energy output = mgh

or

efficiency = useful energy out / energy input(in same time)

or

efficiency = useful power out / power input

C1

energy output = 0.15 × 9.8 × 0.8 = 1.18 J

C1

efficiency = 0.294 or 29.4% e.c.f. from (b)(i)

A1

(allow 29% – 30%)

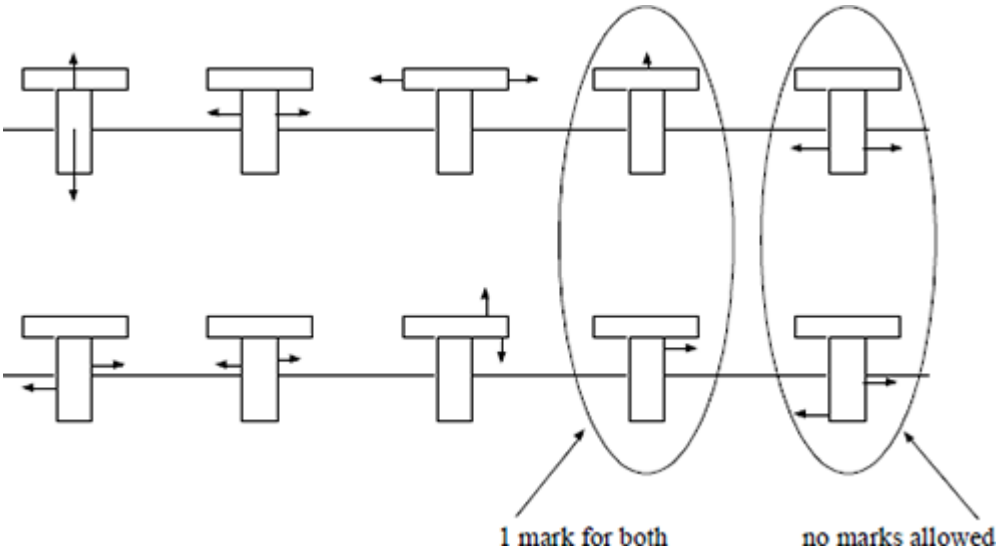
(3)

[11]

STEMUP.CO.UK

8. (a) two forces shown producing tension (see examples below)

B1



(2)

(b) (i) tension / area

or force / area (perpendicular to the surface on which the force acts)

or F / A with terms defined (condone loose definition of area)

B1

(2)

(ii) extension / original length

or extension per unit length

B1

(2)

(iii) the point / stress / strain / force or extension up to which

either all energy supplied in stretching is returned when (deforming) forces are removed

or the object returns to its original shape when (deforming forces) are removed

or beyond which further stress causes plastic deformation or permanent deformation

B1

(2)

STEMUP.CO.UK

(c) (i) force on each bolt = 0.56 MN (ie total force divided by 8)

or

cross-sectional area each bolt = πr^2 plus correct substitution 6.4×10^{-3} m^2

C1

stress = 8.8×10^7 or $\frac{0.56}{6.4 \times 10^{-3}}$

stress / strain = Young modulus

C1

strain = 4.4×10^{-4}

A1

(4)

(ii) area of steel needed = maximum force / UTS

or maximum force / elastic limit

C1

$4.5 \times 10^6 / 5.0 \times 10^8 = 9.0 \times 10^{-3}$ m^2

or $4.5 \times 10^6 / 2.5 \times 10^8 = 18.0 \times 10^{-3}$ m^2

C1

number of bolts = 9.0×10^{-3} / area of a bolt (allow e.c.f.)

= 1.4 bolts

or = 2.8 bolts

A1

answer = 2 bolts (c.a.o.)

or answer = 3 bolts (c.a.o.)

B1

(3)

[11]

9. (a) (i) $E = eV$

C1

$2.9 (2.88) \times 10^{-16}$ J

A1

(2)

(ii) KE = 0.5 mv^2

C1

$v = 2.5(2) \times 10^7$ m s^{-1}

A1

allow e.c.f. for (i) ie $1.5 \times 10^{15} \times \sqrt{}$(their (i)

(2)

STEMUP.CO.UK

(b) (i) force acting per unit charge or F / q with symbols defined

B1

(1)

(ii) $F = eE$ or $F = eV / d$ or $E = V / d$

C1

2.4×10^{-15} N

A1

downwards / towards Q

B1

(3)

(iii) 3.2 (3.17) $\times 10^{-9}$ s
e.c.f. for their (ii)

A1

(1)

(iv) $a = F / m$ or $v = Ft / m$

C1

8.4 (8.36) $\times 10^{6}$ m s^{-1}

ecf their (ii) × their (iii)

A1

(2)

(v) 4.0 cm (3.98 cm)

do not allow e.c.f.

B1

(1)

[12]

STEMUP.CO.UK

10. (a) PE = mgh

C1

= 41 × 9.8 × 3.0 =

1200 or 1210 J

A1

2

(b) (i) $mgh = 0.5mv^2$

C1

$v = 7.7\ ms^{-1}$

A1

2

or ecf from (a)

(ii) F = mgcos50

C1

= 258N

A1

2

[6]

11. (a) (i) momentum before (a collision) = momentum after (a collision)
or
there is no change in momentum (when bodies collide)

C1

reasonably rigorous statement including
reference to total momentum etc. **and**
lack of external force or in a closed system or isolated system

A1

(2)

(ii) in an elastic collision the (total) KE remains constant
or
in an inelastic collision the (total) KE is reduced (not just changed)

B1

(1)

STEMUP.CO.UK

(b) the incident particle stops (loses all its momentum or KE)

M1

the stationary particle moves off with the **same** velocity (speed) as the incident particle (gains **same** momentum or KE as incident particle had)

M1

no other possibility would conserve both momentum and KE
or
original total momentum = mv = final momentum
and original KE = $\frac{1}{2}mv^2$ = final KE

A1

(3)

(c) (i) $130 \times 1.8 = 4.0 \times 10^4 \, v$
or clear appreciation that momentum = mv

C1

e.g. an incorrect momentum equation
5.9 (5.85) $\times 10^{-3}$ m s^{-1} (in opposite direction to that of the astronaut)

A1

(2)

(ii) energy change / time

C1

energy change of astronaut = 211 J

C1

or
power = Fv

C1

force = 390 N from $F = ma$
(need to use v = 1.8 / 2 to obtain average power 350 W)

C1

power = total energy / time = 211 / 0.6 = 350 – 352 W

A1

(3)

(iii) any two sensible comments

e.g. momentum of astronaut and spacecraft reduced to zero
rope stores elastic energy
momentum of astronaut becomes equal and opposite to original
astronaut and spacecraft move toward one another
the astronaut and spacecraft are 'reunited'
taut rope produces a force toward the spacecraft
velocity of astronaut and of spacecraft will be reversed
rope acting like a spring

not astronaut pulled along at a constant speed

B2

(2)

[13]

STEMUP.CO.UK

12. (a) a velocity divided by a time

C1

single reading from graph of v in range 54..56

C1

acceleration in range 90..93.4 ms^{-2}

A1

3

(b) clear attempt to estimate area under the curve

C1

use of correct scale factor: 1 cm^2 represents 10 × 0.2 m

C1

max height in range 80..90 m

A1

3

(c) t^2 = (2 × answer to (b))/9.8

C1

expected answer in range 4.0..4.3 s

allow ecf for height

A1

2

[8]

13. (a) vector quantities have direction (as well as magnitude) and scalar quantities do not **(1)**

1

(b) vector: e.g. velocity, acceleration, momentum **(1)**
scalar: e.g. mass, temperature, energy **(1)**

2

STEMUP.CO.UK

(c) (i) addition of forces (12 + 8) **(1)**

(use of $F = ma$ gives) $a = \frac{(12+8)}{6.5} = 3.1$ m s^{-2} **(1)** (3.08 m s^{-2})

(ii) subtraction of forces (12 – 8) **(1)**

$a = \frac{(12-8)}{6.5} = 0.62$ m s^{-2} **(1)** (0.615 m s^{-2})

4

[7]

14. (a) momentum before (a collision) = momentum after
(the collision) total (resultant) momentum constant
or momentum of system is constant
allow $m_1v_1 + m_2v_2$ = etc
or
reference to isolated/closed system or that no external forces act

C1

resultant/total/sum of momentum of a system is constant/same before and after a collision/interaction provided no external forces act/in an isolated system

A1

2

(b) (i) impulse = Ft ; or I = area under graph (condone ½ Ft)
or clear attempt to multiply a force by a time e.g. multiplies 1.8 by 0.15

C1

0.135 (0.14) Ns or kg m s^{-1}

A1

2

(ii) impulse = change in momentum or 0.135 = $m \times 0.6$
(condone $Ft = mv$)

C1

0.225/0.233 (0.23) kg (ecf from (b)(i))

A1

2

(iii) 0 (no unit penalty)

B1

1

[7]

STEMUP.CO.UK

15. (a) below yield stress material behaves elastically
or returns to original length when forces are removed

B1

above the yield stress: (condone 'at the yield stress')
material behaves plastically/is permanently deformed / is ductile

B1

extends considerably / has large strain / extension

B1

for very small increases in stress / force

B1

Max 2

(b) (i) Strain = 3.33×10^{-4} or $\frac{1.5 \times 10^{-3}}{4.5}$ seen

C1

$E = stress / strain$ **and** $stress = F / A$;
or $E = Fl / A\Delta l$

C1

$A = 2.8 \times 10^{-4}$ m^2 **or** $\frac{\pi(0.0019)^2}{4}$ or $\pi(9.5 \times 10^{-3})^2$ seen

C1

Stress = 7.0×10^7 Pa

C1

2 max for C marks

Force = 19.6 to 19.8 (20) kN

A1

(3)

(ii) Strain energy = $\frac{1}{2}F\Delta l$ or ½ their (b)(i) × (1.5×10^{-3})

C1

condone incorrect power or no 10^{-3} for C mark
or $\frac{1}{2}\ \sigma\varepsilon \times volume$
14.6 to 14.9 (15) J (e.c.f.)

A1

(2)

[7]

STEMUP.CO.UK

16. **AO3a** : **planning**:
measurements:
(to determine the transit time of the falling cake-case)
use a stopwatch (**not** from rest) **(1)**
(to determine (vertical) distance fallen)
use a (metre) ruler or tape measure (**not** from rest) **(1)**
(to determine mass (weight) of cake-case)
measure with balance (not scales) **(1)**
(to determine the cross-sectional area of the cake-case)
measure the (mean) diameter / radius using (300 mm) ruler **(1)** any three **(1) (1) (1)**

strategy:
find v using correct physics e.g. $\frac{\text{(vertical) distance}}{\text{transit time}}$ **(1)**
(no credit for measuring vertical distance in a certain time)

find A from $\frac{\pi(\text{diameter})^2}{4}$ **(1)**

D is same as weight (mg) (when falling at terminal velocity) **(1)**
repeat either using different weights (e.g.stacked cases) or
paper cases of different diameters (cross-sectional areas) **(1)**
shape factor found by graphical method: expect explanation,
suitable graph e.g. D against $\rho A v^2$; determine gradient **(1)** any four **(1) (1) (1) (1)**

control:
any sensible e.g. avoid draughts **(1)**

difficulties:
(*difficulty* + *how overcome* = 2)
any **two** of the following

reduce uncertainty in timing
by making cases fall through large distance (e.g. ≥ 2 m) and / or

by repeating readings and averaging
by avoiding parallax error (viewing at eye level)

reduce uncertainty in diameter / radius
by measuring across several diameters and averaging

reduce uncertainty in vertical distance
by ensuring ruler is vertical: expect description of how this is done **(1) (1) (1) (1)**

[8]

17. (a) (i) resultant force acting on tray is zero [or $P + W = Q$] **(1)**
resultant torque is zero
[or correct moments equation
or anticlockwise moments = clockwise moments] **(1)**

(ii) $W = 0.12 \times 9.81 = 1.2\text{N}$ **(1)** (1.18N)

STEMUP.CO.UK

(iii) (taking moments about P gives)
$Q \times 0.1 = 0.12 \times 9.81 \times 0.25$ **(1)**
$Q = 2.9$ N (2.94 N) **(1)**
$P = 2.9 - 1.2 = 1.7$ N **(1)** (or $2.94 - 1.18 = 1.76$ N)
(allow C.E. for values of *W* and *Q)*

6

(b) placed at Q **(1)**
no additional turning moment about Q **(1)**

2

[8]

18. (a) extension proportional to the applied force **(1)**
up to the limit of proportionality
[or provided the extension is small] **(1)**

2

(b) (i) $8 \times 9.81 = 78$ (5) N **(1)**

(allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8 \times 10^{-7}} \times \frac{2.5}{\Delta L}$ **(1)**

$\Delta L = 3.5 \times 10^{-3}$ m **(1)**

(iii) similar calculation **(1)**
to give $A_S = 5.6 \times 10^{-7}$ m^2 **(1)**
[or $A_B = 2A_S$ **(1)** and correct answer **(1)**]

(iv) (use of energy stored = ½ *Fe* gives) energy stored
$= ½ \times 78.5 \times 3.5 \times 10^{-3}$ **(1)**
$= 0.14$ J **(1)**

7

(c) (i) end A is lower **(1)**

(ii) $= ½\ 3.5 \times 10^{-3} = 1.8 \times 10^{-3}$ m **(1)** $(1.75 \times 10^{-3}$ m)

2

[11]

19. (a) (i) (use of $E_p = mgh$ gives) $E_p = 70 \times 9.81 \times 150$ **(1)**
$= 1.0(3) \times 10^5$ J **(1)**

(ii) (use of $E_k = ½mv^2$ gives) $E_k = ½ \times 70 \times 45^2$ **(1)**
$= 7.1 \times 10^4$ J **(1)** $(7.09 \times 10^4$ J)

4

STEMUP.CO.UK

(b) (i) work done (= $1.03 \times 10^5 - 7.09 \times 10^4$) = 3.2**(1)** $\times 10^4$ J **(1)**
(allow C.E. for values of E_p and E_k from (a**)**

(ii) (use of *work done* = *Fs* gives)
$3.21 \times 10^4 = F \times 150$ **(1)**
(allow C.E. for value of *work done* from (i)
$F = 210$ N **(1)** (213 N)

3

[7]

20. (a) product of the force and the **perpendicular distance (1)**
reference to a point/pivot **(1)**

2

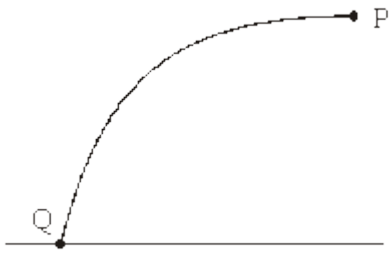
(b) (i) since *W* is at a greater distance from A **(1)**
then *W* must be less than *P* if moments are to be equal **(1)**

(ii) *P* must increase **(1)**
since moment of girl's weight increases as she moves from A to B **(1)**
correct statement about how P changes
(e.g. P minimum at A, maximum at B, or P increases in a linear fashion) **(1)**

max 4

[6]

21. (a) (i)



(1)

(ii) no **horizontal** force acting **(1)**
(hence) no (horizontal) acceleration **(1)**
[or correct application of Newton's First law]

3

STEMUP.CO.UK

(b) (i) (use of $v^2 = u^2 + 2as$ gives) $32^2 = (0) + 2 \times 9.81 \times s$ **(1)**

$s = \frac{1024}{19.62}$ **(1)** (= 52.2 m)

(ii) (use of $s = \frac{1}{2} at^2$ gives) $52 = \frac{1}{2} 9.81 \times t^2$ **(1)**

$t = \sqrt{\left(\frac{104}{9.81}\right)} = 3.3$ s **(1)** (3.26 s)

[or use of $v = u + at$ gives $32 = (0) + 9.81 \times t$ **(1)**

$t = \frac{32}{9.81} = 3.3$ s **(1)** (3.26 s)]

(iii) (use of $x = vt$ gives) x (= QR) $= 95 \times 3.26$ **(1)**
$= 310$ m **(1)**

(use of $t = 3.3$ gives $x = 313.5$ m)
(allow C.E. for value of t from (ii)

6

(c) maximum height is greater **(1)**
because vertical acceleration is less **(1)**
[or longer to accelerate]

2

[11]

22. (a) (i) change of momentum (= 0.44 × 32) = 14(.1) kg m s^1 **(1)**

(ii) (use of $F = \frac{\Delta(mv)}{\Delta t}$ gives) $F = \frac{14.1}{9.2 \times 10^{-3}}$ **(1)**

$= 1.5(3) \times 10^3$N **(1)**

(allow C.E. for value of $\Delta(mv)$ from (i)

3

(b) (i) deceleration $= \frac{24 - 15}{9.2 \times 10^{-3}} = 9.8 \times 10^2$m s^{-2} **(1)**

(9.78×10^2m s^{-2})

(ii) (use of $a = \frac{v^2}{r}$ gives)

centripetal acceleration $= \frac{24^2}{0.62} = 9.3 \times 10^2$m s^{-2} **(1)**

(9.29×10^2 m s^{-2})

STEMUP.CO.UK

(iii) before impact: radial pull on knee joint due to centripetal acceleration of boot **(1)**
during impact: radial pull reduced **(1)**

4

[7]

23. (a) Hooke's law: the extension is proportional to the force applied **(1)**
up to the limit of proportionality or elastic limit
[or for small extensions] **(1)**

2

(b) (i) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $\Delta L_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ **(1)**

$= 1.3 \times 10^{-4}$ (m) **(1)** (1.33×10^{-4} (m))

$\Delta L_b = \frac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4}$ (m) **(1)** (4.66×10^{-4} (m))

total extension = 6.0×10^{-4} m **(1)**

(ii) $m = \rho \times V$ **(1)**
$m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) **(1)**
$m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (kg) **(1)**
(to give total mass of 44 or 43.8×10^{-3} kg)

7

(c) (use of $m = \rho A l$ gives) $l = \frac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ **(1)**

= 2.2 m **(1)** (2.16 m)

(use of mass = 43.8×10^{-3} kg gives 2.14 m)

2

[11]

24. (a) (i) horizontal component = 850 × cos 42 **(1)**
= 630 N **(1)** (632 N)

(ii) vertical component = 850 × sin 42 = 570 N **(1)** (569 N)
(if mixed up sin and cos then CE in (ii))

(iii) weight of girder = 2 × 570 = 1100 N **(1)** (1142 N)
(use of 569 N gives weight = 1138 N)
(allow C.E. for value of vertical component in (ii))

4

(b) arrow drawn vertically downwards at centre of girder **(1)**

1

[5]

STEMUP.CO.UK

25. (a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$

with *F* and *A* defined **(1)**

tensile strain: extension per unit length or $\frac{\Delta L}{l}$ with *e* and *l* defined **(1)**

the Young modulus: $\frac{\text{tensile stress}}{\text{tensile strain}}$ **(1)**

3

(b) (i) $E_S = \frac{F_s}{A}\frac{l}{\Delta L}$ **(1)** and $E_B = \frac{F_B}{A}\frac{l}{\Delta L}$ **(1)** hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$

(ii) $\frac{E_S}{E_B} = 2$ **(1)**

$\therefore F = 2F_B$ **(1)**

$F_S + F_B = 15$ N **(1)** gives $F_S = 10$ N

[or any alternative method]

(iii) $\left(E = \frac{F}{A}\frac{l}{\Delta L} \text{ gives}\right)$ $e = \left(\frac{F}{A}\frac{l}{E}\right) = \frac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ **(1)**

$= 5.36 \times 10^{-5}$m **(1)**

6

[9]

26. (a) (i) car A: travels at constant speed **(1)**

(ii) car B: accelerates for first 5 secs (or up to 18 m s^{-1}) **(1)**
then travels at constant speed **(1)**

3

(b) (i) car A: distance = 5.0 × 16 **(1)**
= 80 m **(1)**

(ii) car B: (distance = area under graph)
distance = [5.0 × ½ (18 + 14)] **(1)**
= 80 m **(1)**

4

(c) car B is initially slower than car A (for first 2.5 s) **(1)**
distance apart therefore increases **(1)**
cars have same speed at 2.5 s**(1)**
after 2.5 s, car B travels faster than car A (or separation decreases) **(1)**

max 3

[10]

STEMUP.CO.UK

27. (a) (i) (change in momentum of A) = – **(1)** 25×10^3 **(1)**
kg m s^{-1} (or N s) **(1)**

(ii) (change in momentum of B) = 25×10^3 kg m s^{-1} **(1)**

4

(b)

	initial vel/m s^{-1}	final vel/m s^{-1}	initial k.e./J	final k.e./J
truck A	2.5	1.25	62500	15600
truck B	0.67	1.5	6730	33750
	(1)	**(1)**	**(1)**	**(1)**

4

(c) not elastic **(1)**
because kinetic energy not conserved **(1)**
kinetic energy is greater before the collision (or less after) **(1)**
[or justified by correct calculation]

3

[11]

28. (a) component (parallel to ramp) = $7.2 \times 10^3 \times \sin 30$ **(1)** (= 3.6×10^3 N)

1

(b) mass = $\frac{7.2 \times 10^3}{9.81}$ = 734 (kg) **(1)**

$a = \frac{3600}{734}$ = 4.9(1) m s^{-2} **(1)**

2

(c) (use of $v^2 = u^2 + 2as$ gives) $0 = 18^2 - (2 \times 4.9 \times s)$ **(1)**
s = 33(.1) m **(1)**
(allow C.E. for value of a from (b))

2

(d) frictional forces are acting **(1)**
increasing resultant force [or opposing motion] **(1)**
hence higher deceleration [or car stops quicker] **(1)**
energy is lost as thermal energy/heat **(1)**

Max 2

[7]

29. (a) scales **(1)**

six points correctly plotted **(1)**

trendline **(1)**

3

STEMUP.CO.UK

(b) average acceleration = $\frac{26}{25}$ **(1)**

= 1.0(4) ms^{-2} (1)

(allow C.E. for incorrect values used in acceleration calculation)

2

(c) area under graph **(1)**

= 510 ± 30 m **(1)**

2

(d) (graph to show force starting from *y*-axis)

decreasing (not a straight line) **(1)**

to zero (at end of graph) **(1)**

2

(e) (since) gradient of a velocity-time graph gives acceleration **(1)**

first graph shows acceleration is decreasing **(1)**

2

[11]

30. (a) (i) (horizontal) force = zero **(1)**

(ii) (vertical) force = 2 × 15 sin 20 **(1)**

= 10(.3) N **(1)**

3

(b) (i) weight (of block) = 10(.3) N **(1)**

(allow C.E. for value from (a) (ii))

(ii) resultant force must be zero **(1)**

with reference to an appropriate law of motion **(1)**

3

[6]

31. (a) the point (in a body) **(1)**

where the weight (or gravity) of the object appears to act

[or resultant torque zero] **(1)**

2

(b) (i) $P \times 0.90 = 160 \times 0.50$ **(1)**
$P = 89$ N (88.9 N)

(ii) $Q = (160 - 89) = 71$ N **(1)**
(allow C.E. for value of P from (i))

3

STEMUP.CO.UK

(c) (minimum) force × 0.10 = 160 × 0.40 **(1)**

force = 640 N **(1)**

2

(d) force is less **(1)**

because distance to pivot is larger **(1)**

smaller force gives large enough moment (1)

3

[10]

32. (a) use of E = mgh **(1)**

2680 J **(1)**

2

(b) use of $v^2 = 2as$ **(1)**

9.1 m s^{-1} **(1)**

2

(c) increases the time taken for the athlete to come to rest/reduced deceleration

force = mass × acceleration/mass × change in velocity/time **(1)**

or momentum argument

or energy argument **(1)**

2

[6]

33. (a) (i) velocity is constant **(1)**

no acceleration **(1)**

(ii) 1.5 sin 50 = *D* cos 55 **(1)**

2.0 kN **(1)**

4

(b) (i) 1.15 kN **(1)**

(ii) total resistance to motion = 1200 + 1150 N **(1)**

use of power = Fv **(1)**

20 **(1)**

kW **(1)**

5

STEMUP.CO.UK

(c) boat now has resultant force of 1200 N acting on it **(1)**

boat will accelerate (until resistance of water = 2350 N) **(1)**

2

[11]

34. (a) $\lambda(=2 \times 38) = 76(\text{m})$

$$f\left(=\frac{c}{\lambda}=\frac{3.0\times10^{8}}{76}\right)=3.9(4)\ \text{MHz}$$ **(1)**

1

(b) (i) angle between cable and horizontal = $\left(\sin^{-1}\frac{12}{14}\right)=59^{\circ}$ **(1)**

$T = 110\cos59^{\circ} = 57\text{N}$ • (56.7N) **(1)**

(allow C.E. for value of angle)

(ii) cross-sectional area $(= \pi(2.0 \times 10^{-3})^2)$

$=1.3 \times 10^{-5}(\text{m}^2)$ **(1)**

$(1.26 \times 10^{-5}(\text{m}^2))$

stress $\left(=\frac{\text{tension}}{\text{area}}\right)=\frac{57}{1.3\times10^{-5}}$ **(1)**

$= 4.4 \times 10^{6}\text{Pa}$ **(1)**

$(4.38 \times 10^{6}\text{Pa})$

(use of 56.7 and 1.26 gives 4.5×10^{6} Pa)

(allow C.E. for values of T and area)

(iii) breaking stress is $\approx$ 65 × stress
copper is ductile
copper wire could extend much more before breaking
because of plastic deformation
extension to breaking point unlikely

any three **(1)(1)(1)**

7

[8]

35. (a) (i) use of appropriate data from graph **(1)**

answer in acceptable range (to be decided) **(1)**

(ii) zero at 0, 0.2 0.58, 0.8 and 1 s (approx) **(1)**

reasonable attempt to show relative magnitudes **(1)**

4

STEMUP.CO.UK

(b) appreciation of area under the graph **(1)**

appropriate counting of squares **(1)**

distance per square **(1)**

correct answer in acceptable range **(1)**

4

[8]

36. (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]

(iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)**

5

(b) (i) length of wire **(1)**
diameter (of wire) **(1)**

(ii) graph of force vs extension **(1)**
reference to gradient **(1)**

gradient = $E\frac{A}{l}$ **(1)**

[or graph of stress vs strain, with both defined
reference to gradient
gradient = *E]*

area under the line of *F* vs *ΔL* **(1)**
[or energy per unit volume = area under graph of stress vs strain]

6

[11]

37. (a) technique one **(1)**

information derived from it **(1)**

technique two **(1)**

information derived from it **(1)**

4

STEMUP.CO.UK

(b) (i) gravitational **attraction** to …**(1)**

…centre of gravity(mass) of mountain **(1)**

(ii) cancellation of some systematic errors **(1)**

3

(c) (i) calculates volume of cone **(1)**

mass = density × volume seen **(1)**

2.2×10^{12} kg **(1)**

(ii) sideways force/mg = tan (0.0011) **(1)**

sideways force = $Gm_{sch}\ 0.5/(1400)^2$ subst seen **(1)**

2.4×10^{24} kg **(1)**

(iii) his density estimate was too low **(1)**

or mean density of the Earth is higher than that of the mountain **(1)**

7

[14]

38. (a) (i) (use of $a = \frac{\Delta v}{\Delta t}$ gives) $a = \frac{4.5}{3600}$ **(1)**

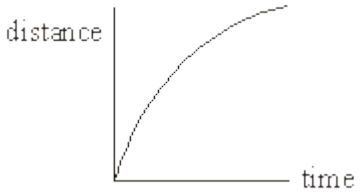
$=1.25 \times 10^{-3}\ ms^{-2}$ **(1)**

(ii) (use of $v^2 = u^2 + 2as$ gives) $0 = 4.5^2 - 2 \times 1.25 \times 10^{-3} \times s$ **(1)**

$s\left(= \frac{20.25}{2.5 \times 10^{-3}}\right) = 8.1 \times 10^3\ m$ **(1)**

4

(b) increasing curve **(1)**
correct curve **(1)**



1

(c) gradient (slope) of graph represents speed **(1)**
hence graph has decreasing gradient **(1)**

2

[8]

STEMUP.CO.UK

39. (a) potential energy to kinetic energy **(1)**
mention of thermal energy and friction **(1)**

2

(b) (use of ½ $mv^2 = mgh$ gives) ½ $v_h^2 = 9.81 \times 1.5$ **(1)**
$v_h = 5.4(2) \text{ms}^{-1}$ **(1)**
(assumption) energy converted to thermal energy is negligible **(1)**

3

(c) component of weight down the slope causes acceleration **(1)**
this component decreases as skateboard moves further down the slope **(1)** air resistance/friction increases (with speed) **(1)**

2

(d) (i) distance (= 0.42 × 5.4) = 2.3m **(1)**
(2.27m)
(allow C.E. for value of v_h from (b))

(ii) $v_v = 9.8 \times 0.42$ **(1)**
$= 4.1(\text{l}) \text{ m s}^{-1}$ **(1)**

(iii) $v^2 = 4.1^2 + 5.4^2$ **(1)**
$v = 6.8 \text{ m s}^{-1}$ **(1)**
(6.78 m s^{-1})
(allow C.E. for value of v_h from (b))

5

[12]

40. (a) resultant force zero **(1)**
resultant torque about any point zero **(1)**

2

(b) (i) force due to wire P = 5.0 - 2.0 = 3.0 N **(1)**

(ii) (moments give) $5.0 \times d = 2.0 \times 0.90$ **(1)**
$d = 0.36$ m **(1)**

3

[5]

STEMUP.CO.UK

Examiner reports

1. A large number of candidates had not grasped the concept of the independence of motion in two directions at right angles.

In part (a) (i), many candidates had difficulties resolving velocities. The use of cos 30 or tan 30 rather than sin 30 was common.

For part (a) (ii), many used the projected speed of 22 m s^{-1} rather than the resolved speed in the equation of motion. Only a small minority of the candidates calculated the time to reach the maximum height and then doubled it. Some quoted $u = at$ so $22 = 9.8t$. This gave the correct outcome for the wrong reason.

The most common answer to part (a) (iii) was to use 22 m s^{-1} as the horizontal velocity. Some candidates introduced gravitational acceleration into the solution of this part.

Few candidates were able to make significant progress with their explanations in part (b) (i). The majority appreciated the lower momentum and/or kinetic energy of the ball on leaving the bat but going on to explain how the effect of air resistance on the object leads to a lower range proved too difficult for most candidates. Answers frequently illustrated conceptual difficulties between energy and force, e.g. more kinetic energy means there is more force driving the ball, or the ball with a lower momentum loses its forward force quicker.

Consideration of the force acting on a ball was often related to the force exerted by the bat which was nor relevant in the context of the question.

There were few carefully thought out diagrams in part (iii). The quality of drawing varied considerably. It was common for the path to be shown unchanged to almost maximum height before deviating. Attempts to show an asymmetrical path were rare

2. (a) Most candidates managed to give an acceptable definition of gravitational field strength. Those who did not usually failed because they omitted to mention unit mass or because they confused field strength with potential or potential energy.

(b) (i) This part was also well done. Some candidates gave confused labelling, showed their forces in the wrong direction, or omitted to show the forces on both of the diagrams.

(ii) Explanations were often not clear: some candidates created a difficulty by referring to the resultant force when they probably were thinking of the resultant force of only F_M and F_S. A few candidates sought to give explanations relating to the distances between the Earth and the Sun or Moon, highlighting the need to advise candidates not to rely on judgements of distance from diagrams which are not to scale.

(c) This calculation was done well by most of the candidates. A few tried to use an equation for potential rather than force and some made processing errors, often forgetting to square the orbital radius even though they had shown it as being squared in their equation.

3. Energy stored by a capacitor was the subject tested in this question, which had been used before in an Advanced level examination. In June 2003 the examination facility was 56%, as opposed to 67% when it was used before. The discrimination index was very similar on both occasions.

STEMUP.CO.UK

4.

(a) There was a significant number of correct responses to this part. However, many answers were not well expressed: statements such as "the upward forces balance the downward forces were common". Many candidates did not manage to convey that it was the sum or resultant force or moment that was zero. A surprising number of candidates gave only one condition for equilibrium, usually omitting the torque condition.

(b) There were three basic methods of tackling this section: resolution of the forces; use of the cosine rule and scale drawing. All three methods were well represented. Those who adopted an approach based on the resolution of forces tended to be successful if they got as far as resolving in two directions. Some candidates tried to measure the angle of the resultant force shown on the diagram. These candidates gained some credit. A few candidates wrote expressions or equations which were clear but unsuccessful attempts to resolve. Those who progressed as far as calculating the two perpendicular components were usually successful in their determination of the resultant but a significant number of these left their answer with too many significant figures. The cosine rule was well used by many candidates with the commonest error being the use of an incorrect angle. Those using this method tended to set out their work more carefully than those using the resolution of forces. This may have been because the cosine rule route produces fewer calculations to be managed by candidates. Those who chose to use a scale diagram were frequently successful but too many candidates used very small diagrams and sometimes omitted to specify the scale that they used. Once again, some candidates used an incorrect angle between the two given forces. Standards of accuracy in the drawing of the diagrams were generally satisfactory.

A small minority of candidates tried to use moments to solve this problem.

6.

(a) This calculation was well done by most candidates. Nearly everyone recognised it as a situation in which the principle of conservation of momentum was important. Some of the weaker candidates made statements to this effect but then proceeded in attempts to use the conservation of energy. Another mistake made by significant numbers of candidates was to use the mass of the uranium nucleus in determining the momentum after the impact, rather than the increased mass of the nucleus, incorporating an additional neutron. Significant figure errors were common in this part.

(b) Few candidates attempted to analyse this situation in terms of conservation of momentum. Very few identified the recoil of the neutron or the reversal of the direction of its momentum. Partial credit was gained by many candidates who used arguments based on kinetic energy conservation in an elastic collision. These candidates failed to appreciate that their arguments were not sufficient to explain the behaviour of the particles.

(c) This part was well done by nearly all of the candidates. There were a few who used incorrect data for the mass or the speed of the neutron and some others who forgot to square the velocity when doing the calculation. Significant figure penalties were not uncommon. Some candidates expressed their answer in a notation similar to that shown on their calculators (i.e. 1.7^{13}). This is clearly incorrect and candidates should be advised that the use of this notation will be penalised.

STEMUP.CO.UK

7.

(a) (i) 'The capacitor stores 0.02 F of charge per volt' was not an uncommon answer. Many simply defined capacitance and some defined the farad. Candidates are required to apply their knowledge to the context of the question.

(ii) Failure to include a unit on the axis was a common error. There were many curves seen, sometimes even when part (i) was correct, which demonstrated poor understanding.

(iii) Many correctly stated that the area under the graph would be determined but did not say what area would be used for any given voltage. Some quoted ½ CV^2 but did not link this with the graph as required by the question.

(iv) Most were successful in this part but there were many who drew capacitors in series and some who did not use a capacitor symbol or label their 'boxes' as capacitors. A few, although knowing the symbol, had no idea how to draw them in either a series or parallel circuit.

(b) (i) Only very weak candidates failed to gain some marks in part (b). In this part the main error was thinking that the answer was given by mgh. This led to problems for some candidates in part (ii).

(ii) The majority of candidates obtained the correct answer. Even those who were confused in (i) often recovered and used energies correctly in this part.

8.

(a) The question asked for the forces required. Many showed only one force. Some showed only arrows below the surface. Many candidates appeared to have had little experience of drawing force diagrams.

(b) There was frequently a lack of precision in stating the meaning of the terms. Although definition of any terms used was asked in the question, many simply quoted, for example, F / A. In (ii) the 'length' involved was often not defined clearly. In part (iii) many candidates wrote that the elastic limit is 'the point at which the material would not return to its original length when the force is removed'. This should have been expressed as the maximum force for which the material would return to its original length when the force is removed. The phrase 'when the force is removed' was often omitted from otherwise good answers.

(c) (i) Working was often hard to follow in many responses. Candidates should be encouraged to state briefly what they are trying to determine when they use a formula as often there seemed no logic to what was being attempted. With some explanation it might have been possible to gain some credit. The 'divide by 8' aspect of the problem often appeared in odd places in the process and lack of analysis of the problem often led to this being done twice. Many failed because they did not know how to calculate area of cross section and others did not read data accurately and used the diameter given as the radius. Obtaining a strain as if one bolt had been used and then dividing by 8 was an unconvincing approach used by many.

(ii) The best answers showed that candidates had good problem solving ability and that they could set out a sensible argument. The obvious approach is to determine the cross sectional area of steel required and divide by the area of one bolt to determine the number of bolts (rounding up). The use of elastic limit or breaking stress was acceptable.

STEMUP.CO.UK

9.

(a) (i) This calculation was generally well done.

(ii) This too was well done but there were more computational errors here.

(b) (i) Many candidates defined field strength correctly but referred to point charge rather than unit charge and others used the expression for potential gradient in a uniform field which was not appropriate.

(ii) Good candidates did this calculation well but a lot of weaker candidates introduced expressions relevant to the movement of charged particles in magnetic fields.

(iii) Many performed this calculation correctly but some used an incorrect value for distance.

(iv) Better candidates had no difficulty with this calculation but some weaker candidates omitted this part and the last part of the question.

(v) There was a tendency to use incorrect data in this calculation. Some of those who managed this part were penalised for giving the answer to only one significant figure.

10.

All but the weakest candidates scored some marks on this question.

In part (a) most candidates who calculated the energy correctly, lost one of the two marks on offer by quoting too many significant figures in their answer.

In part (b) (i), some candidates were penalised for not using their answer from part (a).

Part (b) (ii) proved to be too difficult for many candidates.

11.

(a) (i) Although there was a good proportion of clear responses many gave vague statements which gained only one of the two available marks. Many simply stated 'momentum before a collision is equal to the momentum after' which was given credit but begs the question whether the candidate was referring to the momentum of the system or one of the colliding bodies. For full credit this needed to be clearer and the condition that no external forces act on the system stated.

(ii) Although many gave correct responses there were those who stated that energy would be conserved. This of course is true in any collision so that the inclusion of the word 'kinetic' was mandatory.

(b) There were relatively few completely correct answers to this part. Surprisingly few appreciated that in such a collision the incident particle would stop and the stationary particle would move off at the speed of the colliding body before the collision. This outcome is one of the most basic situations which candidates should have been able to recall from collision experiments with trolleys or air track vehicles. Many thought that the particles would rebound in opposite directions with equal speeds, a situation that would not conserve momentum. Those who appreciated the outcome of the collision had only to state that only this result would conserve both momentus and kinetic energy for full credit.

(c) (i) There were many correct responses to this part. A common error was to treat the situation as a collision rather than an 'explosion' so that working included addition of masses.

STEMUP.CO.UK

(ii) The most straightforward approach to this question was to calculate the final energy and divide this by the time. Most candidates, however, used $P = Fv$. The force was often determined correctly (assuming this to be constant) but most candidates then used the final velocity instead of the average velocity in the power equation, arriving at 700 W.

(iii) There were not many totally realistic outcomes discussed in this part. A common answer was that the astronaut would be pulled along once the rope became taut (a sort of hang-gliding in space). There were many aspects that could have been included in a reasoned discussion of the outcome. The most common one mark answer was that the astronaut would return to the spacecraft. Further discussion was necessary for full credit.

12. This proved to be a difficult question for many candidates.

An accurate calculation of average acceleration was achieved by only about half of the candidates, while rather less than that were able to calculate the correct area under the graph to find the maximum height.

Many of the candidates who gained credit for part (a) did so on the basis of error carried forward from part (b). Other candidates had the rocket falling back to Earth with an initial velocity of 69 m s^{-1}. However, there were a significant number of candidates who did achieve full marks on the question.

13. Parts (a) and (b) were answered well and it was clear that candidates were confident with the distinction between scalar and vector quantities and could provide correct examples of each.

The calculation in part (c) caused more problems with a significant proportion of candidates either not combining the two forces correctly or using an incorrect version of the force equation from Newton's second law. This was a little surprising but was probably the result of candidates trying to overcomplicate a straightforward question. Significant figure errors were common in part (c) (ii), the common answer being 0.6 m s^{-2} for the acceleration.

14. (a) A good proportion of the candidates appeared to have made an effort to learn a formal statement of the principle. Most candidates were able to gain at least one mark for the definition. The most common errors were either not giving the condition of no external force or failing to refer to the total momentum in the definition. It was therefore unclear whether the definition referred to the momentum of a body or the system of bodies.

(b) (i) Most realised that impulse = *Ft* but a calculation using the maximum force and total time was common. Many misread the time axis as 1.5 s and the unit was a problem for a small minority of the candidates. The counting squares etc route was a long way round to the answer in this instance.

More concerning was the significant proportion who, having calculated the area correctly, decided that the impulse had to be halved since half of it would be given to **A** and half to **B**.

(ii) Allowing errors carried forward this was generally well done.

(iii) This caught out a large proportion who thought a calculation necessary but many spotted the application of the principle of momentum conservation.

STEMUP.CO.UK

15. (a) Although there were many good answers this was not well understood by the majority of the candidates. Many candidates seemed unaware of the term and wrote only of breaking or bending. Weak answers implied that for stresses below the yield stress the material (bridge or building) would not 'deform' at all.

(b) (i) Most candidates were able to gain one or two marks here by making some progress toward the answer. Common errors were use of the diameter value in πr^2 or failure to convert the mm dimensions to m. Weak candidates often related the 'original length' to 19 mm.

(ii) Allowing the error carried forward there were many correct answers. A minority simply calculated the strain and some thought that ½ *stress* × *strain* gave the energy stored. Using ½ *stress* × *strain* × *volume* made it hard going but those using it usually succeeded. Some following this route used the increase in volume rather than the total volume of the rod.

STEMUP.CO.UK

16. Candidates were required to describe a method of determining the shape factor, f, of a paper cake-case of cross-sectional area A, falling with terminal velocity, v, the drag, D, being given by $D = f \rho A v^2$, ρ being the (known) density of air.

Most candidates knew some or all of the relevant physics but there seemed to be some confusion whether Newton's first or third law could be applied to the situation. Others tried to bring in the second law, quoting $F = \frac{\Delta(mv)}{\Delta t}$ as the means to determine the drag.

Significant numbers of candidates made the assumption that the cake-case, when dropped, would instantaneously reach terminal velocity rather than 'quickly reach terminal velocity' as the question suggested. Failure to take account of the acceleration of the cake-case before reaching terminal velocity prevented the award of marks, which otherwise would have been given for use of a stopwatch to measure the transit time and a ruler to find the vertical distance covered by the cake-case.

Many candidates referred to the use of one or two light gates in their plans. For credit to be given, examiners needed to see that these were used in conjunction with data logging systems and that the candidate was clear that the gates acted simply as sensors. For single gate methods, candidates were expected to mention that the obscuration height of the cake-case should be measured. Many candidates understood that when terminal velocity had been reached, the drag force was equal to the weight of the cake-case and credit was given for use of a balance to determine the mass, and hence the weight, of the cake-case. Marks were forfeited by the inaccurate use of terminology: 'scales' were not accepted for 'balance', nor was 'timer' accepted for 'stopwatch' or 'stopclock'. The majority of candidates explained that a ruler could be used to find the diameter of the cake-case but few thought it necessary to repeat this measurement in several directions and then average, in order to reduce the uncertainty in the result.

Nearly all the candidates explained how the terminal velocity would be calculated using vertical distance and transit time. Exceptions were those who failed to appreciate the changing pattern of motion during the descent and described the use of equations for uniformly accelerated motion. The correct explanation of how the diameter could be used to calculate the area of the cake-case was nearly universal.

Statements that the drag was equal to the weight once the terminal velocity had been reached were less widespread: some candidates decided that drag was an unknown that could be eliminated by repeating the experiment at some different terminal velocity and then using simultaneous equations.

The idea that a satisfactory result for the shape factor could be obtained from a single set of measurements of velocity, drag and area was not accepted, but many candidates picked up the hint given in the question and wrote that they would repeat the experiment, stacking additional cases together to increase the weight. Relatively few took the further step and explained how a graphical method, e.g. plotting D against $\rho A v^2$, and determining the gradient, could produce a more reliable answer for the shape factor.

There was very little the candidates could suggest about relevant control measures, other than the elimination of draughts ,but surprisingly few did this.

Credit was given when candidates wrote about procedures that would reduce the uncertainty in measurements, although no credit was given for putting multiple cake-cases on the balance to

STEMUP.CO.UK

determine the average mass. Among the stranger suggestions seen was that the experiment would run better if air resistance could be removed altogether by performing the experiment in a vacuum chamber. Other answers that earned credit included increasing the vertical distance over which timing took place, avoidance of parallax error when starting or stopping the stopwatch and the use of a set square to ensure that the ruler used to determine the transit distance was vertical.

In the majority of cases where a procedure mark was awarded the candidate simply said they would repeat the timing and average the result (or check for the presence of anomalous results). When candidates did not specifically refer to a procedure to overcome errors in measurement, as opposed to calculation, it was difficult for the examiners to give credit. An additional mark was given if the specific difficulty that the procedure sought to overcome was identified.

17. The first question on the paper was done well and candidates coped with the moments calculation in an impressive way. They performed less confidently in part (a)(i) where the majority of candidates only gave one of the necessary conditions for equilibrium. In part (b) the majority of candidates knew intuitively that the drinking glass should be placed at the point Q. Explaining why this was the case proved more of a challenge.

18. Responses to part (a) were extremely disappointing. The impression gained by examiners was that many candidates had not heard of Hooke's Law because they attempted to state it in terms of current and voltage. Others, realising that it had something to do with solids, attempted an answer in terms of a wire returning to its original shape and length when the force was removed. It should be pointed out that merely stating $F \propto e$ gained no credit unless the symbols were defined. Of those candidates who gave the correct version of Hooke's Law, most failed to gain the second mark by not giving the condition under which it was valid, i.e. up to the limit of proportionality. Validity up to the elastic limit was not accepted.

The calculation in part (b) was carried out quite successfully and many completely correct answers were obtained. The usual error occurred in part (i) in not realising that the tension due to the 16 kg was shared equally between the two wires. Others did not multiply by g, or used $g = 10$ m s^{-2}, which was not acceptable. The data sheet gives $g = 9.81$ m s^{-2} and this is the value which was required. Incorrect answers to part (i) were allowed to be carried forward into the remaining parts of the section. However, if the force in part (ii) was given as 16 kg or 8 kg, without conversion into a force (i.e. Newtons), then it was considered as a Physics error and both marks were lost.

The majority of candidates deduced (or guessed) that end A of the bar would be lower than end B, although some of the convoluted answers required significant interpretation to know which end of the bar candidates were talking about. The calculation in part (ii) was usually carried out correctly.

19. A significant proportion of weaker candidates were not able to select the correct equations to calculate the loss in potential energy and gain in kinetic energy, which is a little surprising given that these have been tested frequently in the past and do not usually cause problems. Significant figure errors were very common in this question with many candidates quoting the changes in kinetic and potential energies to five and six significant figures respectively. Part (b) proved to be successful with a pleasing number of candidates able to calculate the force of air resistance from the energy differences.

STEMUP.CO.UK

20. This question proved to be a success with excellent discrimination and good accessibility. In part (a) most candidates defined the moment of a force although some did lapse into woolly explanations of the effects of moments.

Part (b) worked well, with candidates of all abilities making a good attempt at sorting out the relationship between the forces *P* and *W*. The better candidates made good use of Physics principles and expressed themselves cogently.

21. This question caused problems for all but the most able candidates. This was particularly true with part (a) in which the path of the crate was often shown as a straight line or curving the wrong way. Candidates also found it difficult to express themselves clearly when trying to explain why the horizontal component of velocity remained constant.

Part (b) was better answered and frequently scored full marks. In part (c) the majority of candidates correctly surmised that the crate could be dropped from a greater height but found it more difficult to explain why. Very often the answer stated that air resistance slowed the crate down, and not that it decreased its acceleration.

22. In part (a) most candidates calculated the momentum correctly, although N s^{-1} was commonly given as the unit of momentum. Many correct answers were seen in part (ii), although a significant number of candidates misread the impact time as 9.2 s. The final answer was often presented with too many significant figures.

Many correct calculations were seen in part (b) (i) although some candidates attempted to use $v^2 = u^2 + 2as$ with $s = 0.62$ m. In part (ii), most candidates calculated the centripetal acceleration correctly. In both parts, incorrect units or provision of answers with too many significant figures were not uncommon. In part (iii), few candidates realized that the radial force pulled on the knee joint although a significant number of candidates knew that the force after impact was less because the speed was less. Many candidates failed to confine their answer to the limits set by the question and discussed features not relevant to the question.

23. Hooke's law, in part (a), was generally known to candidates although many did not state the condition under which it applied. Many introduced temperature into the argument.

The calculation in part (b) was usually correct with comparatively few candidates adding the two lengths or adding the values of the Young moduli to perform just one calculation. Questions on density, similar to those in part (b) (ii), are usually done well, and this question was no exception. Full marks were quite common in part (b).

Part (c) also proved to be relatively easy with the large majority of candidates obtaining the correct answer. Those who failed were usually those who tried to tackle it from a Young modulus point of view.

24. This question was answered well and it was clear that candidates were skilled in resolving vectors. Full marks were common in part (a). A minority of candidates confused the vertical and horizontal components and consequently lost the first two marks. The arrow showing the line of action proved a very accessible mark, although some candidates spoilt their answers by a lack of care in their drawing. It was not clear from these drawings that the arrow pointed vertically downwards.

STEMUP.CO.UK

25. Normally, the question on elasticity realizes high marks. Not so this time, although there were many completely correct answers. The three definitions were usually correct although, as in past papers, the Young modulus was defined in terms of stress and strain, rather than tensile stress and tensile strain. There also appeared this year, references to the *stiffness constant* of the wire. It should be pointed out that the stiffness constant is not the same as the Young modulus.

The algebra involved in parts (i) and (ii) of (b) caused problems and a significant number of candidates failed on this section. However, part (iii) proved to be a straightforward calculation for the majority of candidates.

26. This question proved to be very accessible and full marks were awarded frequently. The only real confusion arose in part (c) where weaker candidates had difficulty organising their thoughts and expressing them in a logical way. Loose use of language was evident, with statements such as "accelerating at a constant speed" cropping up in a significant minority of scripts.

27. This was an unusual question and a considerable amount of work was required in parts (a) and (b). There were many opportunities to make errors. Part (a) was answered quite well but common errors were omitting the 10^3 factor, quoting both changes as positive and the usual unit problem that appears in questions involving momentum.

Part (b) caused real problems for a significant proportion of candidates and calculation errors were common. A significant proportion of candidates confused momentum with velocity and although they were then were able to score marks for a correct calculation of kinetic energy, arithmetic errors were common.

Part (c) provided evidence that there is a common misunderstanding of what is meant by an elastic collision. A relatively frequent response was that this was an example of an elastic collision because momentum was conserved.

28. This question provided excellent discrimination and more able candidates analysed the situation successfully. Less able candidates were confused with the distinction between mass and weight and consequently calculated the acceleration as 0.50 m s^{-2}. Calculating the stopping distance proved more straightforward, although there was the usual confusion of signs for acceleration and whether the given velocity of 18 m s^{-1} was the initial or final velocity. Most candidates were able to identify friction as a reason for the stopping distance being shorter in practice, but were less confident when explaining why.

29. For the most part this question was answered well. In part (a), a significant minority of candidates did choose inappropriate scales for the graph, but plotting errors were rare. The calculation for the average acceleration in part (b) was done well but that for the distance travelled, in part (c) was less so. Most candidates appreciated that they needed to estimate the area under the graph, but many failed to do this within the allowed range.

Parts (c) and (d) caused problems to a number of candidates because they did not understand the term *resultant force*. This was often confused with air resistance which, candidates correctly assumed, increased with speed. The mark scheme did allow candidates to score marks in part (d), even if they had misunderstood resultant force, provided their description of the effect of an increasing resistive force was correct.

30. Responses to this question were extremely mixed with the term *resultant force* once again confusing a significant proportion of candidates. The tension was resolved correctly very frequently, but the next step of calculating the resultant of the two horizontal and the two vertical components was often omitted.

STEMUP.CO.UK

Part (b) produced better responses, although a significant minority failed to answer this part at all. There were also a number of candidates who thought the weight of the block must be 30 N. The written explanation in part (b) (ii) generated better responses than had been found in answers to questions of this type in previous papers, but there is still much confusion about when it is appropriate to apply Newton's Third Law. Comments such as 'the tension is the action on the block, so the weight is the reaction on the block' are still quite common. Candidates who used Newton's First Law were far less confused and were able to explain correctly how the weight was determined.

31. Candidates found this question not very accessible. This was probably due to the trolley having two sets of wheels in contact with the ground as opposed to only one set in the previous paper. This meant that unless candidates were familiar with this type of problem, there was no obvious pivot point about which to take moments. This unfamiliarity was noticeable in the calculations for part (b), which caused difficulties for large numbers of candidates, and it was clear that not all centres had given candidates experience of this type of question on moments. Part (c) proved to be even more difficult and only the more able candidates were able to calculate the force necessary to lift the front wheels off the ground. Part (d) was answered consistently better, with even less able candidates explaining why the required force would be less than that in part (c).

34. Most candidates gave a correct frequency calculation in part (a), although unfortunately some made a significant figure error in their final answer.

In part (b) (i), many candidates correctly calculated the angle between cable P and the ground or the mast. Many were then able to calculate the tension correctly, although some lost the final mark because they mistakenly doubled their answer, presumably on the grounds that the copper wire pulled on each mast. In part (ii), most candidates knew the correct expression for the stress but a significant number of candidates lost a mark through making an arithmetical error in the calculation of the cross-sectional area of the wire, or lost the final two marks as a result of using the expression for the surface area of the wire instead of the cross-sectional area. Other candidates lost the final mark as a result of a unit error in the final answer or an arithmetical error in the final calculation.

Many candidates scored two marks in part (iii) by comparing the breaking stress with their own calculated value and reaching a valid conclusion. Some candidates gained these marks by calculating the breaking force and comparing that with the tension in the wire. Very few candidates considered other relevant points such as the ductile nature of copper.

36. Few candidates gained the maximum mark of five for part (a). In part (i), the necessary condition that the wire had not been stretched beyond the elastic limit or beyond the limit of proportionality was usually omitted. In part (iii) the Young modulus was often defined as stress/strain, which was not acceptable, and finally a large number of candidates failed to give the unit of the Young modulus, many going for the easy option of stating that it had no units.

Candidates who took the trouble to read the stem of the question carefully usually gave good answers, but those who thought that part (b) required a description of the experiment failed miserably. In part (i) the usual answer of measuring the cross-sectional area was not accepted. The only answers that gained both allocated marks were the diameter and the length of the wire. In part (ii) a graph of force vs extension, or stress vs strain (provided both were defined) were acceptable, but many who opted for the stress vs strain graph then went on in part (iii) to give the answer as the area under the graph, which, of course, is wrong, unless they referred to the energy per unit volume.

STEMUP.CO.UK

38. The deceleration and distance travelled by the supertanker were calculated correctly in part (a) by a large number of candidates. The few errors that occurred were either the unit for deceleration or an incorrect conversion of hours to seconds.

Parts (b) and (c) caused more problems and many less able candidates were unable to sketch a correct graph, confusing distance-time with speed-time. The explanation of the shape of the graph generated some quite vague answers with considerable confusion over what the gradient of the graph represented.

39. Parts (a) and (b) of this question involved a familiar theme of energy conversion that has been assessed before. For the most part, candidates identified the energy changes correctly. The calculation of the horizontal velocity did however, cause problems. This was because many candidates applied the equations of uniform acceleration which were not appropriate in this situation as the acceleration changed.

Parts (c) and (d) proved to be challenging. Only a few of the more able candidates were able to identify the component of the weight parallel to the slope as the cause of the acceleration. A significant proportion of candidates concentrated on the changing frictional forces as an explanation of decreased acceleration. Part (d) proved to be too difficult for less able candidates who became very confused by the horizontal velocity and tried to use it in calculations for motion in the vertical plane.

Projectile questions of a similar type have been asked before but the impression given was that candidates found the analysis more difficult this time round. The diagram did, unfortunately, include an incorrect label of a vertical height of 1.0 m. There was, however, no evidence that this caused confusion and candidates were given full credit if they used this value for vertical displacement.

40. The January 2006 examination paper contained a question on moments that was answered very poorly. The evidence from this paper is that candidates had learned from the earlier question and consequently answered this question very well indeed. Many scored full marks with the only significant omission being a second condition for equilibrium.

STEMUP.CO.UK