INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

MARKSCHEME

MAY 2000

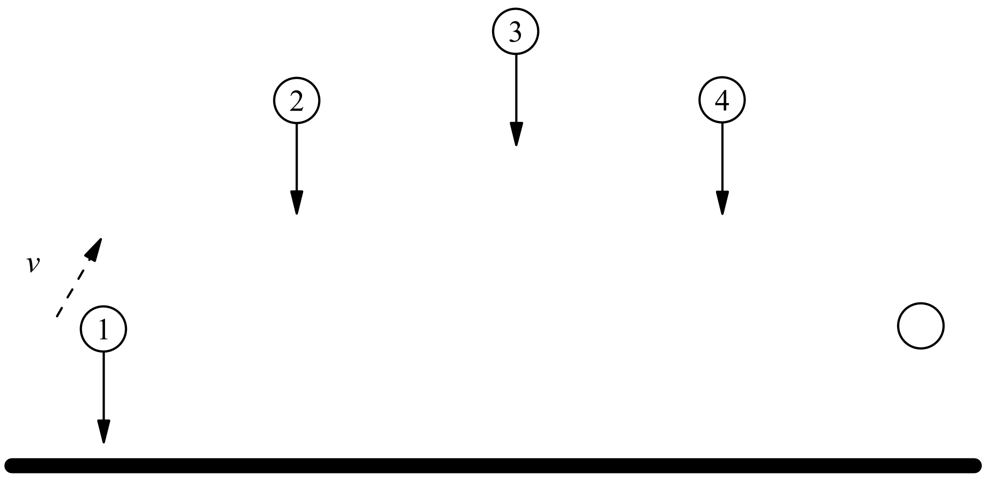
PHYSICS

Standard Level

Paper 3

A1. Forces and motions ***[8]***

(a) *Projectile motion*.



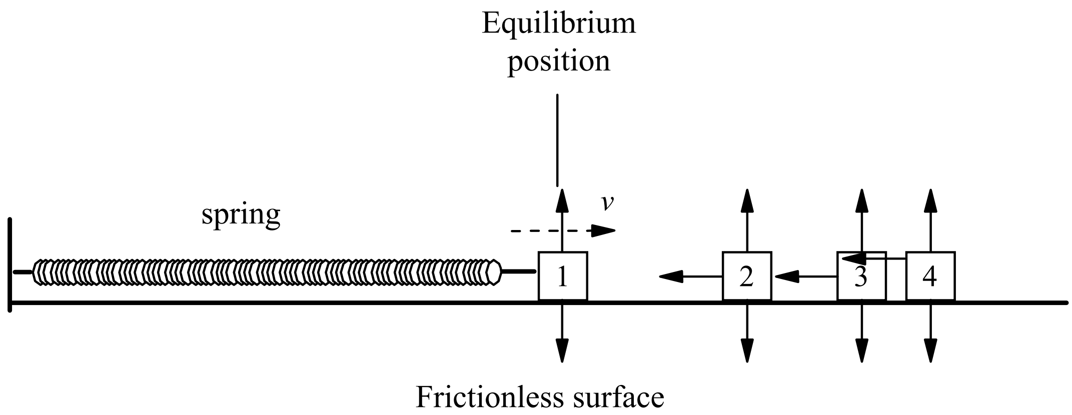
The earth
Yes
Kinetic and potential

(Award marks as follows:
For constant force magnitude and direction. ***[1]*** *Give zero if non-existent forces shown.* ***[1]***
For naming the earth. ***[1]*** ***[1]***
For KE and PE. ***[1]****)* ***[1]***
[3 max]

continued…

Question A1 continued

(b) *Simple harmonic motion on a smooth surface.*



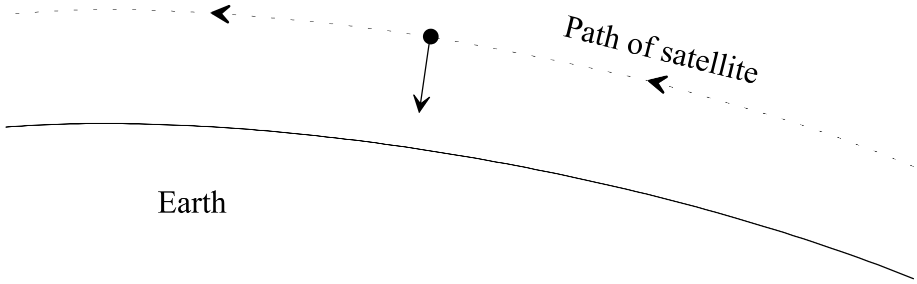
Spring
Yes
Kinetic and elastic

(Award marks as follows:
[1]** for backward spring force direction and **[1]** for increasing magnitude.* ***[2]
*(Remove **[1]** for non-existent forces.)*
[1]** for gravity and normal forces.* ***[1]
[1]** for naming the spring.* ***[1]
[1]** for KE and Elastic E.)* ***[1]
[5 max]

Do not accept just 'potential energy' – it must be qualified as 'elastic', 'strain', *etc.*

A2. Satellite ***[12]***

(a) *Orbit and force*



Earth

(Award marks as follows:
[1] *for force toward earth and no other forces.*
[1] *for 'by earth'.)* ***[2]***
[2 max]

Accept 'gravity' for 'Earth'.

(b) *Orbit radius*

Circumference $= 2\pi r = 4\times 10\,000$ km $= 4\times 10^7$ m

$$r = \frac{4\times 10^7}{2\pi} = 0.6\times 10^7 = 6\times 10^6 \text{ m}$$

(Award marks as follows:
[1] *for method (relating the arc to the radius).*
[1] *for detail/calculation.)* ***[2]***
[2 max]

The question goes to a lot of effort to point out that you start from 'nothing' to make your estimates. Quoting the radius of the Earth (from the data tables) can NOT get full marks.

continued…

Question A2 continued

(c) (i) *Satellite's acceleration.*
Height above earth is very small compared to radius of earth ***[1]*** so universal gravitation law tells us that likewise the gravitational force is only fractionally changed from that on the surface ***[1]***. ***[2]***
[2 max]

(ii) ***[1]*** for saying that gravitational acceleration does not depend on mass, ***[1]*** for reason, (*e.g.* larger force but larger inertial mass *etc.*).
or
Dynamics gives $\frac{GMm}{r^2} = ma$
and we see that m cancels, so a is independent of m. ***[2]***
[2 max]

(d) *Satellite speed.*

$F = ma$

$mg = \frac{mv^2}{r}$

$v^2 = gr$ (or write down $\frac{v^2}{r} = g$ directly). ***[1]***

$= 10 \times 6 \times 10^6 = 6 \times 10^7 = 60 \times 10^6$

$v = 8 \times 10^3 \text{ m s}^{-1}$ ***[1]***

*(Essentially the allocation is **[1]** for method and **[1]** for details.)* ***[2]***
[2 max]

(e) *Orbital period.*

$$T = \frac{2\pi r}{v} = \frac{2\pi 6 \times 10^6}{8 \times 10^3} = 5 \times 10^3 \text{ s} = \frac{5 \times 10^3}{60 \text{ m}} = 80 \text{ minutes.}$$

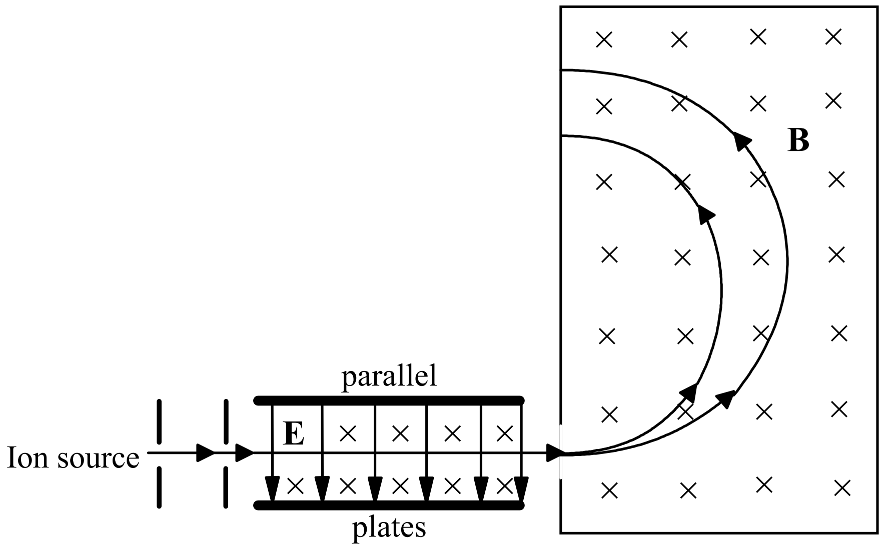
(Award marks as follows:
[1] *for method.*
[1] *for detail.)* ***[2]***
[2 max]

B1. Nuclear masses and the neutron ***[11]***

(a) (i) Velocity selector. (Only ions of one velocity can pass undeflected.) ***[1]*** ***[1]***

Necessary since accelerated ions from source have too broad a range of speeds. ***[1]*** ***[1]***
[2 max]

(ii) Draw larger radius. ***[1]***



Mass Spectrometer

Magnetic deflecting force is the same (same charge and velocity in magnetic field). But mass is greater so acceleration is less, hence more massive ion is not deflected as much, implies larger radius.
An algebraic answer is also acceptable: $mv^2 / R = qvB \Rightarrow R = mv/qB$, *etc.*

(Judge whole answer: ***[3]*** *includes force equality, inertial mass greater, and hence acceleration or deflection less. Lose* ***[1]*** *for missing part of this.)* ***[3]***
[4 max]

(b) Nuclear masses were not equal to the sum of the masses of the protons in nucleus; larger nuclei deviated more from equality; ions of the same element often showed two masses present (isotopes).

(Maximum ***[2]*** *for any one reasoned aspect.)* ***[2]***
[2 max]

continued…

Question B1 continued

(c) (i) $^{9}_{4}\text{Be}+^{4}_{2}\text{He}=^{12}_{6}\text{C}+^{1}_{0}\text{n}$ ***[1]***
[1 max]

(ii) Paraffin is rich in hydrogen, *i.e.* protons.
The neutrons collide with the protons, which are ejected ***[1]***,
and can be detected in ionisation chamber, since moving charged ionises gas in chamber. ***[1]*** (Neutrons do not ionise gas.) ***[2]***
[2 max]

B2. Production of Bremsstrahlung ***[9]***

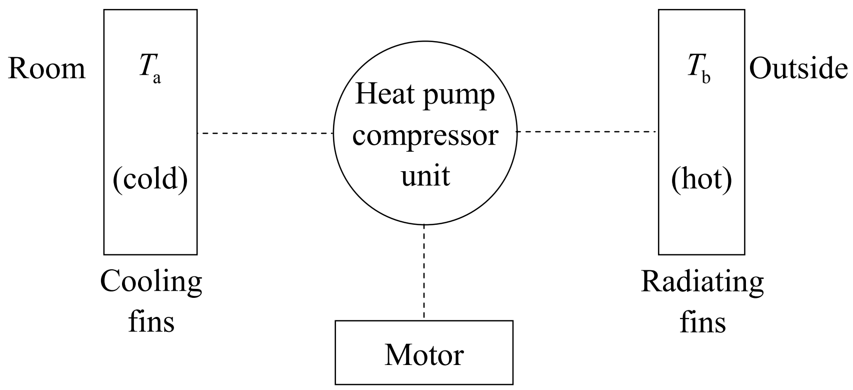
(a) Textbooks give description
Assess overall understanding. By judgement: ***[3]*** for good description of mechanism, incorporating the two questions mentioned. Lose marks for incomplete or confused answers. As a guide: deceleration ***[1]*** of variable magnitude ***[1]*** gives radiation in various wavelengths ***[1]***. ***[3]***
[3 max]

(b) Whole of electron's energy goes into one photon ***[1]*** giving a maximum frequency and minimum wavelength ***[1]***. ***[2]***
[2 max]

(c) If all the energy of an electron goes to an X-ray photon,
$hv = eV$ ***[1]***
$\frac{hc}{\lambda} = eV$ ***[1]***
or $\lambda = \frac{hc}{eV}$
For the specific values:
$\lambda = \frac{hc}{eV} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times25\times10^{3}}$ ***[1]***
$= 4.97\times10^{-11}$ m or 50 pm ***[1]*** ***[4]***
[4 max]

C1. Air conditioner ***[11]***

(a) ***[1]*** for all three transfers, ***[1]*** for relative thicknesses. ***[2]***
[2 max]



(b) $Q_2 = Q_1 + W$ ***[1]***
[1 max]

(c) Yes. ***[1]***
The work is to 'pump' or transfer heat. More heat can be transferred than the work input, since conservation of energy (first law of TD) expresses work in terms of difference between Q_2 and Q_1,
$W = Q_2 - Q_1$ but makes no specific relation between Q_1 and W. ***[1]***
Or other formulation that gets the concepts right. ***[1]***
[1 max]

(d) $Q_2 = Q_1 + W$ (a)

$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$, so $Q_2 = Q_1 \frac{T_2}{T_1}$ (b)

Substitute (b) in (a): $Q_1 \frac{T_2}{T_1} = Q_1 + W$

$$Q_1 = \frac{W}{\left(\frac{T_2}{T_1} - 1\right)} = W \times \frac{T_1}{\left(T_2 - T_1\right)} = W \times \frac{280}{40} = 7\text{ W} = 7 \times 500 = 3500\text{ W}$$

(Award marks as follows:
[3] *for setting up the two equation and combining.*
[1] *for calculation detail.)* ***[4]***
[4 max]

continued…

Question C1 continued

(e) No. ***[1]***
Second law (Clausius statement) says "Heat cannot by *itself* pass from a colder to a warmer body". In this case, the heat transfer if not 'by itself' since there is work input to bring it about. ***[1]*** ***[2]***

[2 max]

C2. Solar energy

[2] for description of required nature/characteristics of material. Of semi-conducting material. (Also accept other material giving photoelectric effect). ***[2]***

[3] for describing processes when photons interact with material, including the provision of energy to electrons (giving pd). Current arises if a circuit path is provided. ***[3]***

[5 max]

Mark by judgment; as a guide, allocate one mark for every correct, sensible and relevant point made by candidates, *e.g.* from the following:
Semiconductor material is required
Two types of semiconductor / p-n junction (additional mark!)
Photon interaction; charge production / electron – hole production
Photons give energy to electrons; production of a PD
Produces a current if a circuit is closed; a photon 'cut-off' frequency exists
A diagram showing a circuit / semiconductor 'sandwich' / other

C3. Energy crisis

Maximum of ***[3]*** for reasoned argument involving:
- First Law (energy conservation),
- energy transformations,
- discussion of more and less 'available' forms of energy,
- with inability to completely transform heat back to useful work (Second Law).

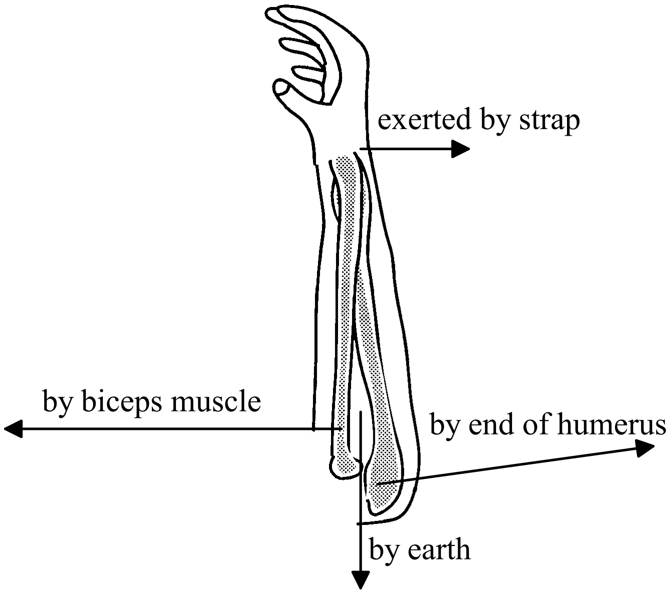
(Award ***[1]*** *for valid example.)* ***[4]***

[4 max]

D1. Forces in human arm ***[14]***

(a) Sum of forces statement. ***[1]***
Sum of torques statement. ***[2]*** ***[3]***
[3 max]

(b)



*(**[4]** for 4 correct forces and names of objects exerting each. Judgements for part marks. (For example, lose **[1]** for omitting humerus force. Judgement if one name is omitted, lose **[1]** if two names omitted))* ***[4]***
[4 max]

(c) $T = F \times d = 100\text{ N} \times 32\text{ cm} = 3200\text{ N cm}$. ***[1]***
Clockwise. ***[1]*** ***[2]***
[2 max]

(d) Greater than. ***[1]***
To get equal torque, muscle force must be greater since lever arm distance is shorter. * *(N.B. No marks for right answer with wrong reason!)* ***[1]***
[1 max]

(e) $Tcw = Tacw$
$100 \times 32 = F \times 4$ ***[1]***
$F = 100 \times \frac{32}{4} = 100 \times 8 = 800\text{ N}$. ***[1]*** ***[2]***
[2 max]

(f) Weight acts vertically and its line of action is through elbow joint ***[1]***,
so it exerts no torque about the elbow joint. ***[1]*** ***[2]***
[2 max]

D2. Walking barefoot on gravel ***[6]***

(a) Mass of man is $2 \times 2 \times 2 = 8$ times the child. ***[1]*** ***[1]***
[1 max]

(b) Force is proportional to mass. Thus force ratio, man to child, $8:1$. ***[1]*** ***[1]***
[1 max]

(c) Area scales as linear dimension squared.
Area ratio, man to child, is $4:1$. ***[1]*** ***[1]***
[1 max]

(d) Force/area scales as $8:4$ or $2:1$. ***[2]***
or
Force/area scales as L cubed over L squared, *i.e.* as L. So ratio is $2:1$ ***[2]*** ***[2]***
[2 max]

(e) Man finds it more painful, since force on a unit area scale of sole is twice that of the child. ***[1]***

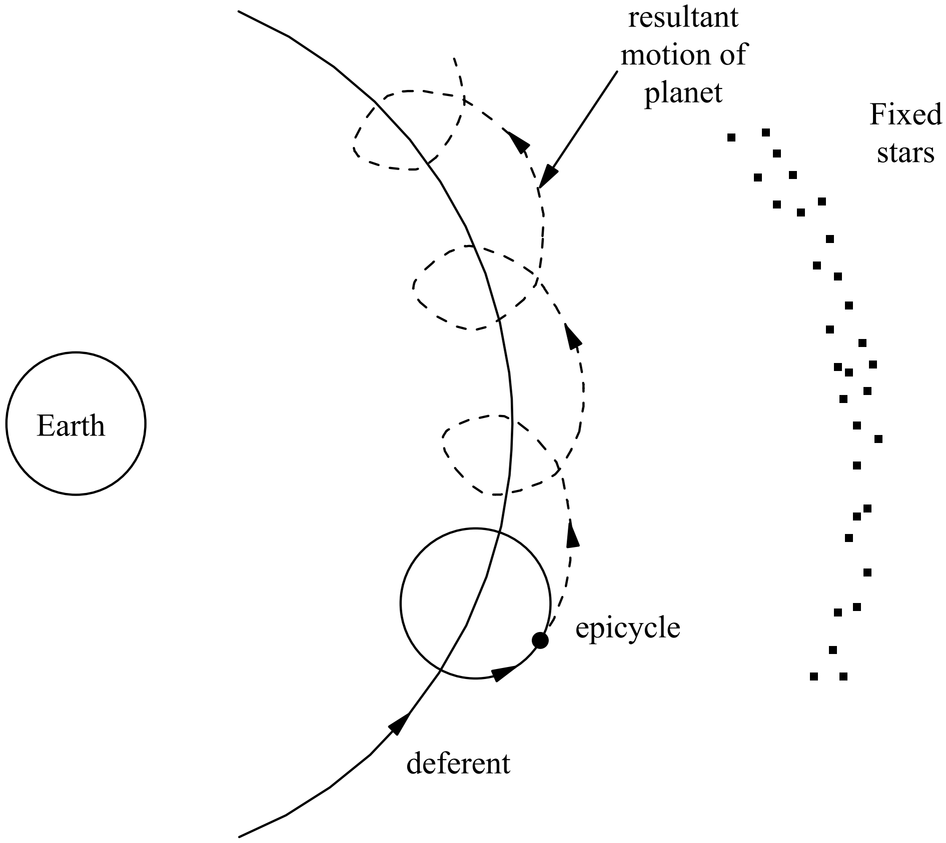
(N.B. Don't worry about force being exerted only by the sharp points of stones, since force on each sharp point will be twice as great for the man, following the same reasoning.) ***[1]***
[1 max]

E1. Models of the universe ***[12]***

(a) (i) Stars were embedded in a celestial sphere which rotated about the earth. ***[2]***
[2 max]

(ii) Moon was carried on another, smaller sphere, also rotating about the earth, but with a somewhat slower rotation. ***[2]***
[2 max]

(iii)

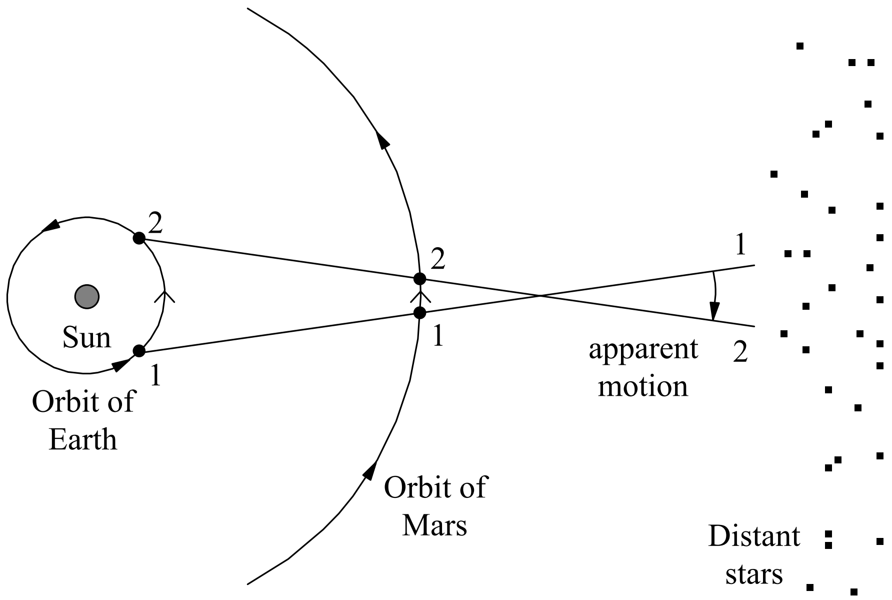


In addition to their own celestial sphere motion (on the main cycles or equants), the planets performed epicycles. During the time that motion on an epicycle was in the opposite direction to main cycle motion, the net motion was 'backwards'. ***[3]***
[3 max]

continued…

Question E1 continued

(b) *Copernican model.*



Both Earth and Mars rotate about the sun, but Mars is slower. As observed from an earth which shifts position, Mars appears to reverse its motion at times, against the fixed stars, as in sketch between 1 and 2. ***[3]***

[3 max]

(c) Kepler gave up trying to describe the motion in terms of combinations of circles (cycles, epicycles and equants), ***[1]*** and found that an **elliptical** orbit matched the observations precisely. ***[1]*** ***[2]***

[2 max]

E2. Cannon boring and caloric ***[8]***

(a) Caloric fluid was set free from a material when it was cut up into small pieces. ***[2]***

(Note that the smaller pieces would then have a smaller heat capacity than the original large piece.) ***[2]***
[2 max]

(b) Prediction: Since less material was cut and fewer shavings produced, so less caloric fluid would be freed, so less heat would be generated. ***[1]***
Yet this was not observed. (Just as much heat was produced.) ***[1]*** ***[2]***
[2 max]

(c) Rumford's own words were: "Anything which … a system of bodies can continue to furnish *without limitation* cannot possibly be a material substance …"

(Any reasonable statement of these ideas. ***[2]****)* ***[2]***
[2 max]

(d) Rumford's words: "… difficult to form any idea of anything capable of being excited … in the manner which heat was excited … in these experiments, except it be MOTION".
In our terms, work done in boring was the source of the heat generated.

(Any reasonable statement of these ideas. ***[2]****)* ***[2]***
[2 max]

F1. Stellar distances ***[8]***

(a) The star is closer than the others, close enough to earth that parallax effect is observable. ***[1]***
[1 max]

(b) Derivation with sketch.
[2] for right idea about parallax method, including diagram.
[2] for details and approximation. ***[4]***
[4 max]

(c) Hubbles's law required measurable redshift, *i.e.* recession velocity at least some small fraction of the speed of light. ***[1]***
Nearby star may not be receding, and if it was it would be too slow, since recession speed depends on distance. ***[1]***
Hubble's law can be used for distant galaxies. ***[1]***

Also accept, for part credit, that 'local' velocities (including those of the earth and sun) are dominant. ***[3]***
[3 max]

F2. Hertzsprung-Russell diagram ***[12]***

(a) Absolute magnitude. ***[1]***
Must be an inherent property of a star, not an observed property which also depends on distance away. ***[1]***
(But no marks for right answer with wrong reasoning.) ***[2]***
[2 max]

(b) ***[2]*** for two of the following three reasons:
- To cover a wide range of orders of magnitude ***[1]***
- And because relative (ratio) differences between magnitude are important, which is reflected in a log scale. ***[1]*** (The smaller values would be lost on an absolute scale.)
- Of historical origin – judges comparative brightness by eye in assigning magnitudes, 1.2,3 *etc.*, and eye response is more logarithmic than linear). ***[1]*** ***[2]***

[2 max]

(c) Surface temperature. Temperature values are determined from radiation received, which comes from the surface of the star. ***[2]***
[2 max]

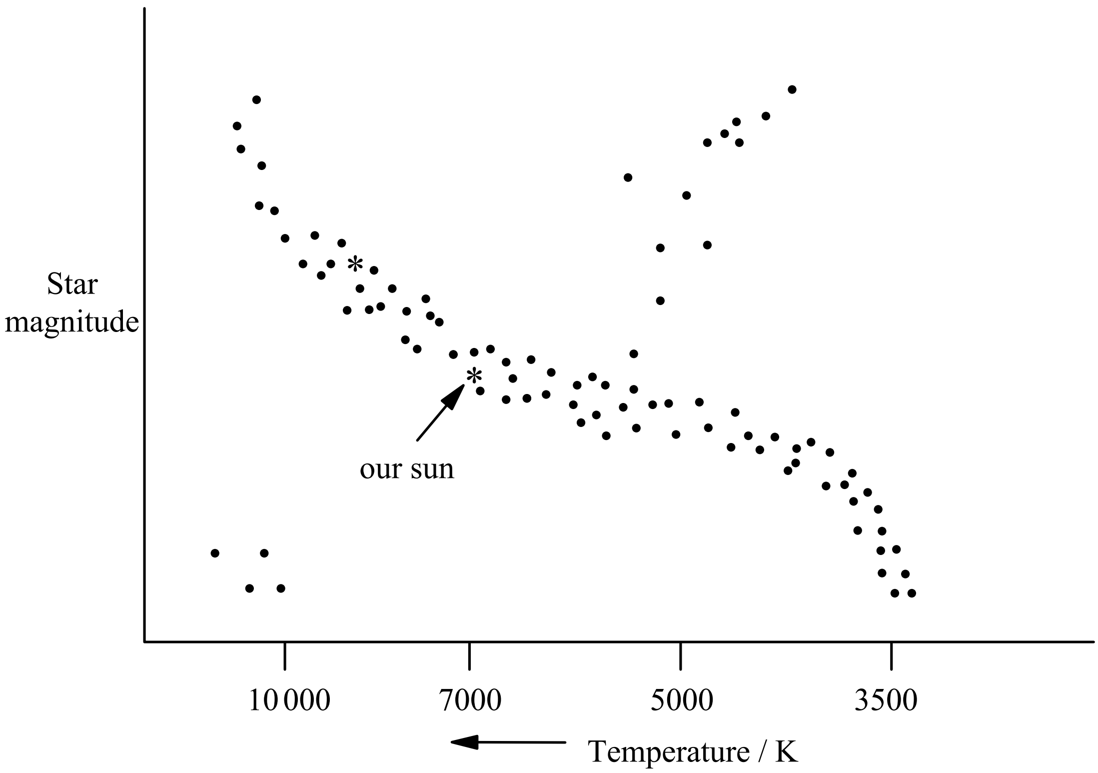
(d) Analyse spectrum of radiation. ***[1]***
From peak (maximum intensity) of continuous distribution of wavelengths, can determine temperature using Wien's law. ***[1]***
Accept answers using the reasoning: Apparent brightness → luminosity → intensity → Stefan-Boltz. $I = \sigma T^4$ ***[2]***
[2 max]

continued…

Question F2 continued

(e) (i) Luminosity greater and colour bluer. ***[1]***
Greater luminosity due to greater size and greater energy production. ***[1]***
Bluer due to higher temperature from greater energy production. ***[1]*** ***[3]***
[3 max]

(ii) ***[1]***
[1 max]



G1. Relativity and simultaneity ***[12]***

(a) ***[1]*** for each postulate. ***[2]*** ***[2]***
[2 max]

(b) Could give sketch of situation (not required however):

Then show train moved a bit, toward one platform scorch mark and away from the other. Given that S sees flashes, travelling toward S with speed of light, as simultaneous. Observer T, moving relative to S, will be in a different position from S when flashes arrive, so for T they will *not* arrive simultaneously. The one coming from the front of the train will arrive first.

Since the speed of light for T will also be c, (irrespective of fact that T is moving relative to S), T will explain the different times of arrival, having travelled equal distances, as due to the flashes not having occurred simultaneously.

[1] for explanation of flashes not arriving simultaneously for T.
[1] for speed of light still c for T.
[1] for infer flashes did not occur simultaneously.
[1] for overall understanding, coherence and quality. ***[4]***
[4 max]

(c) T will say the front strike occurred first. ***[1]***
[1 max]

(d) For T: 100 m ***[1]***
For S: $\frac{100}{\gamma}$ ***[1]***
$= \frac{100}{1.15} = 87\text{ m}$ ***[1]*** ***[3]***
[3 max]

(e) For S: 85 m (Simultaneous marking of train and platform at ends, and train is length contracted according to S). ***[1]***
For T: $\frac{85\text{ m}}{\gamma} = \frac{85}{1.15} - = 75\text{ m}$ ***[1]*** ***[2]***
[2 max]

G2. Space capsule ***[8]***

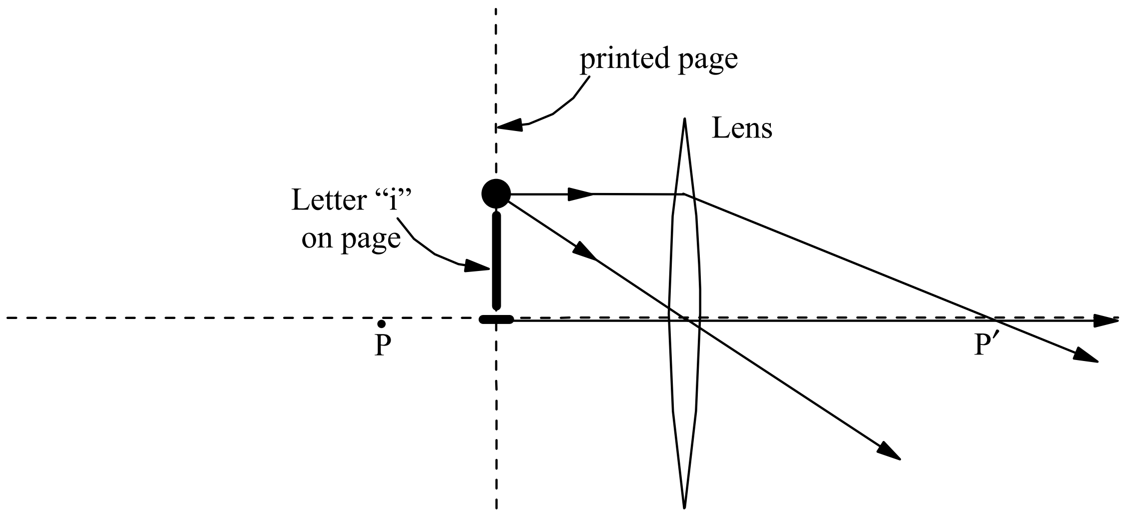
(a) Experiment does not help distinguish. ***[1]***
Lee would explain acceleration as due to gravitational force on the hammer. ***[1]***
Anna would say that if the spaceship is accelerating, the floor of the capsule accelerates toward the hammer ***[1]***,
which just remains in the state of motion it had when released. ***[1]*** Hammer has not accelerated.
(The above allocation is a guide: be flexible in awarding marks for explanations, looking for overall understanding.) ***[4]***
[4 max]

(b) No. Equivalence principle ***[1]***.
(Actually no or yes! A planetary gravitational field is not uniform, though very nearly so across the capsule. So, if they released two objects simultaneously, one above the other, the distance between them would increase as they fell (slightly). No student is likely to think of this, but accept either answer no or yes with supporting statement.) ***[1]***
[1 max]

(c) Anna is likely to be right. ***[1]***
If a spaceship had taken off from the planet, there would have been a stage where sensation **increased** during blastoff, only later diminishing. ***[2]*** ***[3]***
[3 max]

H1. Images in a convex lens ***[12]***

(a) *Lens close to the page.*



(i) Anywhere to the right of the lens. ***[1]*** ***[1]***
[1 max]

(ii) Right way up.
Enlarged.
Behind the lens.
Yes.

(Mark as a whole, ***[2]*** *for complete understanding, lose* ***[1]*** *per error: 2 errors gets zero.)* ***[2]***
[2 max]

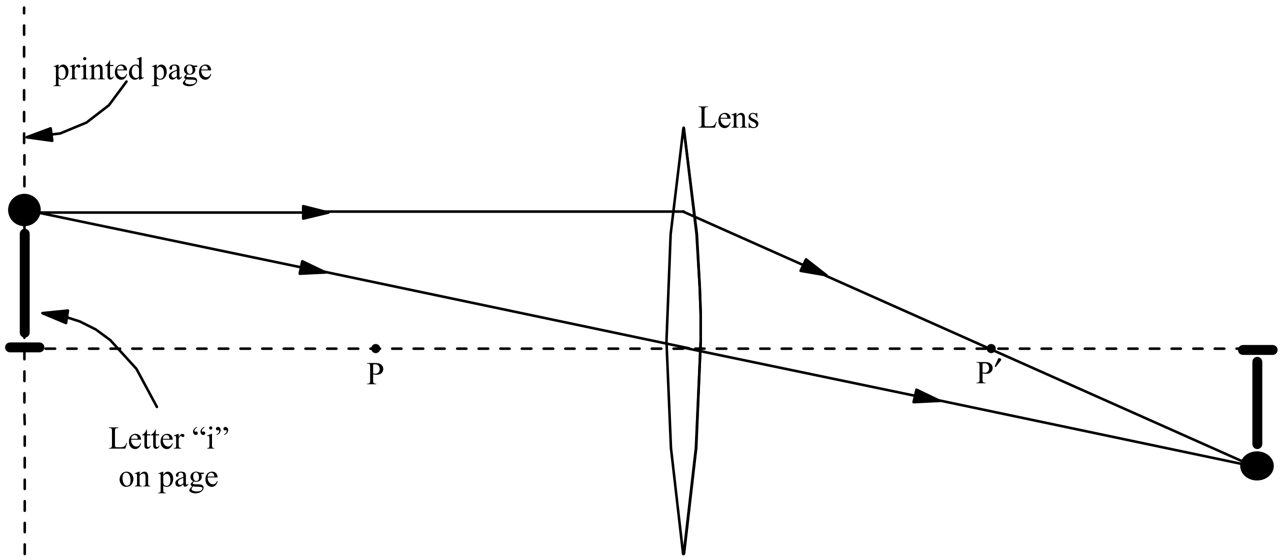
(iii) No. ***[1]*** ***[1]***
[1 max]

continued…

Question H1 continued

(b) (i) *Lens further from the page*
Ray through lens centre ***[1]***, parallel ray deviated through focal point ***[1]***, image correctly located by ray intersections ***[1]***, image inverted ***[1]***. ***[4]***
[4 max]

Mark quite stringently here, *e.g.* penalize inaccurate diagrams, since mark allocation is generous.



(ii) Eye located to the right of the image. ***[1]*** ***[1]***
[1 max]

(iii) Upside down.
Diminished.
In front of lens.
Nearer to her.
No.

*(Mark as a whole, **[2]** for complete understanding, lose **[1]** per error: 2 errors gets zero.)* ***[2]***
[2 max]

(iv) Yes. ***[1]*** ***[1]***
[1 max]

H2. Double-slit interference ***[8]***

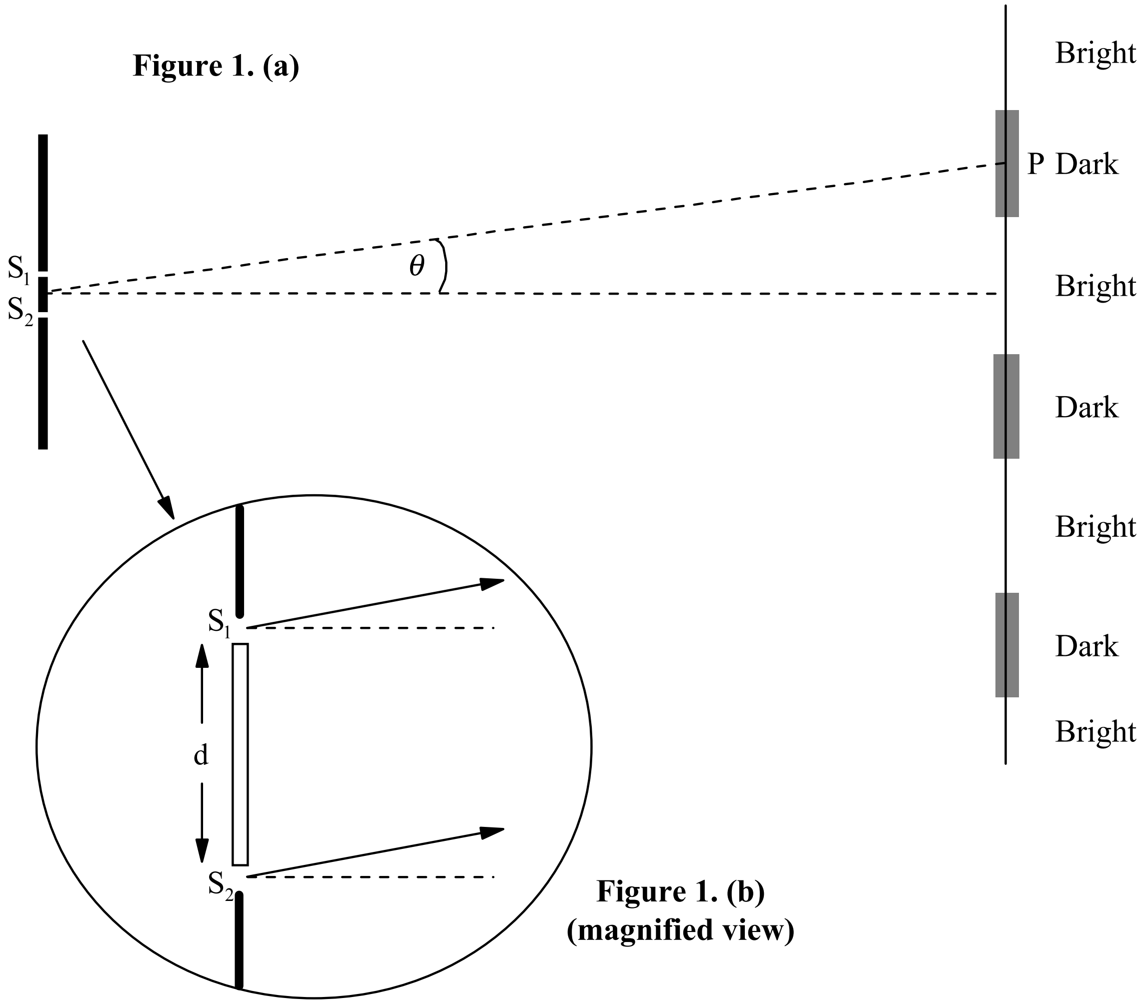
(a) Light waves do arrive from both slits, but out of phase: by half a wavelength because of the path difference. ***[1]***
Crests of one coincide with troughs of the other, giving destructive interference. ***[1]*** ***[2]***
[2 max]

Note that one can approach this from both a wave and particle view of light. On a photon viewpoint it would be problematic to say that 'light arrives' from both slits at a dark spot. If an answer takes the photon view, mark accordingly on its merit by judgment.

continued…

Question H2 continued

(b)



Standard textbook derivation. ***[4]***

By judgement, guided but not bound by the following:
Construction in diagram to show path difference. ***[1]***
Putting path diff $= \frac{\lambda}{2}$ ***[1]***
Expressing path difference in terms of trig of triangle. ***[1]***
Relating angle θ to angle of triangle. ***[1]***
Answers which just take the formula from the formula sheet and put $m = \frac{1}{2}$ get no marks.

[4]
[4 max]

(c) No, P would not remain dark. ***[1]***
Light from all three arrives at P: light from S_1 and S_2 interferes destructively, leaving an effect due to S_3. ***[1]***

[2]
[2 max]